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What Remains: The Enduring Value of Museum Collections in the Digital Age[1]

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Abstract: Why do collections continually surprise? The simple answer for students and researchers is that collections of historic objects contain abundant information not well represented in texts or on the internet. Collections in museums, libraries, campuses and private hands offer a unique source of diversity for research, teaching and broader cultural offerings. In this paper, I look at the wealth of findings resulting from the careful study of objects, collections and provenance. I provide examples from our national science museums in Ottawa, as well as collecting activities throughout Canada. I will also describe recent research in German science collections. The close study of objects has a capacity to reveal multiple narratives and unexpected human dimensions of the past, while also connecting us to complex human relations with what remains in the present. I reflect on how collection keepers and museums can better harness the possibilities stemming from these kinds of approaches.

Keywords: Collections; artifacts; museums

[1] This paper was presented in Lisbon as the 3rd CIUHCT (*Centro Interuniversitário de História das Ciências e da Tecnologia*) Distinguished Lecture, "What Remains: The Enduring Value of Museum Collections in the Digital Age," at the Faculdade de Ciências da Universidade de Lisboa, on December 5, 2019.

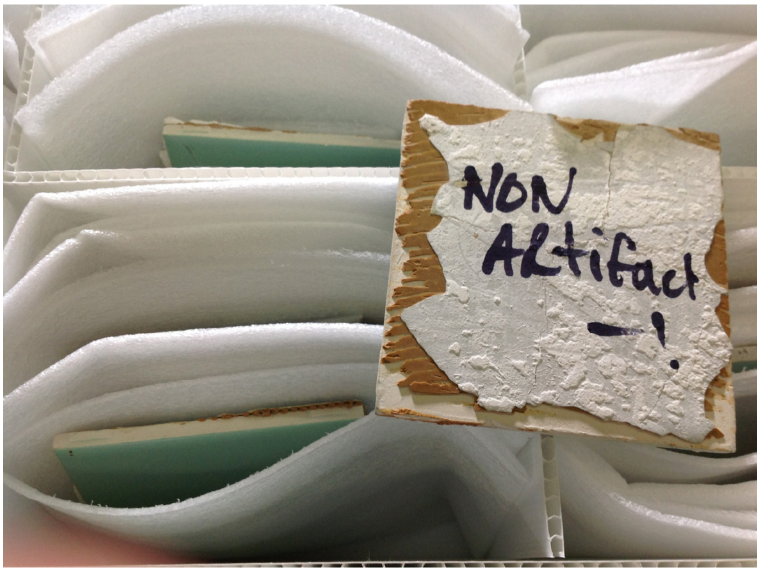

Figure 1 – "NON Artifact—!" green tile. Image courtesy of Ingenium: Canada's Museums of Science and Innovation, artifact no. 2009.0060.

> "A lot of people think that archaeology – archaeologists – discover the past…I think it's more accurate to say that they work on what remains."[2] Archaeologist, Michael Shanks

Introduction: Artifact Lessons

I have taken this tile to several places – a medical museum conference, a conference called the Properties of Things, and a conference on interdisciplinary approaches in medicine. I have also taken it as a guest to classes as a simple demonstration for how to read an object. Like all artifacts, it is a migrant carrying multiple messages into (and within) the present – it allows us to tell the story of the role of the colour green in medical culture; the emergence of design as a central part of hospital life in the twentieth century; the history of an infamous psychiatric hospital in Saskatchewan (where it was actually used); and the history of the manufacturing of this tile in Japan in the 1960s; and we can look at the role of this tile as a museum object *in the present,* and the arbitrary nature of how we acquire objects and build collections, and then construct history from them (the tile "NON Artifact_!" was not accessioned with a larger group of tiles that came to the museum at the same time, but given to me as a prop for talks and seminars). This tile also has striking sensory and material qualities with meaning

[2] Lynn Hershman Leeson and Michael Shanks, "Here and now," in *Archaeologies of Presence: Art, Performance and the Persistence of Being*, eds. Gabriella Giannachi, Nick Kaye, and Michael Shanks, 222–34 (London, New York: Routledge, 2012).

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and exploratory opportunities in their own right.[3] And in Lisbon it has arrived into another welcoming context, a home of magnificent historical traditions with tiles. We see the full splendour of tile culture on and within the buildings throughout this city, and of course at the Museu Nacional do Azulejo in Lisbon (National Tile Museum).

I begin with this tile because it represents the core themes of my lecture – collections as depositories of diverse and often surprising knowledge; the power of one object to tell many stories; the communities and value that can develop around objects and collections in the present; and how we can build research structures and practices that tap the many perspectives within collection knowledge.[4] I shall explore these themes through five case studies – tuning fork collections in Germany and the Czech Republic; a 1960s electronic processor used at a cosmic ray observatory; a 1980s meteorological ocean buoy; a 1940s cyclotron; and a magnet sector from a particle accelerator in Vancouver. What remains in each of these cases? A vast storehouse of untapped knowledge for understanding science, culture and society, and the powerful human connection to things.

Diversity and #CollectionKnowledge: Tuning in Many Forms

Figure 2 - A wide variety of tuning forks used for speech and hearing at Technical University, Dresden.[5]

[3] David Pantalony, "The Presence, Provenance and Presentness of a Non Artifact," *Museum & Society* 17, no. 3 (2019): 301–6.

[4] Samuel J. M. M. Alberti, ed., "Shaping Scientific Instrument Collections," Special issue, *Journal of the History of Collections* 31, no. 3 (2019); Janine Rogers and Sophie Thomas, eds., "On the Properties of Things: Collective Knowledge and the Objects of the Museum," Special issue, *Museum & Society* 17, no. 3 (2019).

[5] "Historische Akustisch-Phonetische Sammlung (HAPS). Wissenschaftliche Sammlungen," accessed April 28, 2020, https://portal.wissenschaftliche-sammlungen.de/SciCollection/4461?hit=13.

Not everything is on the internet. One of the best sources of diversity in the knowledge economy, in fact, can be found in all kinds of collections – from specimens to archives to historic artifacts. And these surprises often challenge experts in a field who may rely heavily on text-based resources. Discoveries in science-related collections, or any kinds of collections for that matter, can tell us about the processes of science and technology, but also larger cultural, social and economic dimensions connected to material things, their production, use, and movement.

For my first case study, I have chosen the humble tuning fork as a guide, found in scientific and musical collections worldwide, and carrying valuable lessons about the nature of science – instrument making, materials, and how it has shaped practice and concepts throughout disciplines, and beyond science. Like the optical glass prism, it is a simple idea that can be expressed in many ways, for many purposes in many contexts. It therefore conveys important lessons about "thing knowledge"[6] and material diversity in the sciences.

This singular focus on the tuning fork's history emerged from a collection visit. In the summer of 2018, I visited a collection of instruments in the physiology collection at the historic Charité medical campus in Berlin.[7] Owing to its lineage from several famous German nineteenth-century physiologists, I knew that this collection contained historic acoustical instruments, as well as connections with the nearby medical museum and collection. I wanted to see the collection in person to examine the instruments carefully and in context of other related objects. It was a small collection housed in a basement storage room – a former enclosed laboratory. But to my surprise, there was more than had been portrayed in existing documentation of the collection.[8] There was a variety of surviving tuning forks from several makers such as Edelmann, Kohl, Appunn, and Zimmerman. There were only a few dozen tuning forks in total, but enough to imagine dozens of complete sets from which they had come, and enough to reveal the archaeological remains of what had once been a thriving and wide-ranging acoustical program. There were also several instruments by the German-born, Parisian maker Rudolph Koenig, who had been a controversial figure in the Charité scientific circles.[9] A set of his brass resonators, for example, had a telling addition of German notation

[6] Davis Baird, *Thing Knowledge: A Philosophy of Scientific Instruments* (Berkeley: University of California Press, 2004).

[7] This opportunity was thanks to an invitation to the workshop "Sound Objects in Transnational Contexts," Max Planck Institute for the History of Science, Berlin, July 12, 2018.

[8] Peter Bartsch, *Historische Instrumentensammlung. Katalog* (Berlin: Johannes-Müller-Inst. für Physiologie, 2000); "Historische Instrumentensammlung (Johannes-Müller-Institut Für Physiologie) Wissenschaftliche Sammlungen," accessed April 28, 2020, https://portal.wissenschaftliche-sammlungen.de/SciCollection/4413?hit=5.

[9] David Pantalony, *Altered Sensations: Rudolph Koenig's Acoustical Workshop in Nineteenth-Century Paris* (Dordrecht; New York: Springer, 2009), 139.

etched next to the French notation.[10] The assemblage as a whole told a story as well, with bits and pieces from the historic institute along with forgotten busts of the founders such as Herman von Helmholtz. Much of these older artifacts were mixed on shelves with post-World War II equipment. The collection as a whole seemed to be a messy—but revealing—depository of physiological acoustics in Berlin.

How was any of this unexpected? In historical studies of acoustics we understand the material and instrument patterns in North America and across Europe,[11] but surprisingly little is known about the surviving collections in Germany and what they tell us about the history of precision instrument making in *that* field of practice. This gap in knowledge is even more surprising if one considers that Germany had such rich traditions in physics, psychology and music.[12] Countless important collections were damaged during the World War II, but there are also many underexplored depositories throughout Germany.[13] What could collections tell us about cross-fertilisation between the musical instrument trade, other trades, and precision instruments in Germany? How would this compare to France? What does this tell us about the movement of skills and material knowledge across disciplines, and geographies?

I had seen collections in Munich (Deutsches Museum) and Leipzig[14] that pointed to prolific yet little-studied German makers such as Anton Appunn, Max Edelmann, Eduard Zimmerman, H. Pfau, G. Lorenz, F. Sauerwald, and Max Kohl. The Berlin collection suggested that further collection-based research could help fill in these historical gaps and build a more complete picture of science, music and artisanal skills at the material level.

Two digital projects enhanced this quest to uncover and document historic tuning forks in German collections. During the summer of 2019, as part of the Max Planck Institute's Epistemes of Modern Acoustics research group, Fanny Gribenski and I visited several collections of acoustical instruments in Germany to explore these material dimensions of acoustical

10 "Variations on a Theme: The Movement of Acoustic Resonators through Multiple Contexts | Sound & Science: Digital Histories," accessed April 28, 2020, https://acoustics.mpiwg-berlin.mpg.de/contributor-essays/variations-theme-movement-acoustic-resonators-through-multiple-contexts.

11 Dozens of catalogues and collections are sited in Pantalony, *Altered Sensations*.

12 Myles W Jackson, *Harmonious Triads: Physicists, Musicians, and Instrument Makers in Ninteenth-Century Germany* (Cambridge, Mass.: MIT Press, 2008); Alexandra Hui, *The Psychophysical Ear: Musical Experiments, Experimental Sounds, 1840-1910*, Transformations : Studies in the History of Science and Technology (Cambridge, Mass.: MIT Press, 2013), http://mitpress-ebooks.mit.edu/product/psychophysical-ear.

13 "Wissenschaftliche Sammlungen," accessed April 30, 2020, https://portal.wissenschaftliche-sammlungen.de/.

14 "Sammlung des Psychologischen Instituts (Wilhelm-Wundt-Raum). Wissenschaftliche Sammlungen," accessed April 28, 2020, https://portal.wissenschaftliche-sammlungen.de/SciCollection/6220?hit=37.

history.[15] The German Science Collection portal serves an invaluable finding aid for this kind of field research.[16] The MPI's "Sound & Science: Digital Histories" project, provides a means for documenting this work, but also a means of curating, understanding and sharing this knowledge in new ways.[17] The simple act of digitizing collections of tuning forks can become complicated by multiple narratives around makers, materials, dates, movement, and use. But this can also be an opportunity that better reflects evolving scholarship around objects and collections.[18]

The Deutsches Museum in Munich has a variety of tuning forks by H. Katsch, R. Detert, and Max Edelmann, none well documented and all needing further research into their histories, connections, workers and evolution as companies. The acoustical and musical instrument collections at the Deutsches Museum, for example, point to deeper cross-fertilizations between scientists (Karl von Schafhäutl), physicians (Friedrich Bezold), musical instrument makers (Theobald Böhm),[19] and instrument makers like Anton Appunn and Max Edelmann, who contributed to the development of acoustical practice at the material level.[20]

One instrument that stood out was the specialized, precision tuning fork made by the Max Edelmann firm of Munich that had emerged from this multi-layered network of knowledge. The Edelmann firm made exceptionally refined, mathematically contoured, precision-graduated, polished, well-designed tuning forks as part of their tonometer, a series of 13 tuning forks covering a wide range of frequencies in the audible spectrum, managed through graduated tines and sliders for adjusting to dozens of frequencies on each fork. Trade literature at the Deutsches Museum indicated that these tuning forks had been sold to speech, hearing and medical professionals, rather than for just basic laboratory work in physics and psychology.[21] The Edelmann tonometer turns up in collections around the world, as it became a central

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15 "Epistemes of Modern Acoustics | MPIWG," accessed April 30, 2020, https://www.mpiwg-berlin.mpg.de/research/projects/RGTkaczyk.

16 "Wissenschaftliche Sammlungen."

17 "Home | Sound & Science: Digital Histories," accessed May 9, 2020, https://acoustics.mpiwg-berlin.mpg.de/.

18 Samuel J. M. M. Alberti, "Objects and the Museum," *Isis* 96, no. 4 (2005): 559–71; Alberti, "Shaping Scientific Instrument Collections"; James Secord, "Knowledge in Transit," *Isis* 95, no. 4 (2004): 654–72; Rogers and Thomas, "On the Properties of Things"; David Pantalony, "Collectors, Displays and Replicas in Context: What We Can Learn from Provenance Research in Science Museums," in *The Romance of Science: Essays in Honour of Trevor H. Levere*, eds. Jed Buchwald and Larry Stewart, 255–75 (Cham: Springer International Publishing, 2017).

19 Silke Berdux, "Deutsches Museum: Sammlung Prager," accessed May 9, 2020, http://www.deutsches-museum.de/sammlungen/musikinstrumente/sammlung-prager/.

20 See for example Rebecca Wolf's research group at the Deutsches Museum, "Deutsches Museum: Materiality of Musical Instruments," accessed May 9, 2020, http://www.deutsches-museum.de/en/materiality-of-musical-instruments/.

21 Max Thomas Edelmann, *Leitfaden Der Akustik Für Ohrenärzte* (Berlin: Karger, 1911).

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instrument used in speech and hearing studies from roughly 1900 to 1940.[22]

These instruments point towards a network. At the Acoustical and Communications collection at the Technical University of Dresden, there is an even larger variety of instruments, makers, and designs all geared towards the field of speech, phonetics, hearing and language. Edelmann's tonometer was present there too as an anchor of precision studies, with connections to acoustical practice coming out of Paris in the early twentieth century. Dresden had been adopting techniques and instruments from Abbé Rousellot's well-known phonetics lab.[23]

Figure 3 - Tuning forks as part of Grand Tonometer in Prague.

[22] "Bezold-Edelmann Continuous Scale (Bezold-Edelmann式連続音叉）など | 東大耳鼻科," accessed May 8, 2020, http://utokyo-ent.org/digital-ent-museum/tuningfork/.

[23] Dieter Mehnert, *Historische Phonetische Geräte: Katalog Der Historischen Akustisch- Phonetischen Sammlung (HAPS) Der Technischen Universität Dresden.* (Dresden: TUDpress, 2012); For context on Rousellot, see Robert Michael Brain, *The Pulse of Modernism Physiological Aesthetics in Fin-de-Siècle Europe* (Seattle; London: University of Washington Press, 2015).

In addition to the German collections, we examined a surviving historic tonometer at the Charles University in Prague that demonstrates this rich material knowledge economy, and a significant level of investment in this field of practice.[24] This series of precision tuning forks in Prague once had a range from 16 Hz to about 4,000 Hz, counting a larger range of frequencies and number of forks than the compact Edelmann series found in phonetics labs. Each tuning fork in the Prague collection has graduated divisions and a sliding weight that can be set to each frequency. They are signed by Henry Lepaute, Paris, a clock making firm that had been in operation since the eighteenth century.[25]

Each fork has the look of a perfected mathematical sculpture representing an enormous amount of know-how. In 1921, the Czech phonetician Josef Chlumský went to Paris to supervise the fine-tuning of 13 tuning forks for speech research modelled on Rousselot's collection at the Collège de France. Twenty years earlier, Rousselot had purchased Koenig's Grand Tonometer, the most extensive series of precision tuning forks produced in the nineteenth century comprising hundreds of instruments and a vast range of frequencies up to 90,000 Hz. Replicating the Koenig tuning forks involved an investment in precision that required months of repetitive tests and fine-tuning in the Collège laboratories. These processes entailed extensive training of the ear, collaboration with a variety of technicians and instrument makers, as well as verification by speech acousticians from the Paris laboratory. Well into the 1930s, Chlumský supervised the making of a full replica of the Paris Tonometer (often remotely), which he and colleagues in Prague continued to use and calibrate into the 1940s.[26]

The Prague tuning forks represent a much more ambitious enterprise for calibration and practice, and, as it turns out, a very complex exchange and movement of skills and materials between Paris and Prague. They survive in the phonetics department along with archival lab notes related to their production, tuning, calibration, use and recalibration at later dates.

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[24] Pavel Šturm, "The Prague Historical Collection of Tuning Forks: A Surviving Replica of the Koenig Tonometre," in *HSCR 2015 - Proceedings of the First International Workshop on the History of Speech Communication Research. Dresden, September 4-5, 2015*, eds. Rüdiger Hoffmann and Jürgen Trouvain, 95–105 (Dresden: TUDpress, 2015), accessed May 22, 2020 https://www.isca-speech.org/archive/hscr_2015/papers/hs15_095.pdf.

[25] Thanks to Paolo Brenni and Anthony Turner for providing background information on the Lepaute firm.

[26] Pavel Šturm, David Pantalony, and Fanny Gribenski, "From Paris to Prague: Precision Tuning across Boundaries," *article in Preparation*, n.d.; Pavel Šturm, David Pantalony, and Fanny Gribenski, "Refining Tuning Forks and Ears: Building a Network of Precision in Early Twentieth-Century Phonetics" a conference paper to be presented at EASST4S, Prague, 18-21 August 2020, https://www.easst4s2020prague.org/; Pavel Šturm, David Pantalony, and Fanny Gribenski, "From Paris to Prague: Precision Tuning across Boundaries" a conference paper to be presented at the XL Symposium of the Scientific Instrument Commission / IUHPST/ DHST Conference, Prague, 25-31 July 2021, https://scientific-instrument-commission.org/sic-conferences/item/xl-symposium-of-the-scientific-instrument-commission.

But they did not just carry these methods to Prague, they also brought with them the values associated with these practices. Even as electro-acoustics was on the rise,[27] these scientists chose to use these rather old-fashioned labour intensive methods. They also still relied heavily on their own ears.[28] Studies of the Czech language, like other language studies around the world, became part of the scientific foundation for connections between linguistics and nationalism; the precision forks and methods helped to legitimize and reinforce ethnic identity through science.

The careful examination of the forks, and their collection history, help us understand the production of and movement of knowledge across multiple boundaries – artisanal, academic, and geographic. The material and biographical history of these tuning forks reveal an unexpected insight into how scientific practice can build networks of practice, disciplinarity, and shape broader forms of cultural expression.

By following the instruments and collections, one discovers these alternative historical narratives. But, it is equally important to remember that these tuning forks and acoustical collections exist in the present, and function in the present. We must be critically aware of their evolving purposes.

Most of these collections are preserved and cared for by scientists and retired scientists who are part of a history group within the International Speech Communications Association. The collections are a prominent part of their resource base, network and culture. Whereas in the 1920s the acoustical instruments supported a network of practice; in the present the collections serve to reinforce a network of values and identity centred on these histories. For the collection at the Technical University at Dresden, one of the largest in Europe, the active preservation of institutional heritage takes on extra value and meaning in a city that has suffered such profound loss and destruction.

[27] Roland Wittje, *The Age of Electroacoustics: Transforming Science and Sound*, Transformations (Cambridge, Mass.: MIT Press, 2016).

[28] These methods fall within a long history around testing and hearing, see Alexandra Hui, Mara Mills, and Viktoria Tkaczyk, eds., *Testing Hearing: The Making of Modern Aurality*, 1st ed. (Oxford, New York: Oxford University Press, 2020).

One Object, Many Worlds: Coincidence Mixing in Inuvik

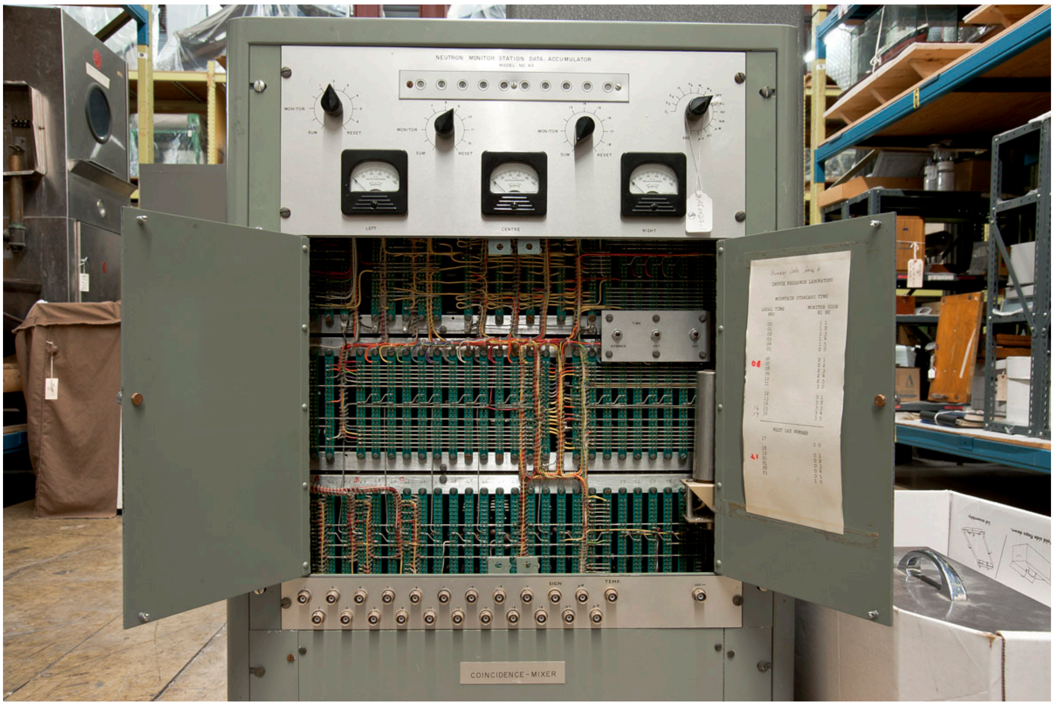

Figure 4 - Data accumulator/coincidence mixer (Hammond Manufacturing Co. Ltd., Guelph) for processing the events in the detector tubes. 1962. Interim no. AS0027. Ingenium: Canada's Museums of Science and Innovation, Ottawa. Photograph by Robert Bean.

Whereas the tuning fork histories show how one instrument can be expressed in so many ways, the present case study demonstrates how one object can have multiple histories and contexts. Rather than talk about the history of the world in 100 objects,[29] it may be more useful to talk about the history of many worlds in one object.[30] In this case, I have chosen a classic twentieth-century black box that opens up into numerous worlds and possibilities for interpretation.

In 2009, this 1960s electronic processor called the Coincidence Mixer came to our museum from a Cosmic Ray observatory in Inuvik, Northwest Territories in the Canadian Arctic. It had been installed there in 1963 as part of an international network of observatories for detecting

[29] Neil MacGregor, *A History of the World in 100 Objects* (London: Penguin Books, 2012).

[30] Brusius Mirjam, "100 Histories of the World in One Object: Itineraries, Islam and Indices," *Material Religion* 15, no. 2 (2019): 243–45; Simon Schaffer, "Understanding (through) Things," paper presented at The Location of Knowledge: A Mellon CDI Conference, Centre for Research in the Arts, Social Sciences and Humanities, University of Cambridge, on March 8, 2013.

cosmic rays – high energy particles (protons and atomic nuclei) that come from the sun and distant galaxies. Scientists detect them with special instruments and then process and count the occurrences with electronic (now computerized) equipment. The Canadian Government set up the Inuvik station as part the International Quiet Sun Year 1964-1965, a period of lower solar activity. It was a major event for the National Research Council of Canada, continuing a tradition of sophisticated research in the field of Cosmic Ray studies and instrumentation. It was also an inaugural event for the new town of Inuvik as a modern outpost of Canadian science. On opening day, there was a drum ceremony by the local Indigenous community.[31]

There are several histories within this object. There is the history of cosmic ray detection going back to the 1920s and 30s. There are the complexities of the concepts and practices that make up coincidences, which themselves resulted in a Nobel Prize. There is the history of the maker of this instrument, Hammond electronics, a major Canadian radio and electronic producer in the mid-twentieth century. There is the neat and tidy Cold War aesthetics of the grey box with two doors that open into the beautiful arrangement of primary-coloured electronics. There is the history of the people and research behind its design from the National Research Council, some this situated within larger Cold War political drama (e.g. Bruno Pontecorvo).[32] And there is the local addition, a paper note taped to the inside of one of the doors with code references labelled "Inuvik Research Laboratory."

The label "coincidence mixer" alone can be unpacked and has special technical meaning here.[33] Physicists uses the word coincidence to refer to the simultaneous detection of a cosmic ray by two carefully aligned detectors. Physicists in the early twentieth century started to use coincidence detections to study atomic decay. A double strike on two detectors at once raised the possibility that the event was a true particle emission rather than background noise. Several physicists developed methods for detecting and processing coincidences and the resulting equipment became a foundation for particle physics.[34] Cosmic rays entered these studies by pointing the equipment towards the heavens. The Polar Regions are well suited for unique exposures to cosmic particle showers.

Where does this object belong? It seems to have multiple histories and claims on a rightful context. On the shelf of our storage space, it certainly seems out of context, and this ambiguity

[31] Jan Houseman and Alan Fehr, "Listening for Cosmic Rays! The Inuvik Neutron Monitor," 1999, accessed May 22, 2020, http://neutronm.bartol.udel.edu/listen/main.html.

[32] David Hanna, "Early Muon-Physics Measurements with Cosmic Rays," *Physics in Canada* 68, no. 1 (2012): 7–11.

[33] David Pantalony, "Artifacts: Coincidence Mixing in Inuvik: Those Uncanny Cosmic Rays," *Arc Poetry Magazine (Joint Issue with The New Quarterly)* 66 (2011): 70–73.

[34] Peter Galison, *Image and Logic : A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997), 438–53.

in fact, can help us imagine it within several contexts. But what about the local context of this instrument? And what does this object mean to people in that community now? I was always curious about this, and wondered about the deeper connections, or lack thereof with the local community. As mentioned above, there was an Indigenous drum ceremony at the opening, which is so important to both the local Inuvialuit and Gwich'in cultures, but this appears to have been a fairly superficial ceremonial connection. In the years that followed, there was not much connection with local Indigenous people to what was going on in the observatory, other than vague knowledge that it was measuring things from outer space. There was more of a connection for locals with the research institute next door (some people worked in labs and others served as field guides). Locals even watched movies in a makeshift theatre in the Research Institute.[35] And as time has passed, and the cosmic ray equipment has become increasingly automated, this separation between the observatory and the town became even more apparent. The University of Delaware currently owns and runs the detectors and processors. They do not even have to visit to make this happen. The data is sent around the world to a network of scientists.

Just as scientists often strip local context from their publications, science museums often remove this kind of context from objects while focusing on the heroic science and technology narratives. However, the lack of connection to the local context offers perhaps the deepest scientific lesson about the limitations of the Western Science, and what has been lost and ignored in this case.

In November 2019, I was able to visit the observatory for the first time while on a trip to Inuvik to meet with Gwich'in and Inuvialuit communities about their cultural connections and practices related to the night sky.[36] They have deep practical, cultural and spiritual traditions related to the stars, the sun and moon and prominent local phenomena such as the Aurora Borealis.[37] This knowledge represents hundreds upon hundreds of years of keen observation and stable knowledge transmission.

During these discussions I was struck by the fact that the people running the observatory had not created a connection to, or taken advantage of this vast knowledge base about the night sky. Indigenous qualitative observations of Northern Lights may not directly relate to the specific kinds of phenomena and energies making up cosmic rays, but this is not known for sure and

[35] Andrew Applejohn, "Coincidence Mixer? A Few Questions," email correspondence, December 9, 2019.

[36] This trip was part of the content development for the International exhibition *One Sky, Many Worlds: Indigenous Voices in Astronomy*, lead by Ingenium: Canada's Museums of Science and Innovation, and Indigenous co-curators Annette lee and Wilfred Buck.

[37] John MacDonald, *The Arctic Sky: Inuit Astronomy, Star Lore, and Legend* (Toronto, Ontario: Royal Ontario Museum/Nunavut Research Institute, 1998).

they could still be a source of insight into cosmic ray observations and research. The observatory data on its own is clearly useful for investigating this subject within a strict framework, while the Indigenous knowledge could compliment and enrich these approaches in unexpected ways. In the same way that observations of weather and climate by locals can complement basic data from automated weather stations, it can be the same for local observational culture that surrounds the Inuvik cosmic ray observatory. The Coincidence Mixer therefore represents both limitations and opportunities of Western science.

One way to liberate the coincidence mixer from the tight grip of its Western context, is to situate it in the local and the present. What does this object mean to the people of Inuvik today? How could they help us interpret it? What does it tell us about both science and museums?

When we examine an object on its own terms, these kinds of alternative possibilities emerge, and with them new ways of researching and interpreting the object. In this case, the local community should be one of the most obvious contexts to investigate, but the Coincidence Mixer was not seen as a local object but rather as a foreign visitor. Each object in our museum collection has multiple connections to diverse communities and people – the people who designed this instrument, the people who made the instrument, the people who used and managed it, the international community of scientists connected to it. Being a curator of a collection of objects with these connections is like being the manager of a collection of communities. And it is a curator's job to study the object with an open mind, let others study it from diverse perspectives, and thus to imagine other connections and communities connected to it. This approach to objects carries with it a massive responsibility that echoes back to the historical core of curating – *curatus* in Latin, or one who is responsible for the caring of the souls of a parish. To care for an object has the additional responsibility of seeking, cultivating and preserving the voices of its associated communities, and using those to bring to light neglected but important dimensions of science, history and the society.

Markings, Dents and the Contours of History

Figure 5 - Metocean Buoy. c. 1988, art. no. 1990.0017. Ingenium: Canada's Museums of Science and Innovation, Ottawa. Photograph by David Pantalony.

Collections and their objects document a history of actual use through markings, graffiti, adaptations, and wear and tear; they can inspire research and the historical imagination. This meteorological ocean buoy sat in our collection warehouse for years without a visitor. The small black and white image in our database showed a fairly simple object with no sense of size or character. But upon my first visit to see it in 2009 with a visiting researcher, we were struck by its immediate qualities and surprising character and presence. Firstly, it is considerably banged up with tears and punctures. The top of the buoy shows a chipped maritime yellow, while below it has a very faded red. It has two phone numbers from opposite coasts of Canada – one with a maker's plate "Metocean Data Systems Limited, Dartmouth, Nova Scotia, Canada," and the other connected to the users of the buoy – "Property of Atmospheric Environment Services, Vancouver, B.C., Canada." Inside various chambers of the buoy, there are precision instruments for measuring pressure and temperature, and for transmitting signals. The longest and heaviest tube on the bottom carries hundreds of commercial batteries. It has a prominent identification number on it "7147."

Figure 6 - Deployment of Metocean 7147 buoy in the Pacific Ocean, 1988. Image located in Supplementary Information Files for art. no. 1990.0017. Ingenium: Canada's Museums of Science and Innovation, Ottawa.

These dents are a window into its rough and tumble life as a scientific instrument. In October 1988, scientists deployed buoy 7147 off a container ship in the Pacific Ocean. It drifted and sent data until January 1990, when it washed up on a rocky beach on the coast of British Columbia. It sat there in the rocks and waves for months before being rescued and returned to the weather office in Vancouver.

In the 1980s the Metocean buoy had been part of an innovative fleet of buoys that drifted throughout the Pacific Ocean transmitting data to a fleet of satellites in space, which in turn sent it back to meteorological centres on earth. This was all part of an ambitious worldwide research project, one of the first of the modern era of climate research.[38]

There are numerous ways to study and appreciate this object, each label and marking having its own story. An entire history, for example, could be told about the company that made

[38] Katherine Swenson and Archie E. Shaw, "The Argos System: Monitoring the World's Environment," *Oceanography* 3, no. 1 (1990): 60–61; Robert W. Stewart and Lloyd M. Dickie, *Ad Mare: Canada Looks to the Sea. A Study on Marine Science and Technology* (Ottawa, Ontario: Information Canada, 1971).

it, Metocean. In the 1980s, it had been an innovative, research-based company situated in Dartmouth, Nova Scotia, with connections to the nearby Bedford Institute of Oceanography.[39] Their work on these buoys came into being through the equally fascinating history of the Argos satellite program developed in the 1970s to transmit and process data from throughout the oceans. The Vancouver office of Atmospheric and Environmental Services was part of a large network across the country with headquarters near Toronto.

But of all the features on the buoy, the dents and punctures captured my curiosity, raising a simple question – where did these happen? Tracking down the exact path of buoy 7147 was not easy. The original Vancouver records had gone missing, for example. I eventually obtained the data from an Environment Canada technician at one of the data processing facilities in Edmonton, Alberta. For years Dennis Oracheski had processed the satellite data with HP computers and then sent this data back to headquarters in Ontario. He kept a hand-written logbook of each buoy for his own records. These logs showed the exact path of buoy 7147, and its rough end following a fierce coastal storm in January 1990.[40]

Pursuing the story of the dents, ended up leading to one of the more surprising dimensions of this history, which is how much of this meteorological research depended on a land-locked computer processing centre. In science museums, we often highlight the heroic technological stories such as the satellite history in this one, as well as the innovative company that made the buoys. But a significant part of this history related on the seemingly mundane processing of that data, and the huge amount of skills, staff and infrastructure that such an undertaking required. Following the story behind the dents took me to a different narrative, and a lesson that it can be useful to pursue our historical instincts about objects and their features, even if they seem trivial. It is sometimes the artifacts themselves and their ability to evoke unexpected questions that can lead us to these alternative historical pathways.

Remarkably, however, the buoy functioned as a scientific instrument for less than two years. In contrast, it has functioned as a museum object for over 30 years. If we are to be honest about this object and its biography, we should say that it has played a larger role as a cultural signifier, than as a scientific knowledge generator. Since 1990 when this buoy stopped drifting in the ocean, it has been drifting through cultural institutions, narratives, contexts and encounters. In 1990 the Canada Science and Technology Museum acquired it and immediately placed it in an exhibition called *Canada in Space*. When that exhibition was over, it was put in the collection storage facility. Since its rediscovery, it has been examined by a researcher looking

[39] David N. Nettleship et al., eds., *Voyage of Discovery: Fifty Years of Marine Research at Canada's Bedford Institute of Oceanography : A Commemorative Volume in Celebration of the 50th Anniversary of the Bedford Institute of Oceanography Dartmouth, Nova Scotia, Canada, 1962-2012* (Dartmouth, Nova Scotia: The BIO-Oceans Association, 2014).

[40] Personal communications by email with Dennis Oracheski, 2014.

into the history of climate change research; it has been studied by students on class visits to the collection space; it has been the subject of early 3D scanning experiments; it even went as a guest to a symposium on the history of oceanography in Halifax, and subsequently put on display at the Maritime Museum of the Atlantic.[41] During and since that visit, the buoy served as a catalyst for research with former scientists at the Bedford Institute at Oceanography. In short, it has had an active and influential life as a museum artifact in the present, building communities, and reinforcing specific narratives within multiple contexts. It is now back in Ottawa on display in the oceanography section of the Hidden Worlds exhibition at the Canada Science and Technology Museum; in that display the buoy is part of a history of Canadian technological innovations in oceanography.

The Object in a Study Room: Harnessing Knowledge in Collections

Figure 7 - The Object Study Room at Ingenium containing the cyclotron particle accelerator made at the National Research Laboratory in Ottawa in 1947, art. no. 1966.0822. Ingenium: Canada's Museums of Science and Innovation, Ottawa. Photograph by David Pantalony.

[41] Katharine Anderson and Helen M. Rozwadowski, eds., *Soundings and Crossings: Doing Science at Sea, 1800-1970* (Sagamore Beach, MA: Science History Publications/USA, 2016).

The home-made quality of this object draws one into its curious mixture of materials and features, but ultimately confounds the average museum visitor as to its original purpose – as part of an electron accelerator. In fact, in 1947 this "cyclotron" was the second one built in Canada (the first being at McGill University in 1946). It was also the first of its kind in the world based on a Soviet design. It represented a unique and short window of free exchange within the physics community from the end of the World War II to the rise of the Iron Curtain.[42]

Also known as a Microtron, this instrument used a combination of strong electromagnets and microwave technologies to accelerate electrons around an inner chamber. Examination and close study of this object brings out narratives about science that are often neglected by science museums, and by historians in general. The maker story here is significant - the cyclotron was made in the workshops of the National Research Council of Canada, where a large number of the technicians were trained in the best labs and workshops of Great Britain. The sealed bolts show the importance of securing vacuum conditions in the main chamber. The design of these features came from the renowned specialist of vacuum physics, Paul Redhead. The waveguides and microwave parts came from the work of Hugh LeCaine, who applied his background in radar development during the World War II to work out how to use microwaves to accelerate the electrons. Aside from work in nuclear physics, LeCaine became well-known for his early innovations in electronic music. His Sackbut electronic synthesizer, the first in the world, comes from the same time and shares some of the homemade qualities of the accelerator, and of course a mastery of managing both electro-magnetic and acoustic frequencies.[43]

These material features each have deeper histories, and potential for research and exhibitions. The microwave parts (microwave vacuum tubes called klystrons) and related instrumentation have their own history to explore. The Curator of Communications at Ingenium, Tom Everrett has begun a project to make LeCaine's Sackbut synthesizer playable again. Part of this research will entail studying in detail the making history of both objects, and how these material histories, technologies and techniques may have influenced each other.[44]

[42] Paul A. Redhead, "Microtrons in Canada," *Physics in Canada* 59, no. 1 (2003): 9–16.

[43] Gayle Young, *The Sackbut Blues: Hugh Le Caine, Pioneer in Electronic Music* (Ottawa: National Museum of Science and Technology, 1989.).

[44] The Sackbut project has been preceded by another reconstruction project at Ingenium; see Tom Everrett, "Writing Sound with a Human Ear," *Science Museum Group Journal* 12, no. 12 (2019), accessed May 22, 2020, https://doi.org/10.15180/191206.

Figure 8 - Close-up of NRC Cyclotron, art. no. 1966.0822. Ingenium: Canada's Museums of Science and Innovation, Ottawa. Photograph by David Pantalony.

The sealed parts speak to the huge effort needed to manage vacuum conditions. In fact, this is a major theme that emerges from our collection of physics (and others worldwide) that speaks to its importance in twentieth-century science. Further exploration of this theme at the material level could provide insights into how these skills and technologies, often overlooked as routine, shaped the practice and industry of physics; preparing an exhibition on the topic of vacuum culture would generate insights through curating this unlikely group of things that have one big thing in common – the quest to perfect "nothing."

Aside from using key features as a springboard for historical imagination and inquiry, we must acknowledge that the study room exists in the present, and that the objects we place in there have shifting value, functions and meaning in the present. The cyclotron was used up until the 1960s as a scientific instrument. Since that time (over 50 years!), it has served a national scientific totem in various ways. For years it was an iconic display item in an exhibition about Canadian innovation. If an archaeologist were to find the cyclotron in 2,000 years, and be lucky enough to piece together its provenance, they would learn that it spent most of its life functioning as an object that helped tell a specific narrative about Canadian science.

By situating the object in the present, we also recognize and embrace the full value of different perspectives that gather around it in the study room. Many people in that room are looking at the object as it is, and not through a historical lens.

These kinds of studies require a new way of approaching objects, but just as importantly the institutional framework and infrastructure to do this. Figure 7 also shows that this object is in a study room in our new Collection, Conservation and Research facility. At Ingenium we have been building programs and structures to tap all the different ways of looking at objects, and thereby tapping the full multi-dimensional potential of collections.[45] This study room is meant as a place where objects can be called up and studied at close range; where seminars can be held, and people from diverse backgrounds can study the same object from different perspectives; where researchers can take advantage of proximate conservation labs for deeper material analysis, as well as nearby digital and media labs for experimenting with new ways of studying multiple dimensions of an object – physically and digitally. In order to fully harness this potential, this careful, yet creative study of objects will be a central part of the Ingenium Research Institute, where the collection and surrounding spaces will encourage and facilitate a culture of open access and exploration. All of these efforts will have spin-offs in research, teaching, exhibitions, policy making and public programs.

Beautiful Fragments:[46] Embracing the Many Dimensions of What Remains

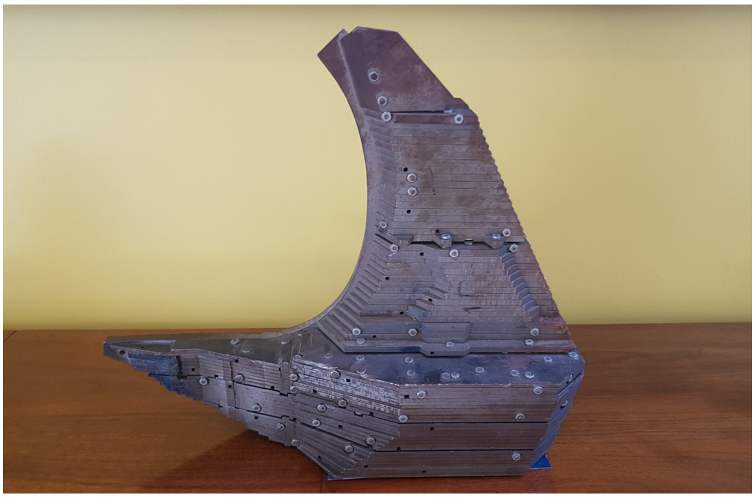

Figure 9 - Section of Experimental Magnet Model for Triumf Cyclotron c. 1969. Interim no. BC0035. Ingenium: Canada's Museums of Science and Innovation. Ottawa.

[45] For several years Ingenium ran a Readings Artifacts Summer Institute based on historian Rich Kremer's collection-based seminars at Dartmouth College, NH.

[46] The phrase "beautiful fragment" is a reference to the description of Babbage's difference engine in Henry Prevost Babbage, *Babbage's Calculating Engines Being a Collection of Papers Relating to Them, Their History and Construction, Calculating Engines* (London: E. and F.N. Spon, 1989), preface: "As to his own contrivance, he was quite content to let it be judged by the beautiful fragment put together in 1833, which will for ever remain to answer all detractors."

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Much of our history depends on, and is constructed from the materials that quite simply survive – papers, images and objects. Some of these things survive due to purposeful preservation, while others due to more arbitrary contingencies.[47] Some objects survive because they are too heavy to move, others because they are beautiful.

The sculptural fragment in Figure 9 was part of an experimental model for the Triumf Cyclotron accelerator at the University of British Columbia. Very few people would recognize it as such. The real cyclotron exists in a large building and measures 18 metres in diameter and weighs 4,000 tons, while this fragment (still over 100 kilograms) is from a smaller table top version used in the 1960s to model the experimental field dynamics before building the real thing.[48]

When this object was rediscovered, it brought to light a forgotten dimension of the cyclotron's history, the sophisticated testing and experiments that went into the making of its final design. It also provides insights into how we do history – the forces that govern preservation, the nature of building narratives from a variety of evidence, and the things we pay attention to, and the things we neglect.

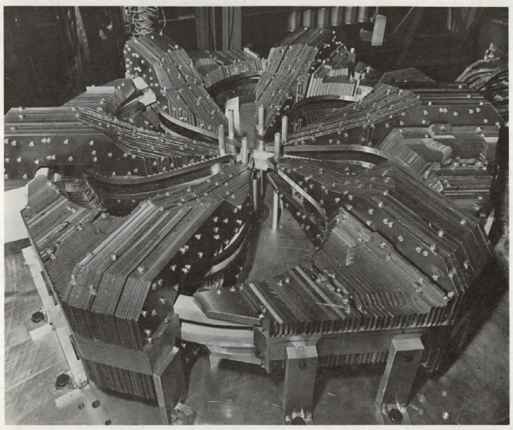

Figure 4.3 A photograph of the Mark VI-1 (scale = 20:1) magnet model

Figure 10 - Magnet sector within larger table top model and experiment. Image: Triumf.[49]

[47] Richard Kremer, "A Time to Keep and a Time to Cast Away: Thoughts on Acquisitions for University Instrument Collections," *Rittenhouse* 22 (2008): 188–210.

[48] Neil Brearley, *TRIUMF Annual Report 1969* (Triumf, University of British Columbia, 1970); Michael K. Craddock and Robert E. Laxdal, "Accelerator Science and Technology in Canada — From the Microtron to TRIUMF, Superconducting Cyclotrons and the Canadian Light Source," *Reviews of Accelerator Science and Technology* 08 (January 2015): 225–67.

[49] Brearley, *TRIUMF Annual Report 1969*.

How do we construct a whole from the parts? Of course this fragment can quite literally be fit into its original context (Figure 10). It also shows something that the case studies outlined above have in common – it serves as an object around which numerous narratives can be constructed; and embracing its ambiguity can serve as a powerful invitation to look at it through multiple lenses.[50] It would not look out of place in an art gallery or a space devoted to materials, function and design. Each of these perspectives entails the creation of value within a particular culture, such as art history, physics, educational institutions, companies and nations. This fragment came to our museum in 2018 and, like the Metocean buoy above, was a special guest at large 50th anniversary party for the Triumf Cyclotron. Objects can be focal points for mobilizing multiple communities; this is a fact of which we should take advantage, but also be critically aware. The more we study objects, and the more we open up these processes of interpretation, the more we build and reinforce these relationships.

Conclusions

> "Porque o único sentido oculto das coisas. É elas não terem sentido oculto nenhum,"
> Alberto Caeiro [Fernando Pessoa], "O mistério das coisas."[51]

> "Because the only hidden meaning of things is that they have no meaning to hide."
> Alberto Caeiro [Fernando Pessoa], "The Mystery of Things."[52]

What Remains? The above case studies show the value of an honest approach to material culture. We must approach and study objects for what are they, not what we want them to be. Objects are not the domain of one subject, or community, but in fact they are part of different fields, geographies and cultures. Objects are often depositories of information not available, or at least not readily available in other media such as text and image. Above all, objects have unique features – they take up space! – that make them focal points for complex relations in the present, as well as generating meaning and value in the present. Collections of these objects are therefore a valuable window into humankind's relationship with the material world, and unique source of diversity in education, culture, research, and knowledge economy.

What do we do with what remains? The recognition of the multifaceted value of collection knowledge requires that keepers of collections develop structures and practices around these collections that tap this potential. We must make them accessible in digital and physical ways, but that commitment alone is not enough as collections are continually confronted by evolving

[50] Jim Bennett, "Beyond Understanding: Curatorship and Access in Science Museums" in *Museums of Modern Science*, ed. Svante Lindqvist, 55–60 (Canton, MA: Science History Publications/USA, 2000).
[51] Austen Hyde and Martin D'Evelin, *Lisbon Poets: Camões, Cesário, Sá Carneiro, Florbela, Pessoa*, bilingual edition (Lisbon: Lisbon Poets & Co., 2015), 168.
[52] Hyde and D'Evelin, *Lisbon Poets*, 169.

physical, intellectual and institutional forces that wall them off from the public – we must be vigilant and creative in striving to make them accessible for teaching, research, and public use.

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Competing interests

The author has declared that no competing interests exist.