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Enigma Rebus: Prolegomena to an Archaeology of Algorithmic Artefacts

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The following article contains preliminary thoughts towards the definition of a necessary novel discipline, the archaeology of algorithmic artefacts. It strives to provide a definition of these artefacts, particularly of algorithmic ones, to describe some general trends in their (ontogenetic and phylogenetic) development, and to work out a methodology for their resurrection, which proceeds theoretically and practically at the same time. In this endeavour, the little creature 'Odradek' invented by Kafka serves as an emblem for the enigmatic state of artefacts before they become and after they have been effective; as a demonstrational object for methods of their resurrection; and as an example for the transcription of technical schemata, by locating several inventions in which this particular set-up reappears.[1]

KEYWORDS Kafka, Odradek, Archaeology of algorithmic artefacts, Genealogy of technical forms, Electron tube, Barlow's wheel, Manchester Mark I, Rubbish theory, Xeno-objects, Bomba kryptologiczna

The consolation of the House Father

> At first glance it looks like a flat star-shaped spool for thread, and indeed it does seem to have thread wound upon it; to be sure, they are only old, broken-off bits of thread, knotted and tangled together, of the most varied sorts and colours. But it is not only a spool, for a small wooden crossbar sticks out of the middle of the star, and another small rod is joined to that at a right angle. By means of this latter rod on one side and one of the points of the star on the other, the whole thing can stand upright as if on two legs.

With these words, the Czech writer Franz Kafka (1883–1924) describes a mysterious being named Odradek in his short story 'The House Father's Concern', written around 1917 and first published in 1919 (Kafka 1919, 428; cf. Figure 1). The strange apparatus moves around autonomously, talks like a child, and occasionally laughs dryly. If this were a report about a robot that operates on a terrain known to it and says 'Odradek', 'No fixed abode' and

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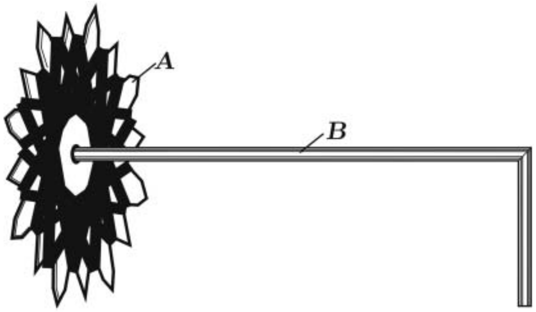

FIGURE 1 Reconstruction of Odradek from descriptive text; A: star-shaped spool, B: wooden crossbar.

'Haha' if spoken to, the text would not be very surprising. Many similar robots have been invented throughout the centuries.

The father guarding the house does not care about Odradek, but is concerned about himself. He suspects that even if the senseless thing copies several characteristics of human beings, it might be immortal or at least more durable than he himself, because it does not wear itself out in the pursuit of an aim. One of the main concepts of the German–Austrian media theorist *avant la lettre*, Günther Anders (1902–1992), the 'Promethean shame', is based on a similar train of thought. Human beings feel embarrassed vis-à-vis their products, because they seem perfect compared to themselves and possess a higher durability, which is brought about by 'platonoidization'. Anders takes the light bulb as an example. If it burns out, he argues, it can be replaced by another one in a process of 'industrial reincarnation', because it is only one out of millions of objects realizing the same idea, which represents the essence of the product (Anders 1956, 51).

Marshall McLuhan called 'electric light [. . .] pure information' and 'the medium without a message' (McLuhan 1964, 8). The bulb neither fits the category of 'tool' or 'instrument', nor that of 'medium'. It does not allow one to manipulate other objects, to produce scientifically interesting effects or to observe yet unknown aspects of nature, nor does it convey a message of any kind. Hence the more general term 'artefact' will be used in this article to denote things that have been skilfully produced to serve a certain purpose, either directly or indirectly. These objects possess a second, symbolic level or a 'matrix', as Anders calls it, which is constituted by the concept of a desired function (artificial light in the case of the bulb) and the idea of an implementation, the association of material elements in a certain *technical form*. Seen from a momentary perspective, this in fact results in an 'eternalization'. But in a more historical view, its effects might serve as a consolation for the house father as well as for the human beings embarrassed by 'Promethean shame': Different from a piece of wood, artefacts disintegrate on several levels and may suffer, as it were, several different deaths:

(1) The desired function might become obsolete, due to change of needs, fashion, or realization of its impossibility.

(2) Another artefact might be invented to better implement the desired function, thus rendering the old one obsolete, as the line of inventions candle — kerosene lamp — gas lamp — incandescent light bulb shows for artificial illumination.
(3) The material basis might disintegrate to a point where it becomes unusable, parts might fall off or wear out, etc.

The idealization of artefacts

The symbolic level of the artefact is realized by configuring a certain material association of individual components. The statement of McLuhan's media theory that 'the "content" of any medium is always another medium' should be reformulated in this context: The components of an invention are in most cases artefacts devised earlier (McLuhan 1964, 8). The light bulb owes its existence to the craft of glassblowing, the invention of the mercury vacuum pump, the generation and transmission of electricity, etc. If the association reaches a certain complexity, for example, in mechanical apparatus, an uninitiated observer can no longer easily read off the intended function from the form, especially if it serves an uncommon, specialized purpose. Consequently, Anders diagnoses alienation of human beings from their artefacts in his book on Kafka (based on a lecture held in 1934): 'The object ["Odvadek"] reminds us of all sorts of items and machines which modern man has to handle day in, day out, even though their performance seems to have nothing to do directly with the needs of human beings' (Anders 1951, 11; translation mine, D.L.).

Incandescent light bulbs stand at the beginning of a development in which this quality of being enigmatic becomes aggravated. The German economist and philosopher Alfred Sohn-Rethel called them 'inscrutable spiritual beings' in his brilliant essay on the Italian way to deal with technology, and noted that in this southern country, these artefacts 'which always leave one wondering if they are even of this world [. . .] flow together uninhibitedly with the nimbus of the religious powers, and the festive Osram bulb is united, in Neapolitan saintly images, with the Madonna's aureole' (Sohn-Rethel 1926, 35f.). With mastery of the invisible force of electricity, artefacts started to get 'platonoidized', or better, idealized in a sense different from Anders'. The light bulb no longer achieved a material effect in the world, but merely a visual one, and one component of the implementation was invisible — the electric current.

In their implemented form, artefacts possess an ambiguity that allows them to be reinterpreted experimentally. In 1904, the British electrical engineer and physicist Ambrose Fleming slightly modified the material association of the light bulb by incorporating a second wire into the vacuum tube and created the first component that was no longer electric, but electronic (cf. Figure 2, Edison 1879 and Tyne 1977, 31–51)[2]. His 'Instrument for converting alternating electric currents into continuous currents' (Fleming 1904, 1), the first rectifier or diode, was incorporated into the Marconi-Fleming valve receiver for wireless telegraphy from 1905 onward.

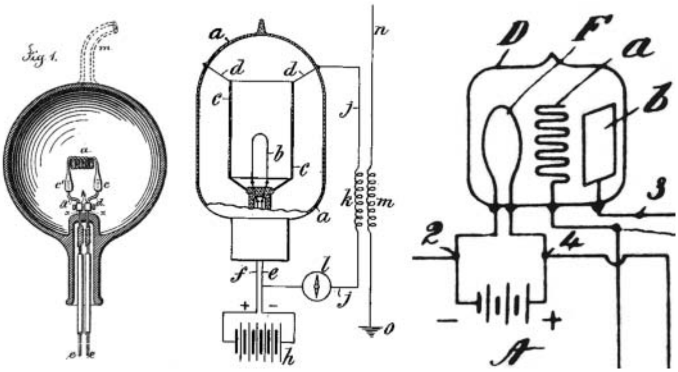

FIGURE 2 Three examples of idealized artefacts: light bulb, 1879; diode, 1904; triode, 1907.

The light bulb created an immaterial, but visible effect, whereas in the electron tube it was immaterial and invisible, constituting an ‘ideal artefact’, in which some parts and, more importantly, its purpose were located in the realm of sub-atomic particles and the waves that could be formed out of their beams. In the space without air, the material resistance that had defined natural matter since antiquity was suppressed and, consequently, the component reacted almost without delay.

As a result, the implemented functions looked increasingly identical from the outside and could only be differentiated by an expert, by using special measuring equipment, which evolved out of the same scientific and engineering movement and at the same time, like Karl Ferdinand Braun’s instrument for ‘the demonstration and study of the temporal sequence of variable currents’ invented in 1897 (Braun 1897).[3] The component that performed its task in invisibility became opaque itself and transformed into a black box. If an external observer was not instructed by documentation or the cultural knowledge around him, it might have seemed as absurd as Odradek to him, because its significance could no longer be read from its form.

The enigmatic quality of artefacts increased even more when these components were in turn integrated into larger, more complex devices such as radio receivers. They encapsulated functionality into single elements that each served a certain purpose, but created the desired effect through their interplay. Similar to a rebus, where the meanings of pictures of objects and letters have to be combined to guess at the sentence represented, when confronted with complex idealized machinery, the observer first has to find out the sense of the different components, and then combine them to derive the overall purpose (cf. Figure 3 from Céard 1499–1506, no. 15-XIV).[4]

To enable their possessors to deduce and use the functionality of complex and, later, idealized artefacts, their constructors complemented them with a manual historically early on. Whereas for natural objects, only the matter has to be protected against deterioration to secure their survival, for more complex artefacts, documents also have to be preserved that ensure their readability and comprehensibility. Anders accentuates the creation of

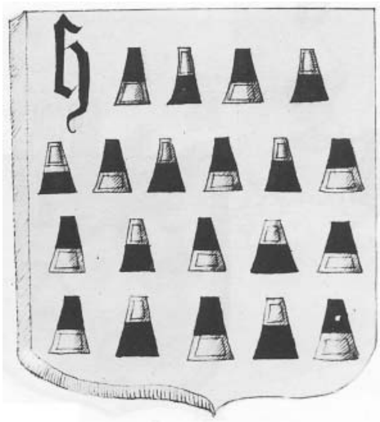

FIGURE 3 A riddle from the Rébus de Picardie, 1506.

durability by 'platonoidization', but the fact that these objects need to be understood to survive actually renders them very fragile.

During its lifetime, the performance of the material set-up visibly resolves its mysteriousness, but when it breaks or becomes obsolete and stops, the enigma emerges. Intellectual and practical effort is then necessary to reconstruct it. The longer this does not take place, the more the unreadability increases, up to a point where even its former overall purpose is forgotten, either because its documentation was lost, or because it was ripped out of a larger machine context, or because its material basis was mutilated. The artefact gets into this peculiar situation of Odradek-like mysteriousness, because it is not sufficiently charged by interest in it. Being purposeless and no longer understood, the thing loses its place in the world, the location where it was effectively used, and starts to wander around:

> 'Well, what's your name?' you ask him. 'Odradek', he says. 'And where do you live?' 'No fixed abode', he says and laughs; but it is only the kind of laughter that has no lungs behind it. It sounds rather like the rustling of fallen leaves. (Kafka 1919, 428)

The obsolete artefact does not worry inventors, engineers, or factory owners trying to make it as effective as possible, but only people that have the leisure to be troubled by its mysteriousness, like the house father. Many websites of enthusiasts of obsolete technology contain a section with photos of unidentified components asking the visitor for help with appeals such as 'No idea what this fine piece of technology is. It has a number W75 309-1-A. Any comments and offers appreciated'.

Reconstructing Odradek, I

In a newspaper article in 1934 (the same year as Anders' lecture) commemorating the tenth anniversary of Kafka's death, the German philosopher Walter Benjamin wrote about 'the most peculiar bastard in Kafka that the Prehistoric has conceived with the Guilt': 'The attics are the location of the discarded, forgotten effects. [. . .] Odradek is the form that things assume in oblivion. They are disfigured'.[5] In the last sentence, he uses the word 'entstellt', which in German once meant to have been forced away from the right, the fitting location (Grimm and Grimm 2004, entries 'entstellen' und 'fuge').

If we consider Odradek as an obsolete artefact that has lost its place and now wanders around as an enigma, we could speculate that a part of it is missing and renders it unreadable. If another rod were added to the crossbar that sticks out of the spool, it already starts to look more useful (cf. Figure 4).

The crank lever could indicate that the artefact was used in the context of a larger mechanical assembly. Around 30 years before Kafka wrote his story, in 1887, the British engineer John Keats patented an 'apparatus for winding thread'. At that time, the biggest challenge facing shoe manufacturers in England was to mechanize their production to be able to compete internationally (cf. Sutton 1990; for the full history of the company, cf. Sutton 1979, especially 131–167). His machine was driven manually by a crank handle, shifted the yarn from left to right, and slid it through the slots of a rotating, star-shaped disc, 'the laps of thread being made alternately on opposite sides of the thread-holder and upon each spur or arm in succession, or on two spurs or arms in succession' (Keats 1893, 1). The quantity of thread on the disc was measured and when a certain length had been reached, the apparatus automatically cut it and switched off. Winding thread in this way was much easier than with round spools, because the yarn did not need to be guided continuously up and down the body of the roll. Keats wrote that the 'holder of novel construction' would, moreover, 'display the thread in a better manner' and 'present advantages in unwinding not hitherto possessed by thread-holders', because the thread would 'run off in the plane of rotation of the holder, and that in a smooth and uniform manner' (Keats 1887, 1f.).

In Kafka's time, around 1915, the technique and form of the thread star reappeared in the context of the cheap and mostly home-made crystal radio receivers, consisting only of an antenna, a coil and an earphone, without any power supply. In the infancy of the medium 'radio hams' tried to ameliorate the reception of the AM waves by devising spools in a large variety of shapes. 'Honey comb' and 'spider web' coils, based on the form of a star and

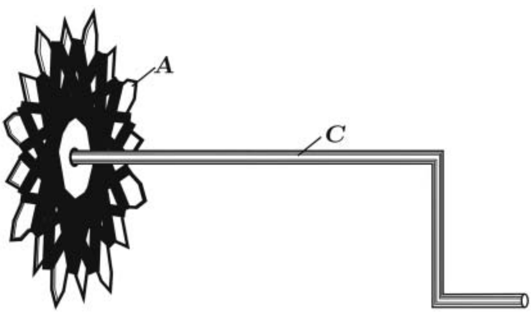

FIGURE 4 A speculative attempt at reconstruction of Kafka's Odradek; A: star-shaped spool, C: crank lever.

wound similar to those in Keats' invention, proved to be very effective in this respect and were widely adopted (cf. Figure 5). From 1909 onward, Kafka's fiancé Felice Bauer worked at the Carl Lindström A.G. in Berlin and marketed the 'Parlograph', an early dictating device that recorded on wax cylinders (Gilman 2005, 61). In 1924, the year of the writer's death, the company brought out its first radio, the G1.

While application areas, implementations, and concrete objects pass away, certain basic techniques or *formal schemata* are put into practice again and again.[6] The obsolete, enigmatic artefact Odradek keeps returning:

> Often for months on end he is not to be seen; [. . .] but he always comes faithfully back to our house again. (Kafka 1919, 428)

The winding method of these antennas and of the thread star originated from the craft of basketry; more specifically, from procedures such as the triple twist, where the weavers are placed between three consecutive spokes and are brought in succession over two and under one of them. The knowledge of technical *schemata* incorporated in the artefact can be transcribed into different inventions in other contexts after it has become useless. Sohn-Rethel observed a spectacular instance of such a transfer: 'A further example would be the wheel-motor, which, liberated from the constraints of some smashed-up motorbike, and revolving around a slightly eccentric axis, whips the cream in a latteria'. His analysis that for the Italian 'the essence of technology lies in the functioning of what is broken' and that hence the artefact quickly oscillates between effectiveness and defect, is mirrored by processes of technical recurrence or reincarnation that span enormous periods of time (Sohn-Rethel 1926, 37; translation altered, D.L.).

In a theoretically momentous report for the 'Conseil des universités' of Quebec in 1979, the French philosopher Jean-François Lyotard denied the possibility of general and coherent theoretical accounts altogether: 'The grand narrative has lost its credibility, regardless of what mode of unification it uses, regardless of whether it is a speculative narrative or a narrative of emancipation' (Lyotard 1979, 37). That this proposition is without substance can already be seen from the fact that it is paradoxical (in a weak sense). If all unifying accounts have lost their credibility, then so has Lyotard's very general one about delegitimation. It follows logically that some are exempt

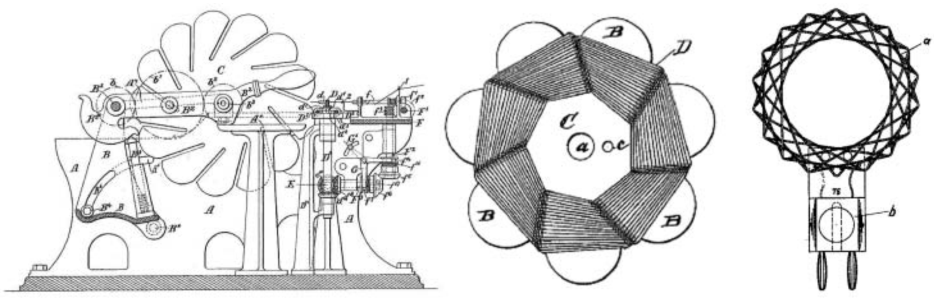

FIGURE 5 Keats' winding machine, 1887, and one of his star-shaped holders; spool for radio in the same form (Gamke 1927).

from this rule, as in the classical case of the lying Cretan. The history of ideas has to continue to tell 'grand narratives' to reduce complexity, otherwise it turns into an extremely voluminous, unordered list of facts. 'A theory is good only to the extent that it compresses the data into a much smaller set of theoretical assumptions and rules for deduction', writes Gregory Chaitin in an article on uncertainty in mathematics, a discipline shaken by crisis much more than the 'soft' sciences, because it possesses methods of falsification (Chaitin 2002, 170). Even if Chaitin's formal requests cannot be fulfilled in the history of ideas, one of the more stable fundaments it can rely on in its quest for lossless reduction of complexity are technical artefacts, because these materialized thoughts travel with slower relative speed in the stream of time than the narratives that conceive and accompany them. Unlike hermeneutic fiction and free association, their identity over time can be proven, and their possible functionalities can be experienced and experimented with at will.

The science historian Hans-Jörg Rheinberger has summarized this research strategy with admirable clarity: 'My emphasis is on the materialities of research. [...] My approach tries to escape this "theory first" type of philosophy of science [like underlining the theory-ladenness of observation in the footsteps of Lyotard]. For want of a better term, the approach I am pursuing might be called "pragmatogonic"'. 'Instead of reading a history of objectivity from concepts, I embark on reading a history of *objecticity* from material traces' (Rheinberger 1997, 26 and 4). Historical materialism is turned off its head, on which it was standing before, and placed upon its feet.

Reconstructing Odradek, II

The second thought experiment in reconstructing the technical schemata Kafka was copying for Odradek starts with another close reading of the only remaining information: several paragraphs written not by the inventor of the device, but by an external observer. The rod leaves the star-shaped spool in the middle, but probably we deduced the set-up of Figure 1 too early, and should have included in the possible configurations the one shown in Figure 6, which was created by turning the wheel 90 degrees around the y-axis.

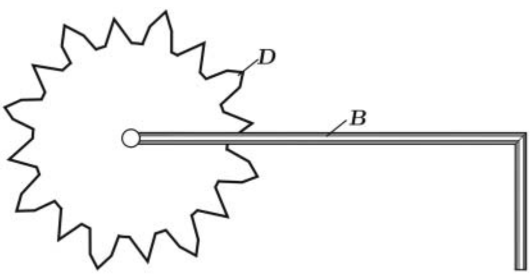

FIGURE 6 Another speculative attempt at reconstruction of Kafka's Odradek; B: supporting bar, D: star-shaped disc.

Very probably, Kafka was introduced to such a device made of iron when he visited the secondary school 'Altstädter Deutsches Gymnasium' in Prague from 1893 to 1901. The English mathematician and natural philosopher Peter Barlow devised it in 1822 in the context of experiments on electromagnetism, and demonstrated that current could produce rotary motion (cf. Figure 7).[7] He mounted a star-shaped wheel on an axis above a trough of mercury in such a way that its points made contact with the electrically conducting liquid. When he applied current, it flowed along the radius of the disc and produced a field that interacted with a permanent or electric U-magnet located under it. 'In effect, the points of the wheel constituted a series of wires radiating from the axle' (Greenslade 1986, 27; cf. Davis 1852, 103–5 and Williams 1971, 132f.).[8] The star-shaped disc started to revolve.

While the invention demonstrated the possibility of electro-mechanical motion, it did not realize it effectively enough to be useful as a driving force for machinery. The final set-up presumably emerged from a series of experiments with earlier prototypes, whose components and forms we do not know. A direct predecessor, however, is known, Michael Faraday's revolving wires from 1821 (Faraday 1821). The fragile association produced by a *bricoleur* provided functions that could be used in a variety of contexts outside the laboratory, and was consequently transformed into a unified component.[9] Brushes replaced the impractical trough of mercury, and the device was hardened by applied engineers to withstand the randomness of ignorant widespread use. The electrical motor allowed things to move around 'nimbly' like Odradek, and could then be used, in turn, as a part in a newly invented, tinkered set-up to create effects even more interesting.

The line of very early computers developed at the University and the firm of Ferranti in Manchester from 1948 to 1951 serves as an example of what happens when complex idealized machinery becomes obsolete. If it is reasonable to regard a group of engineers that deploys the possibilities of a certain technology as a 'culture', united by a set of objects, theories, and methods, then the title of a once popular fiction story might be suitable for the discussion.

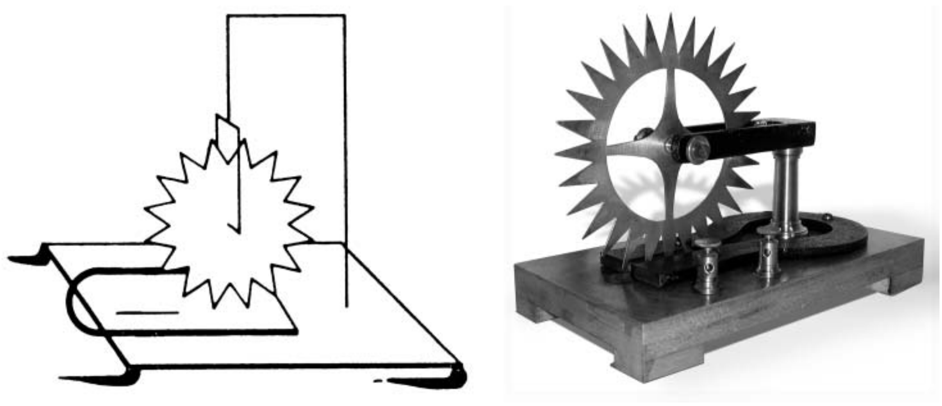

FIGURE 7 Barlow's wheel, original drawing, 1822, and demonstration apparatus, ca. 1890.

The last of the Mohicans

The electrical engineer Frederic C. Williams (1911–1977) developed the first reliable means of volatile, random-access memory, the Williams tube, at Manchester University in 1946 (cf. Figure 8 and Williams 1946). He was joined in this effort by an assistant, Tom Kilburn (1921–2001), who in large part worked out the intricate technical details. On the screen of a standard cathode-ray tube (CRT), 1280 dots were detected by a pickup-plate in front and regenerated before they faded away. At first, the engineers manually switched the bright points on and off with a keyboard (Williams and Kilburn 1949, 193). To test if their store would also work reliably when operated quickly and in a mode of random access, they built a very simple, but Turing-complete computer around it, the Manchester 'Baby' prototype (1948). It evolved organically into the Manchester Mark I (1949) and the Ferranti Mark I (1951), of which two machines were delivered to the Computer Departments at Manchester and Toronto University.[10]

When the first machine using the volatile memory was produced industrially in 1951, the feet of those who would carry the newly invented technology out were already at the door. Core store had been developed in 1949 by An Wang from Harvard University and been incorporated into the flight simulator project 'Whirlwind' at the Massachusetts Institute of Technology (MIT) by Jay Forrester. From 1954 on, it was commercially available in the form of IBM's 737 magnetic core unit, and by the mid-1950s, most major computer manufacturers had switched to the new technology (cf. Reilly 2004, 262ff., and Lavington 1980, 31–35). In 1954, the team under Tom Kilburn completed the next computer at Manchester University, 'MEG', employing Williams tubes for storage. Before producing it and marketing it as 'Mercury' in 1957, the Ferranti company replaced them with core memory. One of these machines was installed in the Computing Laboratory of the University in the same year and superseded the Ferranti Mark I, which was dismantled in June 1959 (Campbell-Kelly 1980, 131). The culture of electrical engineers modifying CRTs in intricate ways with the purpose of storing data in them, their technological progress and insights into the properties of the material set-up did not last; it only endured for a brief period of eight years.

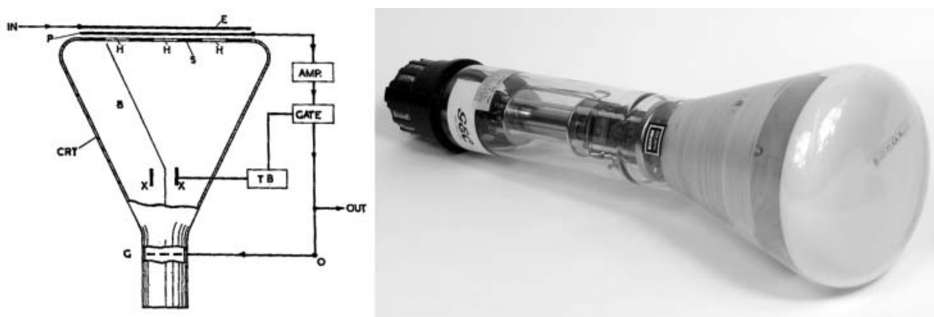

FIGURE 8 Williams tube, 1946.

Every time a new component was invented, the knowledge of the *bricoleurs* was rendered obsolete: 'For engineers, the juggernaut of ever-changing technology presents a constant problem of learning new things and a reluctance to forget the old, in case the old may turn out to be useful' (Burton 2005, 44). If they can no longer keep up with the speed of developments, they are regarded by those around them as the last of an exotic tribe almost extinct, as Mohicans, in a mixture of respect and pity.

With the 'Last of the Mohicans', Tom Kilburn and a few other electrical engineers directly involved in the development, the complete and living knowledge of an obsolete generation of automata, which can only be acquired by building them, died away around 2001, and with it, the possibility of obtaining details from them that were transferred informally and undocumented, either because they were presupposed as 'common knowledge' or because they were considered profane. At last, the durability of the paper on which the copies of the manuals circulate, the interest of the owners in their conservation and their readiness at transcription determine the duration of survival of the remaining information and, hence, of the artefact itself.

The rustling of Fallen Leaves

If machines only survive on paper, a general effect of abstraction can be observed, in which an increasing number of details is forgotten and material elements are sacrificed to the mysterious force of entropy. Full information is only stored in the artefact, as long as it is operational, and in the brains of its constructors, while they remember it. The intact apparatus is the shortest expression of its complexity (in the sense of Kolmogorov 1965). Repairing it is therefore easier than understanding the mechanism completely, because only the functionality of the broken part needs to be reconstructed, while the rest of the knowledge is still implemented.

The surviving documentation can be divided roughly into several categories. The efforts of the next generation of electrical engineers in Manchester to resurrect the prototype computer, headed by Christopher P. Burton, serves to illustrate their usefulness and the information contained in them.

Apart from material remains, construction plans of parts or even of the whole machine would permit one to form a precise picture of the hardware. Unfortunately, these only very rarely exist for pioneering efforts, because they are developed experimentally, by modifying or exchanging components and by trying to tune them to a point where their consonance produces the desired results:

> The pioneers had no need for formal engineering drawings. Their working documents were a set of hand-drawn schematic circuit diagrams on a table (jokingly called Tom Kilburn's office), in the corner of the laboratory, together with their personal notebooks. [. . .] The machine was constantly being modified and added to, as were the diagrams that always represented the current state. Those circuit diagrams no longer exist, so we have had to rely on secondary sources. (Burton 2005, 50)

Engineers sometimes set down valuable technical details in their notebooks, as an aid to memorize certain aspects of the work under construction. This was the case in the rebuild of the Manchester computer, which could rely on such sketches of Dai Edwards, Geoff Tootill, and Alec Robinson, who copied some of the diagrams on the table. Documentation often occurs when a transfer of knowledge is involved. In this case, the three research students were trying to catch up with the work underway.

After having acquired all surviving documentation and the original components, the struggle of the Baby rebuild project to make the Williams tubes they had constructed work, gives an impression of the effort required to turn the abstraction concrete again:

> Although the description of the CRT memory operation given elsewhere seems straightforward, as an analogue electronic device it was **tricky to adjust**. Controls for brilliance, focus, astigmatism, high-voltage supply, deflection voltages, amplifier gain, threshold level, dash width, dot width, and strobe pulse timing **all interacted**. (56, emphasis mine, D.L.)

Photographs might elucidate certain details that cannot be obtained elsewhere. In the case of the prototype reconstruction, photographs proved extremely useful, after they had been located: 'The circuit diagram fragments [from the engineers' notebooks] and photographs were the key sources in our achieving authenticity'. They made it possible to identify components that were not documented elsewhere, because they were not essential for the working of the machine, like the exact type of push-button switch used on the keyboard: 'I spent many hours gazing at the original photograph through a jeweller's eyeglass [. . .]. In one serendipitous moment, the pattern of holes on the panel suddenly brought to mind a set of five push-buttons that I had bought in 1953, and which I still had'. Burton looked up the Royal Air Force part number in a catalogue, and finally found the exact component pictured on 'a photograph of the Spitfire fighter's cockpit: It was a control box for the VHF radio' (51f.). Despite their idealization and even as black boxes, the components possess a certain appearance that helps to tell them apart, even if their functionality can no longer be read off their surface.

To be able to build a faithful replica of complex machinery, at least two types of documents are absolutely necessary. Diagrams of at least the most important subsections make it possible to reach an understanding of the logical functionality of the device. Photographs, on the other hand, permit determination of the physical properties of the components, their concrete type and location within the whole. They also show objects such as racks, cables and switches which are not specified in a circuit diagram.

Given the fact that usually a lot of information that would be necessary is no longer available at the time the resurrection project is undertaken, the only means to fill in the gaps is by identifying with the engineers of the time, their technology and method of design, and by imagination, as indicated by Christopher P. Burton: 'Lastly, by being immersed in the project I found it possible to "think pioneer" and make plausible judgements as to what was correct'.[11] Due to their interrelatedness, the information about the missing parts can be obtained from the remaining ones by deductive speculation, if somebody is willing to invest the time necessary to solve the puzzle. The situation corresponds to a rebus with known meaning in which one signifying element is missing and must be reconstructed. Although there are possibly several objects that can fill in the gap, their number is limited, especially in the advanced technology of an era. It might well be that sometimes this method is misleading, but unfortunately and in a number of cases, it is the only chance to complete the missing parts in the picture of an extinct artefact.

Inventions *in nuce*

Michael Thompson's *Rubbish Theory* is a witty study on the career of objects, which complements the linear arrows of economic theory pointing from the producer to the consumer with the idea of a cyclical return. He distinguishes three categories into which things fall in different moments of their history (cf. Figure 9). In the first one, transience, the commodity circulates on the market and its value decreases slightly over time. Two factors, fashion, which moves in cycles, and technology, which proceeds linearly, bring about a more radical drop in its price. The latter applies to singular components of a construction, as in the following example:

> [I]n the mid-eighteenth century, the owner of a new house in the City of London would find that his property gradually became obsolete [. . .] [H]is plumbing system discharging into a cesspit in his rear basement room, whilst perfectly adequate when the house was new, would gradually appear less and less attractive after the invention in 1779 of Alexander Cummings's patent water closet [. . .] [T]he march of technological evolution is irreversible and linear. (Thompson 1979, 38f.)

While the water closet is still around today, 250 years later, more complex artefacts, especially in the early period after their invention, become obsolete and are replaced at a much faster pace, as demonstrated above.

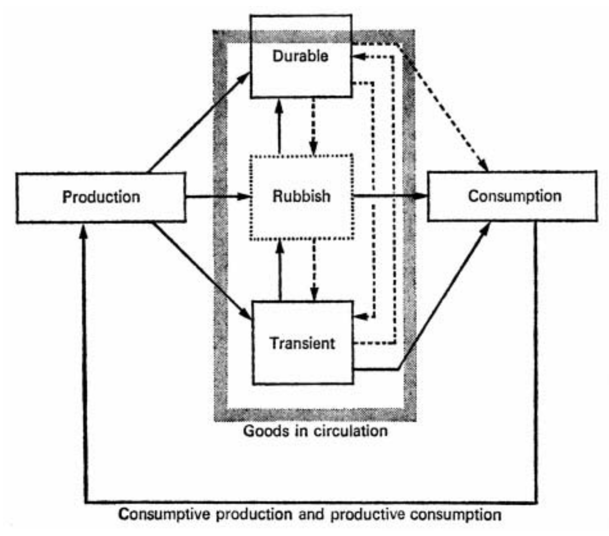

FIGURE 9 Schematic view of Thompson's rubbish theory (Thompson 1979, 113).[12]

When the commodity has become completely worthless, it enters a category considered covert by Thompson, that of rubbish. The object is suppressed and disappears from the consciousness of society. But astonishingly, at a certain point which is dependent on the end of its production, some artefacts resurface from the trash and are transferred to yet another category, durability. Eccentric evaluations by a few individuals lead to a renewed interest, enthusiasts start to collect them, and their value increases again. Finally, their price rises so high that they fall out of the market at its upper edge and are bought by museums, which reduce their relative speed in the stream of time to the smallest possible value. The increasing disintegration of other copies of the same thing enhances the singularity and value of the remaining exemplars, and reverses the effects of Anders' 'platonoidization' (which, in eternalizing its 'idea', renders the concrete light bulb worthless) by fetishizing the beautiful unicum.

Because Thompson takes artefacts as given and does not question how they come into existence, his theory does not treat another covert phase, in which they are first and foremost conceived, the experimental one, which precedes the overt state of transience. While belonging to this category, the material association is slightly altered, parts are replaced, optimized and tuned, until it delivers the desired performance. Before this happens, it possesses the same enigmatic, Odradek-like appearance as the one that belongs to the rubbish. Being no longer and not yet useful results in the same type of object. And indeed, the specific form might have been adopted from an obsolete artefact, or even from a device invented for an impossible purpose, such as perpetual motion or the communication with the dead. In a number of cases, an experimental set-up is devised for a certain aim, but since the function it provides cannot be used by a wider public, it stays in the closed realm of the laboratory for a shorter or longer duration, sometimes even centuries, without ever entering the state of transience.[13] Or its effects are purely epistemic in that they challenge a current paradigm as an anomaly and only have theoretical, but no immediate practical consequences.

By invalidating all attempts to understand Odradek as an obsolete artefact, Kafka ensures that the interpretations, which are always only partial, are continuing. His riddle cannot be solved and, consequently, constitutes an enigma that survives. It is exactly this quality that Rheinberger takes as a condition for the durability of experimental systems, described aptly by Brian Rotman as 'xenotext': 'What [a xenotext] signifies is its capacity to further signify. Its value is determined by its ability to bring readings of itself into being. A xenotext thus has no ultimate "meaning"' (Rheinberger 1997, 36f.). Because Kafka's story can be understood differently forever, but never perfectly, it lives on. As long as formal schemata of material association allow reinterpretation once their present purpose has become obsolete, they recur and are perpetuated. It is impossible to determine beforehand if a further fertile implementation is possible.[14]

The process of 'poietic' engineering employed to reach a new understanding of the set-up is similar to innovative processes in language. A word combines elements from one class, the alphabet, for the purpose of conveying meaning, and in ordinary usage, convention prescribes which letters to use. The primary goal attained is symbolic, but would not be effective without imaginary (world reference) and real (contract, instruction, etc.) consequences. Avant-garde poets create new significations by trying out new combinations of letters and words. The artefact, on the other hand, employs material elements from different classes (glass, air pump, electricity in the case of the light bulb) to achieve immediate material goals at first, but later also imaginary and symbolic ones (media, algorithmic machinery). The situation of designing an experimental set-up corresponds to the free construction of a rebus for a given meaning. Forms need to be selected that are known to perform a certain function and must be combined in the right way. The number of possibilities is high to begin with but reduced by reasoning and experiment. Similar to poets, scientists challenge conventional implementations by modifying the material association to see if new effects arise.

The processes of replacing and tuning parts to make the *bricolage* work in the desired way can be compared to the operations of metaphor and metonymy in language. They exchange components or adjust certain parameters, but only slowly transform the formal core of the artefact. Rheinberger writes: 'Science, viewed from a semiotic perspective, does not escape the constitutive texture of the inner workings of any symbol system: metaphoricity and metonymicity. Its activity consists in producing, in a space of representation, material metaphors and metonymies' (Rheinberger 1995, 114f.). Poets are constrained in their innovative combinatorics by the linguistic conventions of society that secures understanding, and inventors, engineers and scientists by the laws of nature: 'We have to recognize that the qualities objects have are conferred upon them by society itself and that nature [. . .] plays only the supporting and negative role of rejecting those qualities that happen to be physically impossible' (Thompson 1979, 9).

Certain transfers are theoretically ruled out by Thompson. An object cannot move from rubbish to transient or from durable to transient under normal circumstances governed by the laws of the market. In the construction of the artefact precisely these transfers happen on an immaterial level (cf. Figure 10).[16]

The experimental phase reintegrates the outcome of earlier cycles. The components of the 'machines for making the future' (Rheinberger 1995, 110) can be of natural descent, such as the bamboo filament of early light bulbs, but they usually result from prior inventions, such as the vacuum tube. The transfer takes place from the transient category back into new, tentative systems. Techniques of associating and shaping components, technical schemata, can be extracted from museological or almost forgotten devices and be transcribed to new, tinkered constellations. And it is the effects of artefacts as anomalies in basic research, changes in paradigms, which open up the possibility to invent new, vague ideas of purposes and their implementation. The transfer from rubbish or durable back to experimental and later transient transcends the demarcation lines between the categories postulated by Thompson. The 'communicable things' (Thompson 1979, 44) are transacted at each station of their life cycle, even if they no longer change their physical location, be it the rubbish dump or the museum.

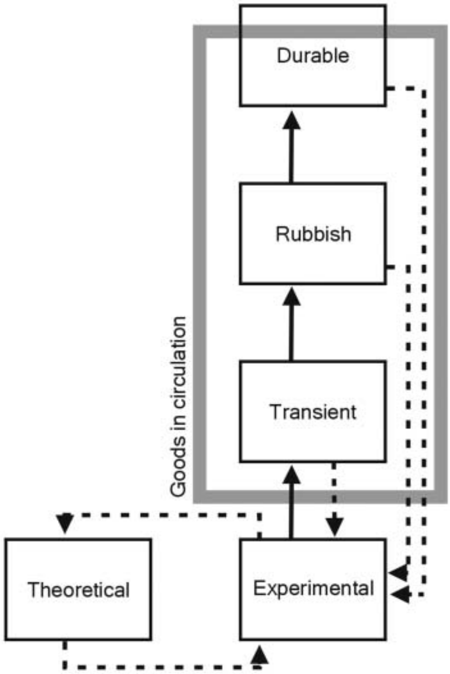

FIGURE 10 A cyclical extension of Thompson's rubbish theory.[15]

The fact that epoch-making inventions started their life cycle as Odradeks, abstruse and purposeless creatures, which were sometimes doomed from the beginning, is a strong argument against forcing all research in science to be of an applied nature. This would have prevented the creation and transformation of absolutely useless artefacts that in the past led to important and far-reaching discoveries.

To raise some issues concerning algorithmic objects in particular, the last section discusses a case of crypto-history: the German Enigma and its decipherment by Polish mathematicians before and in the Second World War.[17]

The archaeology of algorithmic artefacts

If algorithmic machinery is described without experimenting with it, there is a danger of adulteration, even if the methodology employed is scientifically impeccable and the author's background knowledge most extensive.

On the first pages of *Seizing the Enigma*, the cryptohistorian David Kahn describes the *éthos* of his research: 'The book [. . .] focuses upon personalities and rests as much as possible upon primary sources, namely documents and interviews'. He decided to include the technical details into his text: 'This material [on Enigma cryptanalysis] may seem dry, but to leave it out would obscure a main point of this book: the fearful difficulty of the work of the cryptanalysts' (Kahn 1991, X). Because of the tactical relevancy of the intelligence obtained, which played a role as important as the findings by radar and other technical advances, any account omitting the hidden cryptographic battle would be incomplete. The official historian of the British Crown, Harry Hinsley, estimated that the breaking of Enigma shortened the war by at least two years (Copeland 2004, 218). Given the prevalence of myths and cover stories concerning the events of World War II, it seems even more important than with other topics to rely as much as possible upon primary sources.

In *The Codebreakers*, Kahn has given an extensive and historically rich overview of cryptological technology throughout the centuries, and it would be difficult to name any other author who possesses a comparably intimate knowledge of the field. But when it comes to the first machines built by the Poles and the procedures executed on them, despite his cautious methodology, the book strangely teems with errors. Concerning the cyclometer, one of the earliest devices, he writes: 'The maximum of 26 [letters] was reached in only three ways, or cycles: two chains of 13; six chains of 10, 10, 2, 2, 1, and 1 letters each; and six chains of 9, 9, 3, 3, 1, and 1 letters each' (Kahn 1991, 63). If this would have been the case, the apparatus would have been useless, because it would not have reduced the number of combinatorial possibilities to a manageable level. Actually, 82 different characteristic patterns exist. A later machine, the 'bomba kryptologiczna', is described in the following way (cf. Figure 11):

> [The Polish cryptologist] Rejewski soon found a way of determining the keys when the indicators in three messages fulfilled certain conditions. [. . .] One pair [of the three pairs of Enigmas incorporated into the bomba] would be testing the indicators of messages 1 and 2, another those of messages 1 and 3, and the third those of messages 2 and 3. (73)

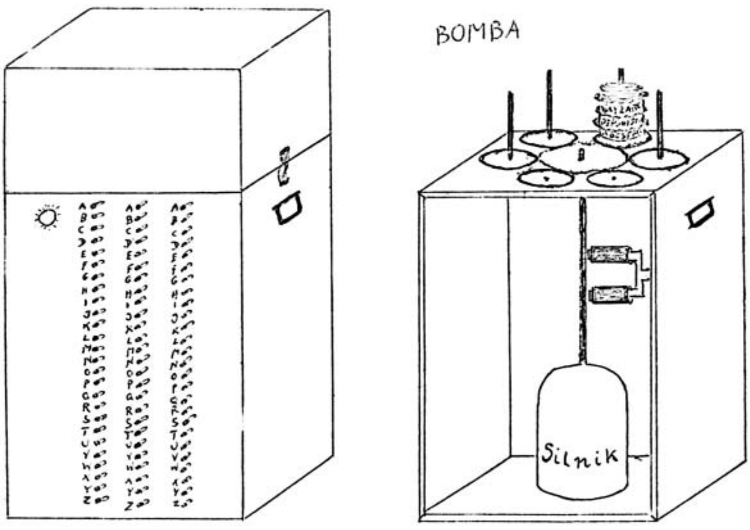

FIGURE 11 Sketch of Polish 'bomba' by Rejewski, 1976.

This is all the more astonishing since Kahn could rely on the descriptions and especially the appendixes in the English translation of Kozaczuk's very detailed and precise book, which clearly detail that each pair was simply working on one female indicator received (Kozaczuk 1984, 266f.). It shows, and this is the only purpose of the two examples quoted, that one cannot understand, describe or research these devices without practically experimenting with them, either by rebuilding them or by simulating them in software.[18] Turing's statement that '[i]t is possible to produce the effect of a computing machine by writing down a set of rules of procedure and asking a man to carry them out', his concept of a 'paper machine', is theoretically and practically true for Enigma, but only theoretically (under the condition of almost eternal time) for the cyclometer and the bomba. The only reason these apparatuses were built is that it was no longer possible to perform the corresponding routines with 'paper, pencil and rubber, and subject to strict discipline' (Turing 1948, 34). The concrete details of their functioning cannot be captured in descriptions, and even if there was a complete one, it would be impossible to grasp it without putting it into practice.

That these devices execute procedures that are too lengthy and complicated for humans to perform radically reinforces Kant's dictum that 'we have complete insight only into what we can ourselves make and accomplish according to concepts' (Kant 1790, 264). Not incidentally, the mixing of theory and practice is already typical for the cryptanalyst's work. Rejewski wrote about the invention of the bomba and the Zygalski sheets: 'Yet, within a very short time [. . .] we had two ideas, or rather, what was more important, we found ways to realize those ideas' (Kozaczuk 1984, 266). The historian and any other scientist trying to depict the developments suddenly finds himself in the same situation as the codebreakers. To verify the claims of different parties in the event and to really grasp these devices, he needs to be able to perform the procedures that have been employed.

It may seem that the title 'computer history' is better suited to designate the investigation of bygone algorithmic artefacts. But several arguments suggest a preference for an archaeology rather than a history.

Because of the irrelevance, exchangeability and opaqueness of their components, symbolic machinery moves with higher speed in the stream of time, quickly becomes obsolete and is subject to a much stronger burying. The language that is coupled to it to control it, like in Enigma, creates a new field in the usage of signs. After a very long time, the question how to achieve certain effects through symbols could be posed again, in a different way. Unlike natural expressions, their complete arbitrariness is not conserved by collective tradition. In the proliferation of programming languages, ways of formulation change in fast succession and are forgotten (Sammet 1991, 48). The text in which Robert Recorde introduced the equal sign 450 years ago is understood today without much effort: 'And to auoide the tediouse repetition of these woordes: is equalle to: I will sette as I doe often in woorke vse, a paire of parralles, or Gemowe lines of one lengthe, thus: ==, bicause noe. 2. thynges, can be moare equalle' (Cajori 1928, 165). This does not apply to the words that caused the Manchester Mark I to compose love letters 45 years ago, even for programmers: '//I/ //ZO ZA/: DEQO AIQB RE/: S:LO DSWO IST/ . . .' (cf. Link 2006). Archaeology investigates buried, incomplete and often enigmatic artefacts.

The study of symbolic apparatuses opens up a field in which theoretical and practical aspects, immaterial procedures and their technical implementation refer to and emerge from each other. The *difference of execution*, which separates them from other artefacts and consists in their autonomous carrying out of almost endless sequences of instructions, creates an opaque area between the input of the original data and the incalculable moment in which the machine returns with the result, which is not easily penetrated. The technical history of ideas cannot omit this space of time and is like cryptology thrown onto the question: What exactly is executed here? The theoretical investigation is forced to pass through the practical work of reconstructing the apparatus and the operations performed on it. The mixing of narration and practical reconstruction, of firmed fragments and deducto-speculative complements is likewise typical for archaeology.

The display and output of an algorithm are a surface without obligation. What they show does not necessarily represent the real workings of the program; computer viruses are one example. The symbols that encode the procedures can indeed be found in the source code. But because of the difference made by executing these procedures, merely reading the code can only give us a complete picture for very simple algorithms. Only the execution unfolds the complexity implemented in them and allows to formulate reliable propositions about processes that cannot be described or run on paper for principal and for practical reasons. The authoring of experimental software becomes part of the theoretical investigation, because it is the only way algorithmic artefacts can be fully and concretely grasped.

Michel Foucault's *The Archaeology of Knowledge* (1969) aimed at localizing *dispositifs*, objective symbolic structures whose effectiveness appeared in generating a multitude of concrete phenomena like regulations, truths, architectures, etc., comparable in principle to the workings of the Hegelian *Weltgeist* (world spirit). The more the humans that constitute this *Weltgeist* attain their aims by instruments and software, investigate reality with apparatuses and change it through material associations, the more the history of ideas is forced into matter. The archaeology of algorithmic artefacts endeavours to reconstruct from objective technical forms the theoretical currents that generated them, and were generated by them.

Notes

1 A more extensive version of this article can be found in the fifth volume of the *Variantology* book series, eds. S. Zielinski *et al.*, forthcoming.

2 All patents quoted are accompanied by their date of application.

3 The predecessor of today's 'oscilloscope' antedates the first 'ideal artefact', a 'diode' in modern terminology, by seven years.

4 'H' (letter name pronounced 'ash' in French) is followed by 'vingt pions', twenty pawns: 'ch'vin pions' — 'This wine we drink'.

5 Benjamin 1934, 431: 'Der sonderbarste Bastard, den die Vorwelt bei Kafka mit der Schuld gezeugt hat, ist Odradek. [. . .] Die Böden sind der Ort der ausrangierten, vergessenen Effekten. [. . .] Odradek ist die Form, die die Dinge in der Vergessenheit annehmen. Sie sind entstellt'. In English translation p. 127.

6 Cf. Kant 1781, A138: 'How, then, is the *subsumption* of intuitions under pure concepts, the *application* of a category to appearances, possible? [. . .] Obviously there must be some third thing, which is homogeneous on the one hand with the category, and on the other hand with the appearance, and which thus makes the application of the former to the latter possible. This mediating

representation must be pure, that is, void of all empirical content, and yet at the same time, while it must in one respect be *intellectual*, it must in another be *sensible*. Such a representation is the *transcendental schema*'.

7 It was first mentioned in a letter to Michael Faraday on 14 March 1822, cf. James 1999, 254f. Barlow's wheel was a popular object for demonstrations in physics classes and several companies continued to produce it even after it had been superseded, well into the twentieth century.

8 My thanks go to John D. Jenkins for providing the high-resolution image of the wheel shown at the Spark Museum, http://www.sparkmuseum.com/MOTORS.HTM. (17/10/2010)

9 Cf. Rheinberger 1995, 111: 'Scientists are *bricoleurs*, not engineers'.

10 For the emergence of the storage technique out of radar research and a discussion of early programming on these machines, see Link 2006.

11 C.P. Burton, email message to author, 8 March 2007. This kind of imagination is not to be confounded with free fantasy and association.

12 Full lines indicate possible, dotted ones impossible transfers.

13 An example of this are letter wheels. After Alberti had established that they could be used as cryptographic devices in 1467, it took more than 450 years until the military practically employed them in this way; cf. Link 2010, 262f.

14 In parallel to Thompson's 'father of all the Tiv', Odradek could be called the (forgotten) ancestor of all artefacts; Thompson 1979, 65–9.

15 Full lines indicate material, dotted ones immaterial transfers.

16 The first one, he concedes, occurs 'to a limited degree, which does not seriously threaten the boundary maintenance, in the business affairs of the dealer' and is 'implicit in the slogans "we want what you don't" and "houses cleared free of charge"'. He similarly shows that the second one only takes place in troubled times by quoting the example of wartime privations in Germany 'that caused the (regretted) exchange of Old Masters for tins of corned beef' (Thompson 1979, 106f.).

17 More details and a complete reconstruction of the *cyclometer*, the *bomba* and their procedures can be found in Link 2009.

18 Kahn's book contains a wealth of historical details that are not found in other accounts and therefore remains an excellent historical survey on the topic.

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