

Design of a Contemporary Elementary Non-Trivial Machine

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> Context • Cybernetics owes much of its development and proliferation to the introduction of technical devices. Such devices, which are often conceptual, one-of-a-kind artifacts, are rarely available to wider audiences. Once archived, in disrepair, or even lost altogether, they are impossible to experience firsthand. **> Problem** • How can historical cybernetic devices be conserved, and how can access to the experiences they offer be ensured and promoted? **> Method** • We examine this question from a design perspective and with a focus on the Ashby Box and, by extension, Heinz von Foerster's Non-Trivial Machine (NTM). We discuss the Ashby Box, its position between first- and second-order cybernetics, its significance in W. Ross Ashby's epistemology, and its role in von Foerster's ethics. We then describe our redesign of an Elementary NTM based on the Ashby Box for batch manufacturing and distribution. **> Results** • We have redesigned the Ashby Box as a handheld product based on contemporary technology and production processes to facilitate firsthand experiences of constructivist and cybernetic ideas. **> Implications** • We describe the purpose and continuing relevance of the Ashby Box and the NTM and present a redesigned Elementary NTM to disseminate constructivist and cybernetic concepts to new audiences in the 21st century. Like the original Ashby Box, the device depends on suitable contextualization to perform its intended purposes effectively. **> Constructivist content** • We present a contemporary redesign and recontextualization of the Ashby Box, a prototypical object of constructivist epistemology. Our approach relies mainly on reflective design practice, whose qualities the NTM is said to embody. Our redesigned Elementary NTM aims to disseminate further the constructivist epistemology of Ashby and the humanistic, second-order cybernetic ethics of von Foerster. **> Keywords** • Ashby Box, cybernetics, epistemology, ethics, experience, history, machines for showing, materiality, non-trivial machine, trivial machine.

Introduction

« 1 » In the mid-20th century, cybernetics emerged with a focus on technical applications in control engineering. Between 1968 and 1975, a branch of second-order cybernetics with a focus on epistemology and ethics joined the original first-order branch. Different characterizations of the relationship between the two branches abound. Some emphasize continuity between them, while others emphasize discontinuity in terms of intellectual milieus, historical periods, and application areas (Heylighen & Joslyn 2001: 3f). Ranulph Glanville (2012: 176), for example, highlights the continuity between the two branches, describing the concerns of first-order cybernetics as a subset of the broader concerns of second-order cybernetics. Heinz von Foerster (1979: 7), by contrast, highlights the difference between both branches, describing first-order cybernetics as “the cybernetics of observed systems” and second-order cybernetics as “the cybernetics of observing systems.”

« 2 » A connecting thread between the technical and epistemic concerns of both branches came into focus during a 1945 discussion involving Warren McCulloch, Norbert Wiener, John von Neumann, and others. The question was how one should interrogate the second of two mystery machines captured from the enemy after the first machine exploded in response to an attempt at opening it (McCulloch 1989: 40). In a 1951 exchange with W. Ross Ashby and others, Wiener raised what, by then, he called “the problem of the black box,” that is, “the question of how to take a box with unknown electrical contents, feed an input into it, observe the output, deduce the contents, and then make a machine with the same performance.”¹ In the introduction to the second edition of his book *Cybernetics*, Wiener elaborates with apparent reference

1 | Journal of W. Ross Ashby, Volume 13 (20-Jan-51): 3076, <https://ashby.info/journal/page/3075.html>

to earlier telecommunications engineering theory (Breisig 1921; Feldtkeller 1937):

“I shall understand by a black box a piece of apparatus, such as four-terminal networks with two input and two output terminals, which performs a definite operation on the present and past of the input potential, but for which we do not necessarily have any information of the structure by which this operation is performed. On the other hand, a white box will be a similar network in which we have built in the relation between input and output potentials in accordance with a definite structural plan for securing a previously determined input-output relation.”² (Wiener 1961: xi)

« 3 » Soon, opaque systems that could be understood only by way of observing and manipulating their inputs and observing their outputs became known as “black boxes.” In 1957, Ashby notes that, besides characterizing technical puzzles, the concept of the black box can be seen as a metaphor for objects of epistemic inquiry in general: “In our daily lives we are confronted at every turn



Figure 1 • The Ashby Box.

with systems whose internal mechanisms are not fully open to inspection and which must be treated by the methods appropriate to the Black Box” (Ashby 1957: 86). Ashby (1957: 87) then asks: “How should an experimenter proceed when faced with a Black Box?” This line of thought brings Ashby to second-order cybernetics decades ahead of his time: “We, the system theorists, have in fact been studying, not a Black Box, but a larger system composed of two parts, the Black Box and the Investigator, each acting on the other” (Ashby 1958b: 6). The black box has since been used to exemplify not-knowing and reciprocity in the work of cyberneticians including Gregory Bateson (1972: 39), Niklas Luhmann (1995: 109), Ernst von Glasersfeld (1995: 46), and Glanville (1979, 2009a, 2009b).

« 4 » As a connecting thread between both branches of cybernetics, “the problem of the black box” pulls together the (first-order) nuts and bolts of technical machinery and the (second-order) puzzles of probing inquiry, connecting the technologist’s interest in literal black boxes with the epistemologist’s interest in metaphorical black boxes. It is not surprising, then, that Ashby implemented “the problem of the black box” in the form of a physical device, which he named the “Black Box.” Consisting of four input switches users could manipulate and

four output lamps users could observe, as well as a plug board and a rotating internal switch to establish different transfer functions, this Black Box is, maybe not surprisingly (Fischer 2013; Fischer & Cretu 2023), reminiscent of the Nazi-era Enigma cipher machine.

« 5 » Ashby brought his Black Box along when he relocated from the UK to the US to join the Biological Computer Laboratory (BCL) at the University of Illinois, where, under the leadership of Heinz von Foerster, the development of second-order cybernetics was in full swing. Since then, the device itself appears to have been lost. Handouts surviving from classes he taught at the BCL show that Ashby tasked his students with “programming” the Black Box to establish predetermined behaviors (Fischer & Cretu 2023: 177f) – a capability he described as an indicator of control.² Probably inspired by von Foerster, Ashby then set out to create an elementary deterministic device that could thwart attempts at “whitening” it by way of repeated input manipulation and output observation.

« 6 » The apparent result of this challenge is another device designed and built by Ashby at the BCL, namely, the “Ashby Box” (see Figure 1). This electromechanical device is a simple aluminum box with two input toggle switches and two output lamps. Any change of the machine’s two-bit input results in its displaying a new two-bit output. The device has an internal state that codetermines its output, resulting in a large combinatorial space that makes it very difficult to predict. Accounts of students attempting and failing to determine the Ashby Box’s 10¹²⁶ “possibilities” testify to what von Foerster calls its “analytical indeterminability” (Foerster 2003: 312).

« 7 » Von Foerster further abstracted the Ashby Box to develop his so-called Non-Trivial Machine (NTM), which he contrasted to his Trivial Machine (TM). Both the NTM and the TM are hypothetical machines presented as schematic diagrams. The TM is characterized by fixed input–output relationships that can be listed in a truth table as shown on the left of Figure 2. The

NTM has an internal state z that changes with every input–output translation and codetermines the NTM’s outputs, as shown on the right of Figure 2. Therefore “whenever z changes, the machine becomes a different trivial machine” (Foerster 2003: 142), resulting in a potentially vast set of input–output relationships that can overwhelm human attempts at analytical determination.

« 8 » The Ashby Box remained at the BCL until the lab’s resolution in the mid-1970s. After that, it was taken care of by Ricardo Uribe until his death in 2019. Today, it is kept in the University of Illinois Archives along with Uribe’s papers under Record Series 11/6/40. From its BCL days, it bears a sign, apparently affixed by von Foerster, reading “Ashby’s elementary NTM.” Being a technical device, the Ashby Box can, in principle, be opened. Practically, however, this was, and is, not allowed. Uribe, as well as, presumably, Ashby and von Foerster before him, guarded the interior of the Ashby Box from prying eyes.

Purpose and continuing relevance

« 9 » Ashby’s journal, which he kept from 1939 almost until his passing in 1972, records questions he pursued and insights he gained over the years. A few months before finishing the Black Box in 1954, for example, he notes in his journal: “A machine of n states requires (at least) n steps before the observer can know its design.”³ In 1971, having completed the Ashby Box and retired from the BCL, he states: “Interaction between parts with input raises the complexity by [factor] ki (i = no. of inputs to each part; k = no. of values (states) of each part).”⁴ Ashby’s journal is less explicit when it comes to the evolving motivations to build his devices. An exception is a 1958 entry in which he ponders the possible remake of an earlier device he built, named DAMS. In this entry, Ashby notes:

3 | Journal of W. Ross Ashby, Volume 18 (02-Mar-54): 4809. <https://ashby.info/journal/page/4808.html>

4 | Journal of W. Ross Ashby, Volume 25 (19-Apr-71): 7124. <https://ashby.info/journal/page/7124.html>

2 | Journal of W. Ross Ashby, Volume 18 (06-Apr-54): 4840. <https://ashby.info/journal/page/4840.html>

“[T]he basic conception is that all proofs are elsewhere, in print probably; the machine is intended purely to enable the by-stander to see what the print means + to get some intuitive, physical, material feeling for what it is about. (Its chief virtue will be that it will teach me, by letting me see something actually do the things I think about.) Summary: Build devices for demonstration. [...] I am now regarded more as a teacher than as a research worker. The world wants to hear what I have found out [and] is little interested in future developments. Demonstration should therefore be my line, rather than exploration. In this connexion it occurs to me that building many small independent machines, each to show just one point, may be much easier (being reducible) than building a single machine that includes a lot. Summary: Build small specialist machines, each devised to show one fact with perfect clarity.”⁵

« 10 » After Wiener characterized inquiries into opaque systems analogously to the diagnosis of faulty communications networks, Ashby advanced the “problem of the black box” from an abstract challenge to a concrete, shareable experience. His Ashby Box invites practical epistemic inquiry and compels its users to ask: “How should an experimenter proceed when faced with a Black Box?” Unlike so many other puzzles, the upshot of using the Ashby Box lies not in some simple solution to a seemingly complex problem. On the contrary, it lies in recognizing the virtual futility of trying to solve a seemingly simple problem. The Ashby Box is a prototypical Black Box: a “device for demonstration,” a “machine for showing” (Herr & Fischer 2013: 201) – an epistemic object, that is, “an entity whose unknown characteristics are the target of an experimental inquiry” (Rheinberger 1997: 238).

« 11 » Von Foerster, then, prescinds from the materiality of the Ashby Box. He turns it into his diagrammatic NTM, which he contrasts against his TM – somewhat along the lines of “Aristotle’s distinction of explanatory frameworks for inanimate matter and living organisms” (Foerster 2003: 208). Using this juxtaposition to illustrate the effects

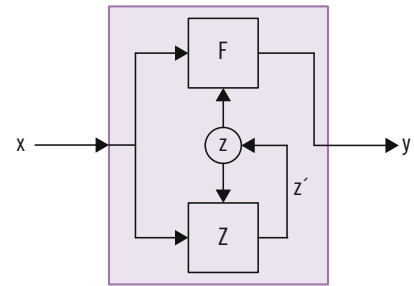
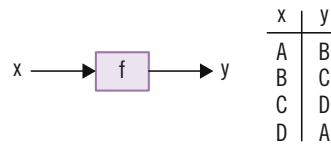


Figure 2 • Trivial Machine (left) and Non-Trivial Machine (right), redrawn from von Foerster (2003: 310f).

of technization on how we see ourselves and one another, he notes:

“All machines we construct and buy are, hopefully, trivial machines. A toaster should toast, a washing machine wash, a motorcar should predictably respond to its driver’s operations. In fact, all our efforts go into one direction, to create trivial machines or, if we encounter non-trivial machines, to convert them into trivial machines. The discovery of agriculture is the discovery that some aspects of Nature can be trivialized: If I till today, I shall have bread tomorrow. [...] While our pre-occupation with the trivialization of our environment may be in one domain useful and constructive, in another domain it is useless and destructive. Trivialization is a dangerous panacea when man applies it to himself.” (Foerster 2003: 208)

« 12 » As von Foerster acknowledges, both predictable reliability and surprising unpredictability have their place (Fischer 2010: 611; Fischer & Cretu 2023: 165). Yet, demands for predictable reliability are frequently misplaced. Von Foerster notes that people tend to view themselves as (spontaneous and surprising) NTMs and others as (predictable) TMs (Foerster 1999: Disc 1, Track 3, 11’34”–11’59”). When holding others to the standard of the TM, then, anything but the others’ fulfilling of our expectations appears to us as irritatingly erroneous and calls for the panacea of trivialization. In defense of the spontaneity, creativity, whimsicality, and opaqueness to inquisition from outside that distinguish us from predictable mechanisms, von Foerster rejects trivialization in the social domain. He argues:

“Instead of searching for mechanisms in the environment that turn organisms into trivial machines, we have to find the mechanisms within the organisms that enable them to turn their environment into a trivial machine.” (Foerster 2003: 152)

« 13 » Von Foerster illustrates this using multiple images and narratives. One is a story about a schoolchild. Asked “How much is two times three?” the child responds “Green,” is promptly reprimanded, and then undergoes further trivialization to hopefully produce the previously established, “correct” answer in the future (Foerster 2003: 196, 311). Another is his juxtaposition of the TM and the NTM (ibid: 310f) and the implied question “Which one are you, and how do you see your fellow humans?” Von Foerster delivers his humanist appeal in mechanistic terms, presumably to make it palatable for those who are mechanistically minded. In this way, von Foerster’s TM and NTM serve as boundary objects, that is, as objects that “have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation” (Star & Griesemer 1989: 393).

« 14 » Von Foerster points out that the Ashby Box and the NTM show the limitations of analytical determinability, joining “famous sisters” that show other limitations such as Kurt Gödel’s Incompleteness Theorem, Werner Heisenberg’s Uncertainty Principle, and Richard Gill’s Indeterminacy Principle (Foerster 1984: 13). In addition, the Ashby Box can be seen as a sister of the Turing Machine in that both demonstrate the limits of two basic avenues to knowl-

5 | Journal of W. Ross Ashby, Volume 22 (29-Sep-58): 6059–6060. <https://ashby.info/journal/page/6058.html> and <https://ashby.info/journal/page/6060.html>

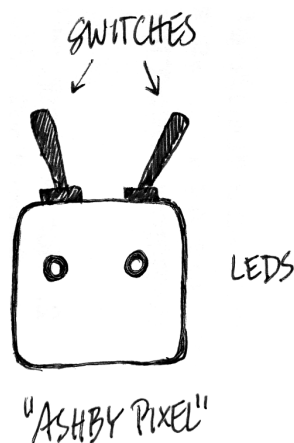


Figure 3 • Early concept sketch by Christiane M. Herr, from 2018.

edge. Specifically, Alan Turing presents the Turing Machine in response to David Hilbert's *Entscheidungsproblem* (Hilbert & Ackermann 1938: 90) to show the limits of formal deduction, whereas Ashby proposes the Ashby Box to demonstrate the limits of experience-based induction (Fischer & Cretu 2023: 170, 181).

«15» In the development of cybernetics, the Ashby Box (and, by extension, the NTM) bridges the first- and second-order branches of the field by placing a deterministic (first-order) mechanism within an opaque boundary, thereby rendering it non-determinable to the (second-order) observer. In design cybernetics (Fischer & Herr 2019: 12–14), the NTM serves as a metaphor for the (openness toward) non-determinability that renders design processes unpredictable. On occasion, moreover, the NTM inspires applied, variety-amplifying design across various fields from architecture (Gage 2006, 2008) to digital audio synthesis (Chandra 2007) to typography (Fischer 2012) and jewelry design (Fischer & Herr 2015).

«16» With this continuing relevance, the Ashby Box and the NTM require continuing introduction and explanation to new generations of students and scholars. For these purposes, both have drawbacks. Print-based introductions of the theoretical

NTM are easily replicated and distributed but abstract and theoretical. The tangible Ashby Box offers an engaging interaction experience aligned with constructivist learning principles but is difficult to access and operate. Aiming to combine the advantages of both, we decided to produce a contemporary implementation of the Ashby Box: a new Elementary NTM. In the following, we outline the design development of this device. Then, we discuss it in the context of contemporary cybernetics.

Designing a contemporary elementary NTM

«17» In 2023, we set out to design and implement an updated version of the Ashby Box as a contemporary cybernetic demonstration object. Early ambitions to this effect date back to the 2018/19 production of speculative remakes of the original Ashby Box (Fischer & Cretu 2023: 178–187). A short Python 3 script implementing the logic of the speculative Ashby Box remakes served as a point of departure and the logical blueprint for this redesign project.⁶ In the context of producing the speculative remakes, von Foerster's (2003: 312) mentioning of the Ashby Box's 10^{126} "possibilities" provided a clue as to how Ashby's device functions.

«18» As von Foerster (2003: 312) notes, a machine with a two-bit input and a two-bit output behaves at any given time according to one of $4^4 = 256$ possible transfer functions (i.e., internal states). In non-trivial machines, these transfer functions change from each operation to the next. Each such state transition from one out of 256 possible transfer functions to the next is this one out of $256^{256} \approx 10^{616}$ possible state transitions. The 10^{126} "possibilities" mentioned by von Foerster suggest that the Ashby Box implements a subset of 52 out of the possible 256 transfer functions, as $256^{52} \approx 10^{126}$. This, in turn, suggests that the Ashby Box is built around a 52-position uniselector – a uniselector being an electromechanical rotary stepping switch that was commonplace in

the mid-20th century. Ashby (1957: 84) had previously used a 25-position uniselector in each of the four units of his 1948 Homeostat, likewise to achieve a large number of possible internal states. The speculative remakes were implemented in accordance with this assumption. Likewise, the redesigned electronic version was to be based on the same logic, also implementing 10^{126} possible state transitions.

«19» In contrast to the mid-20th century electromechanical one-of-a-kind original, the redesigned version should be based on contemporary technology and available to larger numbers of users. The general convergence of once-discrete technologies (Knight & Weedon 1995: 5) suggests emulating the Ashby Box in a mobile app. The considerable computational power and network connectivity of smartphones and tablets, however, would defeat the purpose of a minimal yet non-determinable mechanism and not make for an effective demonstration platform. We therefore opted to design and manufacture a contemporary, redesigned "Elementary NTM" as a self-contained, single-purpose electronic device. Figure 3 shows a 2018 conceptual sketch of what a redesigned electronic version of the Ashby Box might look like.

«20» The radical minimalism of the Ashby Box is ideally suited for demonstration purposes and a quality we aimed to preserve in our redesign. Accordingly, we retained the essential elements of the Ashby Box, that is, the two input switches, the two output lamps, and the (presumed) logic that relates the inputs and the outputs. In choosing the new device's physical scale, by contrast, we decided to deviate from the original. The "tabletop"-sized form factor of the Ashby Box, with its dimensions of about 6 by 5 by 4 inches (15.24 cm × 12.70 cm × 10.16 cm), was most likely determined by technical necessity and is, in our view, not ideal. On the one hand, it is relatively small for demonstrations to groups. On the other hand, it is somewhat bulky as a personal interactive object. We decided to make the new device (shown in Figure 4) smaller and more personal than the original rather than a shared device, with the potential to be an attractive small gift or souvenir.

«21» The integration and miniaturization of contemporary electronics allow the

⁶ | Ashby Box remake implementation in Python 3, by Thomas Fischer, 2023. https://gitlab.com/tomfischer/Cybernetics-Experiments/-/blob/master/Ashby_Box/Ashby_Box_EN.py

implementation of the functionality of the Ashby Box at an extremely small scale. Rather than shrinking the device to the full extent possible in terms of function, however, our design development (shown in Figure 5) aimed for physical dimensions that allow for meaningful human interaction, relating directly to the size of the human hand, as well as to the human hand's relationship to the human eye. This scale has been established across numerous human-made handheld objects, from Paleolithic hand-axes to decks of playing cards, the original Apple iPod, and the common soap bar. At this scale, the object would not only be easy to hold and interact with manually but could also be shaped to be conveniently portable and pocketable.

« 22 » Instead of the incandescent lamps of the Ashby Box, we chose LEDs with a clear, round, 10 mm diameter plastic body, emitting a warm yellow light reminiscent of that emitted by the lamps of the Ashby Box. Based on extensive online research and physical evaluations, we chose KCD-168 three-pin single-pole double-throw rocker switches released in 2022 to replace the toggle switches of the original Ashby Box. Rated for 250 V~ at 6 A, the power rating of this switch model is significantly above what is required for toggling logic levels. We nevertheless chose it for this project due to the relatively low profile of its rocker section. In contrast to the protruding toggle levers of the switches used in the original Ashby Box, this low profile allows for the above-mentioned “pocketability.” We furthermore chose this switch for its material (texture, color), haptic, and acoustic qualities. Moreover, its movable “rocker” protrudes about 2 mm from its main body, allowing the switch to be mounted within a 2 mm thick shell such that the depressed half of the rocker aligns flush with the shell's exterior surface. The width of the movable rocker furthermore matches the 10 mm diameter of the LEDs closely, allowing for a neatly aligned arrangement of the two switches and the two LEDs. While the original Ashby Box featured its two switches in the upper section and its lamps in the lower section of its front panel, we turned this placement around to match the eyes being located above the hands on the upright human body, and to prevent hands manipulating the switches



Figure 4 • Front view of the Elementary NTM.



Figure 5 • Form factor evolution and refinement of the Elementary NTM. The two objects on the right are the final “clear craze” special edition and the “black box” regular edition.



Figure 6 • Side view of the Elementary NTM.

from obscuring the view of the LEDs (Ponza, Vilanova & Amante García 2009: 428).

« 23 » We designed the device's shape to subtly hint at the external arc of an imagined interaction loop between the user and the device, in the way the speaker and the microphone mounted in either end of an old-style, C-shaped telephone receiver do. In our device, this gesture is more subtle than it is in an old-style telephone receiver, and more reminiscent of the design of the Panasonic 855 (also branded as Olympia CD 81) electronic calculator from 1971/72. The

LEDs and the switches protrude through the front of the device within filleted recessions. The two user-facing surfaces that make up the ends of the abovementioned C-shape are not raised equally from the main body of the device. Instead, the lower of the two surfaces holding the switches is shallower than the upper one holding the LEDs. This brings the tips of the switches' rockers to the level of the upper surface, as shown in Figure 6. The device has no dedicated on/off switch. To turn it off, the user simply interacts with the device until both lamps are off. To turn it



Figure 7 • The Elementary NTM in a cradle.



Figure 8 • The Elementary NTM in its “black box” cardboard package.

on, the user likewise interacts with the input switches.

« 24 » We designed the plastic shell as a combination of two halves, parted across its front-facing “coronal” section plane. The two half shells are held together with two rotatable hook joints at the lower edge of the device and with a single, black T8 screw at its upper edge. We added a wrist strap at the upper edge of the device, with a spherical cord lock. The cord lock’s availability in a color and a texture that match those of the switch rockers settled the corresponding color and texture choices for the plastic shell. The new product thus having become a literal black box, we also fabricated a clear plastic shell variant to explore a possible special edition with a semantic play on the white or “clear” box concept in engineering and a reference to both the notion of “whitening” black boxes (Glanville 2012: 179) and the 1990s “clear craze” fad in product design and marketing.

« 25 » While the original Ashby Box depends on a wired connection to a 110 V~ mains power outlet, we opted for using an internal 3.7 V~, 1,000 mAh rechargeable lithium-ion battery as the new device’s internal power supply to allow convenient wireless operation. To implement its functionality, we chose the Seed Studio XIAO ESP32C3, a roughly thumbnail-sized Internet of Things (IoT) development board built around Espressif’s ESP32-C3 System on Chip with a 32-bit RISC-V micropro-

cessor. This board offers more than the required input/output functionality as well as the necessary lithium battery charging management via its onboard USB-C port. We extended this board with a custom-designed daughter board holding suitable miniature connector headers for the internal connections to the rocker switches, LEDs, and battery. The XIAO ESP32C3 board and its daughter board, both sharing the same footprint, were “sandwiched” together through solder pads. We placed the “sandwich” combination such that the XIAO ESP32C3’s USB-C port is accessible through the plastic shell at the lower edge of the device. This allows for battery charging via an external USB power supply as well as for USB-powered interaction with the device. It also allows for the upright display and charging of the device using a range of available USB-C smartphone docks and cradles, as shown in Figure 7.

« 26 » The XIAO ESP32C3 board offers various advanced and “smart” features, such as the ability to communicate data via its USB port, as well as built-in 2.4 GHz Wi-Fi, Bluetooth Low Energy connectivity, and connectivity to a wide range of sensors, motors, and display peripherals. To preserve the radical minimalism of the original Ashby Box, we decided not to make use of any of these features. The C++ code we wrote to implement its logic based on the above-mentioned Python 3 code holds the processor in a low-power-consuming light-sleep

mode most of the time, spending 50 ms between checks for changed switch states. A somewhat “advanced” function is the use of pulse width modulation to ramp the LEDs’ brightness up or down in 30 steps in quick succession during state changes. These moments are a tip of the hat to the slowness of the incandescent lamps of the original Ashby Box and constitute the computationally most intensive moments in the operation of our code. Like the original Ashby Box, the new device does not have an on/off switch. It can be viewed as if switched off by interacting with it until both LEDs are in their “off” states. After 60 seconds of non-interaction, it enters its standby mode where changed switch states are checked every 500 ms and exits if changes are detected. If no interaction is experienced for 60 minutes, it commits its internal state to the onboard non-volatile memory and enters an extremely low-power deep-sleep mode. It “wakes up” from this mode when either switch is toggled. At this time, it recovers the internal state stored at the end of the previous session from non-volatile memory, thereby ensuring the continuity of its state transition logic, analogously to the “solid-state” mechanical position of a uniselector switch.

« 27 » We completed the Elementary NTM with the design of a custom folding lid box (shown in Figure 8) for protection during transport and storage. In keeping with the “black box” image, and with a tip of the hat toward the entirely black collector’s

box edition of Glanville's *Black Box* trilogy (Seaman 2022: 227), the packaging box is constructed of a single sheet of black 1.2 mm corrugated cardboard. It contains neither glue nor any other materials, except for a glossy-black-on-matte-black varnish print showing an NTM diagram on the top lid and the name of the device in both English and Chinese along the side panels.

Conclusion

« 28 » The production and use of technical devices are (quite literally) instrumental to the development of cybernetics (Müggenburg & Pias 2017: 39; Pickering 2010: 6f). In this development, the Ashby Box occupies a pivotal role, marking a transition from technical to epistemic and, ultimately, ethical concerns. Yet, over time, cybernetic devices in general, and the Ashby Box in particular, have had a limited and steadily diminishing reach. Archived, eventually in disrepair, or lost altogether, these historical one-of-a-kind implementations tend to become inaccessible such that they cannot be experienced firsthand. From this situation arises a need for continuing access and, more fundamentally, conservation and proliferation.

« 29 » Addressing this need is not straightforward as it demands the negotiation of three competing objectives, namely, fidelity to original objects and materials, to original contexts, and to original aims (Lowenthal 1992: 82). This negotiation can be approached in a variety of ways. Paul Pangaro and Thomas J. McLeish (2018), for example, present a replica of Gordon Pask's Colloquy of Mobiles installation that is "as close as possible to the 1968 original" in its material manifestation, yet is "driven by modern digital software" that allows both its operation in updated "modes" and, thus, its adaptability toward new contexts and/or aims.

« 30 » In this project, we prioritized fidelity to the original aims of the Ashby Box over fidelity to the original's appearance, materiality, and context. This choice was based on experiences gained in producing materially faithful speculative remakes of the Ashby Box (Fischer & Cretu 2023). As rare objects that are crafted from scarce

historical components, those remakes – enlightening as their production was to their producers – are neither amenable to public access nor generally relatable in today's technological context. Yet more fundamentally, it is doubtful whether fidelity toward original experiences and contexts can be a meaningful objective at all when conserving historical cybernetic machines and their operative experientiality. As Wolfgang Ernst (2016: 117) points out, operative media, in contrast to sculptures and paintings, "are temporal objects in the present, and their implementation thus sublates museumality." Ernst concludes that media archeology is, therefore, not "reproduction" but "re-enactment" (Ernst 2016: 117, 243), a view supported by Collingwood (1999: 244), who states "that all history is the history of thought, and that the historian knows a past thought by re-enacting it in the present." If operative media are experienced and interpreted in the present context, then changes in the social and technological context pose a significant challenge to the work outlined above.

« 31 » To illustrate this, consider how the TM corresponds to electromechanical vending machines of the mid-20th century, dispensing the same output every time the same selection is made. Contemporary students of cybernetics are unlikely to be familiar with vending machines of the mid-20th century variety. They are more likely used to vending machines with customizable screen-based interfaces, regular automatic advertising and security updates, cloud-based stock and transaction reporting, face-recognition-based demand prediction, and electronic payments, offering changing selections of products. Not only is our tendency to trivialize one another unabated but it seems to run in parallel with a tendency of technology to take on non-trivial characteristics.

« 32 » To perform, in this context, as an effective boundary object to reach across interpersonal and disciplinary boundaries in defense of the qualities that distinguish us from predictable mechanisms, our Elementary NTM can hardly be understood by itself. Instead, it requires contextualization in the form of explanation and underpinning discourse. This is also the case for the Ashby Box and its performance as a pro-

typical epistemic object and for the NTM in von Foerster's humanistic social critique. The one-of-a-kind Ashby Box could rely on its custodians, and the diagrammatic NTM could rely on the prose surrounding it, to supply the requisite explanation and discourse. By itself, a batch-produced redesigned elementary non-trivial machine will not be able to evoke comparable insights. It requires a contextualization to ship along with it, probably in the form of a product leaflet or printed package. Following the described redesign of the Ashby Box, we are now taking the next steps to design this contextualization, to be made available in conjunction with our redesigned elementary non-trivial machine.

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