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Reverse engineering and the archaeology of the modern world

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Abstract

This paper explores the practical and conceptual connections between the archaeology of post-industrial societies and the process of reverse engineering. It explores common themes such as industrial decline, the loss of technical expertise, and the growing problem of obsolescence both in technological infrastructure and in the management of digital data. To illuminate the connections between the two fields it considers several examples. These include the implicit applications of reverse engineering in archaeology, such as chemical analyses of Egyptian mummification and alchemical equipment, as well as the use of archaeological concepts and terminologies in reverse engineering. The concept of archaeology as reverse engineering is examined with regard to military aircraft, post-industrial landscapes and so-called 'non-places'. These illustrate the difficulty in inferring different forms of human activity and knowledge in past technologies, in particular so-called 'tacit knowledge'. The final part of the paper discusses the potentials and limitations of building links between reverse engineering and the archaeology of the modern world, raising questions for further consideration.

Zusammenfassung

Dieser Beitrag erörtert die praktischen und begrifflichen Zusammenhänge zwischen der Archäologie postindustrieller Gesellschaften und dem Prozess des Reverse Engineering. Das Augenmerk hierbei liegt auf den diesen Feldern gemeinsamen Themen, wie dem Verlust technischer Expertise und dem zunehmenden Problem der Obsoleszenz bei der technologischen Infrastruktur und der Aufbewahrung digitaler Daten. Zur Ausleuchtung der Zusammenhänge werden mehrere Fallbeispiele herangezogen, unter anderem die impliziten Anwendungen von Reverse Engineering in der Archäologie – zum Beispiel die chemische Analyse ägyptischer Mummifizierungsprozesse und alchemistischer Gerätschaften – sowie der Gebrauch archäologischer Konzepte und Terminologie im Bereich des Reverse Engineering. Die Auffassung der Archäologie als Prozess des Reverse Engineering wird anhand von Militärflugzeugen, postindustriellen Landschaften und sogenannten „non-places" untersucht. Hierbei wird demonstriert, wie schwierig der Folgeschluss von der Technologie der Vergangenheit auf vergangene Formen menschlicher Aktivität und menschlichen Wissens ist, vor allem wenn es sich um implizites oder „stilles" Wissen handelt. Der Schlussteil des Beitrags bespricht die Möglichkeiten und die Grenzen der Zusammenarbeit zwischen dem Bereich des Reverse Engineering und der Archäologie der modernen Welt und wirft Fragen zur weiteren Debatte auf.

Keywords

archaeology of the modern world; deindustrialisation; industrial heritage; reverse engineering

Schlüsselwörter

Archäologie der modernen Welt; Deindustrialisierung; Industriekultur; Reverse Engineering

Introduction

A colleague once told me a story about visiting a Royal Air Force maintenance facility in the 1980s that specialised in repairing and refitting the weapon systems of Blackburn Buccaneer nuclear strike aircraft. The Buccaneer had by then been in service for more than two decades, and several of the instruction manuals for refitting components included the cryptic instruction 'Take to Sid in 9a'. Sid in building 9a was an older technician who had worked on Buccaneer assembly lines decades before, and he alone had the know-how to refit certain recalcitrant components that required being jiggled or twisted just so. Behind the Oz-like illusion of an advanced nuclear deterrent, there was a wizard (of sorts) pulling the strings.

This striking example of the human factor and the role of tacit knowledge in the maintenance and operation of even the most powerful of technologies is significant, and it raises a number of important questions about archaeological interpretation and our understanding of material culture. If as archaeologists we encountered and attempted to reverse engineer these apparently mass-produced military artefacts, would we be able to infer the existence of Sid the wizard/technician? Even if our archaeological research uncovered the repair manual that confirmed Sid's existence, would we be able to reverse engineer the processes he carried out (given that even most of his contemporaries lacked his tacit knowledge)? If the answer to both of these questions is no, as I suspect it would be, what does this tell us about the limitations of archaeological approaches to technological artefacts?

In his 1995 book *River out of Eden*, Richard Dawkins employs an extended archaeological analogy to illustrate the concepts of economy and utility in evolution:

> *The slide rule, talisman until recently of the honourable profession of engineer, is in the electronic age as obsolete as any Bronze Age relic. An archaeologist of the future, finding a slide rule and wondering about it, might note that it is handy for drawing straight lines or for buttering bread. But … if you examine the spacing of the graticules you find precise logarithmic scales, too meticulously disposed to be accidental. It would dawn on the archaeologist that, in an age before electronic calculators, this pattern would constitute an ingenious trick for rapid multiplication and division. The mystery of the slide rule would be solved by reverse engineering, employing the assumption of intelligent and economical design. (Dawkins 1995: 103)*

Whatever the intention of Dawkins' elegant thought experiment, he inadvertently highlights a strong connection between the processes of reverse engineering and archaeology. My principal aim in this paper is to explore this connection, identifying the points of similarity and overlap between reverse engineering, both in theory and in practice, and the archaeology of late- or post-industrial societies. It is my belief that this connection is a potentially fruitful and productive one, particularly with regard to the archaeology of modern technological artefacts such as vehicles, computers and industrial machinery.

Reverse engineering, discussed in more depth below, can be summarised as the process of reasoning backwards from a technological artefact to the initial problem or design specification it was created to solve or fulfil. Dawkins described this reasoning in terms of a trial-and-error thought process: "If I had wanted to make a machine to do so-and-so, would I have made it like this? Or is the object better explained as a machine designed to do such-and-such?" (Dawkins 1995: 103).

One of the defining tropes of the modern material/cultural world is the encounter with abandoned, obsolete technological artefacts, many of them still familiar (to some). A recent internet meme picked up on this theme of rapid change and unfamiliarity, depicting an audio cassette tape and a pencil with the caption "Our children will NEVER know the link between the two"[1] (Hansen 2012), while another claimed that a child had interpreted a 3.5 inch floppy disk as a 3-D printed model of the 'Save' icon. This younger generation's encounters with such already obsolete technologies is an archaeological one, as well as (if they care to examine the artefacts in any depth) a process of reverse engineering.

[1] The pencil (hexagonal in cross-section) or a similarly shaped pen, finger or other tool could be inserted into the toothed part of the reel to wind the tape backwards or forwards, or to wind in loose tape.

Technology and the human factor

Why does this matter? Bruce Trigger quoted from Marx's *Capital* as a justification for industrial/historical archaeology, and the extract is particularly applicable to this study:

> *Relics of by-gone instruments of labour possess the same importance for the investigation of extinct economic forms of society, as do fossil bones for the determination of extinct species of animals. It is not the articles made, but how they are made, and by what instruments, that enables us to distinguish different economic epochs. Instruments of labour not only supply a standard of the degree of development to which human labour has attained, but they are also indicators of the social conditions under which labour is carried on. (Marx, quoted in Trigger 2006: 331)*

An archaeological/reverse engineering approach to these antique instruments of labour, taking the time to examine them in depth, can reveal more than Marx probably imagined: not so much the broader themes of social and economic relations, but rather the specific and frequently idiosyncratic mechanisms through which the technologies of modern society operate.

This brings me to a second key point of this paper, regarding the nature of the interactions between human beings and the gleaming technologies of production (and their outputs) in late industrial societies. In short, I would argue that the supposedly dehumanising technologies of mass production were never as smoothly mechanised as they appeared, and that the human factor remained (or remains) a key component in even the most advanced technological processes. This human factor can, I would argue, be at least inferred (if not fully reconstructed) through a reverse engineering approach to late-industrial archaeology. This in turn has led me to question some of the ideas about 'modernity' and 'supermodernity' that are currently employed in the archaeology of the modern world.

This concern with the human factor in material cultures of modernism and modernity is reflected in Graves-Brown's (2013) wide-ranging exploration of archaeology and embodied, material knowledge which draws (inter alia) on Polanyi's (1983) idea of 'tacit knowledge', commonly summarised as that which we know but cannot tell. Tacit knowledge (such as how to ride a bicycle) is hard or impossible to verbalise and therefore difficult to transfer or teach: much of the technical knowledge discussed in this paper could be defined in these terms. As Graves-Brown notes:

> *even in the most 'hi-tech' of circumstances, tacit knowledge and skill persist. The Manhattan Project might seem about as far as one can get from knapping flint, yet … it has proved impossible entirely to formalize the process of making nuclear weapons. (Graves-Brown 2013: 302)*

This problem is a particularly interesting one in a largely post-industrial society such as contemporary Britain where processes such as the systematic deskilling of the workforce and the privatisation of state assets have been going on for some time. Here the process of archaeological reverse engineering is not merely an academic exercise but a frankly terrifying daily reality of the struggle to operate and maintain old and decaying infrastructure, including vital services, for which the necessary skills and knowledge have long since been allowed to fade away.

Reverse engineering

At this point it is worth examining the concept of reverse engineering in a little more depth:

> *Reverse engineering is the process of extracting the knowledge or design blueprints from anything manmade [sic] … it is very similar to scientific research, in which a researcher is attempting to work out the 'blueprint' of the atom or the human mind. The difference between reverse engineering and conventional scientific research is that with reverse engineering the artifact being investigated is manmade, unlike scientific research where it is a natural phenomenon'. (Eilam 2005: 3)*

By this definition reverse engineering closely resembles archaeology and arguably encompasses all of the

social sciences. The uses of reverse engineering within industry are numerous, including the analysis of secret or proprietary technologies, replication of existing objects, satisfying curiosity, and re-constructing the function of obsolete technology or technologies for which the documentation has been lost. This last category describes the entire archaeological record. So-called 'black box' reverse engineering involves the observation of an artefact in use, while the 'white box' alternative allows for destructive analysis to obtain more information, for example on manufacturing methods. An example in computer technologies is the careful etching or grinding-away and recording of silicon chips: recently a team of self-described "digital archaeologists" excavated a MOS 6502 microprocessor – an early and highly successful example of the kind – following the loss of the original hand-drawn schematics (Swaminathan 2011; Edgeworth 2013).

Messler's recent study of reverse engineering refers to it as, variously, "mechanical dissection" and "backward problem solving" (2014: 17). Importantly, his definition of reverse engineering recognises its value in determining not only the aims of the original process but also the starting conditions, intermediate stages, and path from beginning to end. Messler's discussion of reverse engineering notes that the simple practice of "taking things apart to learn" (2014: 3) is a common childhood behaviour based on curiosity about the material world, linked in particular to models of experiential learning. At its most basic, he describes the process of problem solving in engineering as running from *analysis* of the problem to a solution based on the *synthesis* of the available resources: reverse engineering (and archaeology) could therefore be described as running from *decomposition* (in chemistry, at least, the opposite of synthesis) to *analysis*. Messler is clear that the latter is a process of deductive reasoning, a practice with a rich and contested history in archaeological thought (e.g. Kelley and Hanen 1990) and an area of connection that would bear exploring in much more depth. Messler makes the link between reverse engineering and archaeology but focuses explicitly on past feats of structural engineering:

> *Another valuable use of reverse engineering … is to aid in the understanding of an ancient or very old design for which there are no written records of the purpose of the structure or, alternatively, the method by which it was built or manufactured. (Messler 2014: 52)*

The examples suggested include Stonehenge, Hadrian's Wall, and the Tunnel of Eupalinos.

Theories of reverse engineering have not hitherto been employed in archaeology to any great extent (but see Bouzakis et al. 2011), although they are used (most often implicitly) in experimental archaeology as discussed by Pierce (2005). Reverse engineers have frequently used the analogy of archaeology to describe the exploratory and speculative elements of their work: "we're trying to gain an understanding of existing systems by examining ancient artifacts and piecing together the software equivalents of broken clay pots" (Chikofsky 1990: 122). The term 'software archaeology' is often used to describe the reverse engineering of computer code:

> *Like the Antikythera Mechanism [discussed below], many applications were created years ago by unknown coders who left no documentation and can't be reached any more. Yet the mystery of their work can be as important to a business as the Antikythera Mechanism is to an archaeologist, as uncovering the business value encoded into an old application can tell a business a lot about its past and help shape its future. (Sharwood 2004)*

The emphasis on lost or absent documentation is an interesting archaeological trope here, as is the terminology used by software archaeologists which includes describing their projects as "digs". (Sharwood 2004)

Archaeology as reverse engineering

Archaeological analyses of technological artefacts and processes have frequently employed the methods of reverse engineering to examine the operational sequence or *chaîne opératoire*. In this broad field of research archaeologists have also drawn upon – and responded to – a strong and growing body of work in science and technology studies, itself grounded in part in archaeological and anthropological critiques of technology in the works of Leroi-Gourhan, Lemonnier, Latour and others (Latour 2014). Within science and technology studies more widely, there are studies that complement the arguments made in this paper, for example in Suchman's (1987; 2007) work

on the anthropology of human-machine interaction and Law's (2002) of Actor Network Theory and the sociology of technoscience. A full engagement with these bodies of work is beyond the scope of this short paper, but will no doubt emerge in future discussions.

The study of early metallurgical and extractive technologies is an excellent example of the analysis of a *chaîne opératoire* through reverse engineering, where the analyses of the products and traces of technological processes are used to reconstruct the production sequence. Martinón-Torres and colleagues carried out a study of sixteenth century alchemical equipment from an Austrian museum, with the aim of discovering the kinds of work undertaken in the original laboratory. Using the non-invasive or 'black box' analytical technique of energy-dispersive x-ray fluorescence they concluded that the materials had been used for fire assaying, a process of chemical analysis used to check the purity and makeup of metals, particularly gold and silver (Martinón-Torres et al. 2003). This was classic reverse engineering, illuminating the thought processes and work practices of a long-dead alchemist.

In the mid-nineteenth century the surgeon and antiquarian Thomas Pettigrew set about unrolling Egyptian mummies with the aim of discovering precisely how the embalming had been carried out. While classical sources such as the writings of Herodotus and Diodorus Siculus described the processes as they then understood them, Pettigrew hoped that the application of modern analytical methods might shed further light on the subject. At one of his first mummy unrollings in 1833 he appealed to his audience at the Charing Cross Hospital, which included many scientists and medical men, for guidance and assistance in analysing the mummy's flesh and bandages (Moshenska 2014). His 1834 *History of Egyptian Mummies* describes some of the tests including dissolving mineral samples in water and alcohol, and even licking and sniffing the various materials (Pettigrew 1834). He asked friends including the scientist Michael Faraday to conduct further analyses and carefully recorded the results. Pettigrew was keen that he and the other archaeologists of his era should be regarded as men of science, and his analytical approach to 'white box' reverse engineering the processes of mummification were a key part of that effort. Towards the end of his career he was able to put his learning into practice by mummifying the Egyptophile Duke of Hamilton in the traditional Egyptian manner and placing his body in an authentic sarcophagus, where it remains to this day (Moshenska 2014).

Figure 1: Fragment of the Antikythera Mechanism by Giovanni Dall'Orto (source: Wikimedia Commons).

Another application of more traditional reverse engineering in the archaeological world concerns the century of research devoted to analysing and interpreting the Antikythera Mechanism mentioned above, an extraordinary mechanical calendar from second century BCE Greece (Messler 2014) (Figure 1). Fragments of this elaborate contraption, made up of geared and inscribed wheels, were discovered by sponge divers in 1901. The Mechanism has been subjected to reverse engineering in the truest sense: a series of hypothetical uses and applications have been proposed and tested through physical and virtual modelling (Freeth et al 2008). The current consensus seems to be that it was a celestial calculator, although there are numerous conflicting theories and models suggesting it might be an astrolabe or navigational device. The account of the study of the Antikythera Mechanism (Price 1974) is a fascinating history in itself, and strongly reminiscent of Dawkins' idea of the future archaeologist confronted with a slide-rule.

Reverse engineering as archaeology

The examples above show how closely the practices of reverse engineering and archaeology can align, to the point that it is worth asking how we might distinguish between the two. One possible distinction is overall aim: while archaeology tends to seek knowledge about the past for its own sake, reverse engineering is generally more directly connected to larger industrial, military or economic endeavours.

Figure 2: The archive of 70mm tapes at the Lunar Orbiter Image Recovery Project by Steve Jurvetson (source: Wikimedia Commons).

One area where reverse engineering is taking on ever more archaeological tones is in the field of data recovery, particularly the efforts to access and interpret data from proprietary technologies and obsolete storage media. The rapid advances in digital technologies have left an ocean of data that is difficult if not impossible to access due to degradation or the loss of appropriate hardware, software and expertise. In some cases efforts are being made to overcome this: since 2008 the Lunar Orbiter Image Recovery Project has been attempting to recover, restore and enhance images of the moon taken by five different spacecraft and beamed back to earth in 1966 and 1967 (Jardin 2013). Team leaders Dennis Wingo and Keith Cowing obtained the original tapes containing the data and set up the project in an abandoned McDonalds restaurant in California (Figure 2). They describe their working method as "technoarchaeology": they found the original tape drives gathering dust in a farmer's barn and gathered

equipment and expertise from "eBay, discarded government equipment, new hardware reverse-engineered from math equations in 50 year old documentation, modern laptops, the expertise of retired engineers and scientists, and the dedication of young students" (Cowing, quoted in Jardin 2013).

The archaeology of a nuclear bomber

One interesting area of archaeologically informed reverse engineering is the practice of restoring antiquated technologies to their original, fully functioning state, often when their supposed replacements have failed or lack key capacities. An example of this, illustrating the lengths sometimes required to reverse engineer to the point of functionality, is the operational use of Avro Vulcan bombers in *Operation Black Buck* during the Falklands War of 1982 (Figure 3).

The Avro Vulcan first flew in 1952 as a high altitude, high speed nuclear bomber and was later adapted into all-weather, low-level strike aircraft. By 1982 their navigational and bombing equipment had not been upgraded in twenty years, many were being scrapped and a few were already museum exhibits (White 2007: 49). The few survivors had had many of their key systems removed or disabled. To ready the Vulcans for their mission required a considerable amount of scavenging, improvisation and reverse engineering, much of it notably archaeological.

One of the challenges facing the teams working on the Vulcans was the lack of standardisation in their manufacture and maintenance, as White notes: "Although built in the 1960s using what was then cutting-edge technology, they were, in many respects, hand built" (2007: 109). Across the entire Royal Air Force only one maintenance expert – John Williams of 50 Squadron – was found to have sufficient knowledge of the Vulcan to carry out the necessary restoration work, as White notes: "Much that was once known about the Vulcan had been lost … If [Williams] said, 'You need to tweak the third nut on the left one quarter-turn to the right,' you did it. And it usually did the trick." (White 2007: 177).

Figure 3: An Avro Vulcan by Łukasz Golowanow (source: Wikimedia Commons).

To restore the aircrafts' redundant systems required a range of archaeological and reverse engineering efforts. The filler was painstakingly chipped out of long-sealed-over refuelling valves, while replacement parts were sought, many of which were long out of production by firms that no longer existed. One key component for testing the fuel system was discovered being used as an ash-tray by maintenance crew (White 2007: 119). The rarest parts were the inflight refuelling probes, several of which were scavenged from Vulcans already donated to museums in the UK, Newfoundland, Nebraska and California (White 2007: 189). The original bomb carriers were found in a scrapyard in Newark. To carry the large external Electronic Countermeasures (ECM) pods necessary for the mission, the crews needed to find 'hardpoints' beneath the aircraft's wings: these were only fitted on some of the

aircraft and the blueprints were long lost, so engineers were forced to poke and tap at the surfaces and drill holes into the wings (White 2007: 202).

Should we consider the Vulcan to be an archaeological artefact or an archaeological site? At times it took on aspects of both, and it is notable that in studying technological objects, such as the Ford Transit van excavated at Bristol in 2006, the artefact/site distinction often begins to break down (Bailey et al. 2009). I am by no means the only scholar of humans and technology to find aircraft good to think with: the doomed TSR2 project (conceived in part as a successor to the Vulcan) is the subject of *Aircraft Stories*, John Law's (2002) study in Actor-Network Theory. The archaeology of the Avro Vulcan was an exercise in reverse engineering and related processes with a specific set of aims: an ultimately successful military operation.

Archaeologies of deindustrialisation

As I proposed at the start of this paper, the conceptual framework of reverse engineering is both similar to the archaeological process and appropriate for the study of industrial objects and sites. I would contend that these two factors enable us to extend the concept of archaeology as, or including, reverse engineering beyond the arbitrary boundary of the technological artefact or the factory gate and out into the industrial society as a whole. In this model reverse engineering becomes a key component and starting point for social industrial archaeologies of the types proposed by Orange (2008) and Penrose (2010), taking up the challenge laid down by Marx in *Capital*.

Recent studies in industrial archaeology have begun to situate the discipline within processes of deindustrialisation. Orange's (2008) historical survey and critique of the field suggests that post-industrial sites are frequently integrated into heritage landscapes to elide and ameliorate the social and economic traumas of industrial decline. She contests Edensor's more playful and aesthetically informed rhetoric of industrial decay with its largely positive perspective on ruins as spaces of transgression and transcendence (Edensor 2005; Orange 2008). The incorporation of redundant industrial sites and artefacts into heritage threatens to freeze them in time, moving them outside of their contexts of on-going social and economic decline and the real-world impacts of deindustrialisation (cf. Orange 2015; Graves-Brown 2015) (Figure 4).

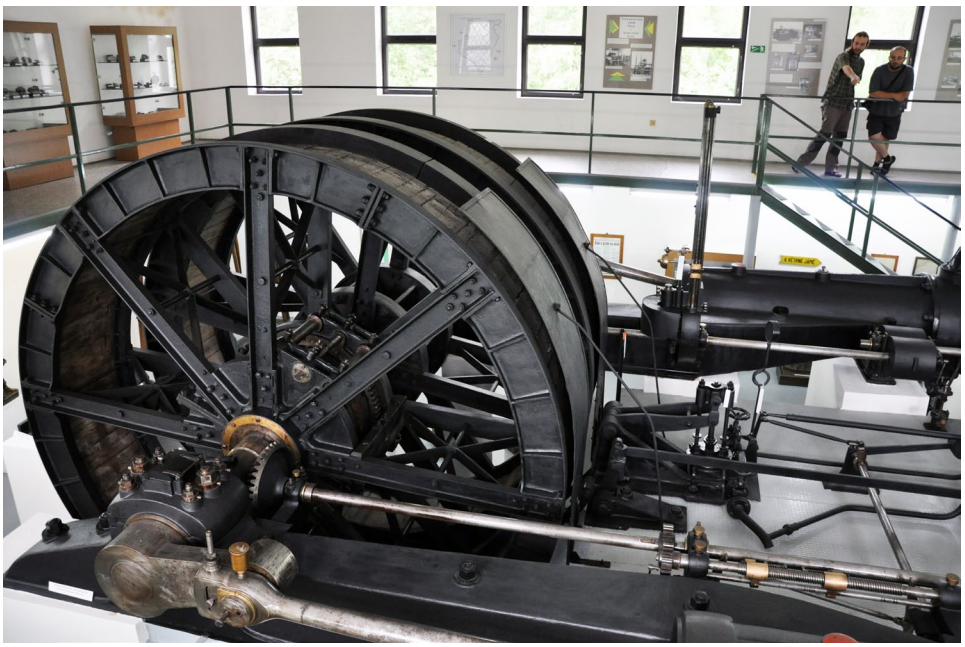

Figure 4: Industrial heritage in a mining museum, clean and out of place by Ben Skála (source: Wikimedia Commons).

Penrose's (2010) study of industrial remains in Cowley, Oxford, is resolutely post-industrial, tracing the archaeological and material forms of "creative destruction, industrialisation, deindustrialisation and postindustrialisation that have typified heavy manufacturing in Britain" (2010: 177). These include not only the sites of industry themselves; the empty, ruined and demolished car factories, but also the residential communities associated with the factories and a civic memorial to the Cowley car industry and its founders. Penrose reflects on the place of the archaeologist in studies of this material, and suggests that, "We are in a unique position of insight into society in transition from one set of economic resources to another" (2010: 171).

I would argue that this unique position is even more extraordinary than Penrose suggests. Scholars of the material world including archaeologists, geographers, planners and architects in the post-industrial UK and elsewhere have tended to work within an increasingly anachronistic model of modernity. Specifically, we have long been accustomed to thinking of ourselves as members of a technologically innovative society built upon and frustratingly constrained by our material world: a relic of earlier, less socially and technologically advanced eras (Fletcher 2002). This arrogant modernism is no longer tenable. Not only have the processes of industrial progress stalled or reversed in many areas, but the technological traces of past eras are increasingly challenging our perception of progress (Edgerton 2006). In the first case they are still palpably here because we have neither the means nor the motivation to remove them: the drive to redevelop industrial sites has declined as the financial crisis bites. In the second case many de-industrialised or post-industrial sites have, in their dotage, gained a certain mystique: we no longer know what many of them were, how they were operated or what larger processes they formed components of. They and the ever more remote society they represent will increasingly come to present a challenge to both archaeologists and reverse engineers.

Questioning 'modernity' and 'non-places'

The concept of 'modernity' has been much used in the archaeology of the modern world: Harrison and Schofield contrast Western, industrial modernity with post-industrial 'late modernity', regarding them as "social and technological processes [rather] than as entirely distinct time periods" (2010: 3). González-Ruibal's archaeologies of modernity have consistently looked beyond the margins of the industrial and post-industrial world to examine the limitations or failures of modernity in colonial and post-colonial contexts (González-Ruibal 2006, 2008). In addition, he focuses on 'supermodernity':

> *The short twentieth century … a period of extreme, baroque modernity, modernity qualified or upgraded rather than modernity overcome … The apogee and decadence of industrialism, colonialism, and neo-colonialism, the world wars, the environmental crisis, and the heyday of globalization are among its defining features. (González-Ruibal 2008: 247)*

Elsewhere he contrasts the alleged triumphs of modernity – "progress, construction, production, control, order" – with its failures – "war, genocide, alienation, mass destruction and mass dispossession" – crimes that he places at the feet of "the Age of Reason" (González-Ruibal 2006: 176)

Harrison's wide-ranging 2011 survey and analysis of the archaeology of the modern world examines these and other approaches to modernity, focusing in part on the pervasive obsession with the 'ruins of modernity'. He suggests a move

> *away from an idea of the archaeology of the present as an investigation into modernity 'in decline' … and instead towards the archaeology of the present as an investigation into modernity as partial, fragile and unfinished. However, to do this we must engage with modernity in very particular ways – not as something which is romantically falling into ruin, and hence both inevitable and anaesthetized against its influence in the present, but rather the opposite, as an unrealized social and material project. (Harrison 2011: 152-3)*

Echoing González-Ruibal, Harrison argues that an archaeology of the modern world can shed light on the "failings and fragile underpinnings" of modernity (Harrison 2011: 153).

My analysis of reverse engineering in and as an archaeology of the modern world leads me to question several of the core concepts that underlie these archaeological critiques of 'modernity'. For the archaeologists, photographers and urban explorers drawn by the romance of modern ruins, the visual rhetoric of industrial decay has come to be seen as the antithesis of the post- or anti-human modernity of the assembly line and the myth of endless progress and prosperity. One of the aims of this paper has been to begin to show that this conception of modernity as inhumanly technological was and remains an illusion. Furthermore I would argue that it is an illusion to which archaeologists of the modern world have been both too credulous and too critical, implicitly accepting at face value the claims of modernity even as they castigate it for its alleged failures. How has this come about? In part, it is a result of the too common (but by no means universal) use of 'modernity' as a straw-man, and in part it results from the fascination with the grandiose and gruesome ruins that Harrison noted and the resulting inclination to aestheticize rather than humanise or socialise the material remains of the recent past. More critical archaeological engagements with concepts of modernity have been productive but fleeting (see Shanks et al. 2004 and other papers in the same volume, and Thomas 2004).

This preference for concepts over people can be seen in the relatively uncritical acceptance of Augé's theory of the non-lieu or 'non-place' (1995, and González-Ruibal 2008; Harrison and Schofield 2010). While there is undoubted value in Augé's theory as a means of categorising some contemporary spaces, its use in archaeology exemplifies the problem of dehumanisation and demonstrates a startling lack of self-awareness. Augé's non-places – shopping malls, airports, motorways, undergrounds – are only non-places to the privileged observer: the planner, the traveller or the bourgeois archaeologist. 'Non-places' have cleaners, caretakers, repair crews, security guards, CCTV operators and technicians, some of whom – as this paper has shown – will have developed an intuitive understanding and appreciation of the space, its nuances and quirks. To attempt to study these spaces without appreciating the knowledge held by their invisible inhabitants is futile and myopic. A reverse engineering of these spaces as proposed in this paper would seek to incorporate these bodies of knowledge and practice, or at least to acknowledge their existence.

Discussion

In this paper I have tried to show that the vision of modern industry as an inhuman, technological edifice was always to some extent an Oz-like illusion maintained by skilled human beings. To study the machinery of the industrial age between the extremes of arrogant modernity and nihilistic post-modernity requires us to reverse engineer the industrial processes on a microscale while keeping in mind, as Marx noted, the macroscales of society and materiality that rose and fell on these industrial foundations. The examples and ideas outlined in this paper raise a number of questions and wider areas of concern.

What is archaeology as reverse engineering the archaeology of?

One possible answer is that reverse engineering is the archaeology of technical ability and expertise, or of specific individuals – such as the RAF technicians discussed above – upon whom these vast technological edifices rested. Thus the point in a process of reverse engineering where our reconstruction stumbles or fails is the point where we might infer human agency or tacit knowledge, as we infer human bodies from the body-shaped voids in the ashes of Pompeii.

Given its roots in deductive reasoning, does reverse engineering replicate some of the problematic aspects of the cruder end of processual archaeology?

One of the problems in integrating reverse engineering into archaeology, even into the archaeology of industry and technology, is that it rests in part on the assumption that all human activities have a set of mechanistic, rational aims. This may hold true in a very limited sense for certain technological artefacts, but in the broader understanding of industrial societies this is a limiting factor and a sobering insight into the limits of this interesting analogy. I doubt that archaeology as reverse engineering can ascend beyond the lower rungs of Hawkes' (1954) allegorical 'ladder of inference'.

In contrast, one of the greatest strengths of considering reverse engineering and archaeology together is the means it offers for thinking about technology and the producers and operators of technologies in late- and post-industrial societies. As noted earlier, heritage-based perspectives on technological artefacts risk freezing them in time, abstracting them from humanity, processes of decline and decay, and the human-scale narratives of economic decline and suffering that so often accompany deindustrialisation. The idea of reverse engineering archaeological artefacts implies breathing life and humanity back into them, and placing them in their social and technological contexts of innovation, use, discard and destruction. In this sense archaeological reverse engineering resembles to some extent Gell's conception of *abduction*, "a kind of inference to explanatory hypotheses" (Holland et al. 1986: 89) or for Gell a process of reasoning from a material artwork or artefact to the agency of its creator:

> *let us suppose that, strolling along the beach, we encounter a stone which is chipped in a rather suggestive way. Is it perhaps a prehistoric handaxe? It has become an "artefact" and hence qualifies for consideration. It is a tool, hence an index of agency; both the agency of its maker and of the man [sic] who used it." (Gell 1998: 16)*

The similarities with Dawkins' slide-rule analogy are clear, but Gell's superficially simplistic model of abduction is characterised by a cautious, incremental and iterative approach to reasoning from artefact to agent that more accurately describes the thought-processes of the archaeologist-as-reverse-engineer.

What is the use of bringing together reverse engineering and archaeology?

For the archaeology of the modern world, reverse engineering offers a point of contact with related and overlapping fields such as data recovery, legacy system management and software archaeology. More generally it may offer insights into the management of decline and shrinkage, whether in specific installations or in entire urban areas. There is also some potential for reverse engineering as a concept for archaeologists to think with. I remain uncertain as to what extent the analogies and similarities between archaeology and reverse engineering that I have outlined in this paper can make a substantive contribution to thinking about archaeology. It remains for archaeologists to take up this challenge and build something out of it.

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Gabriel Moshenska's „Reverse engineering and the archaeology of the modern world": a response

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Gabriel Moshenska's „Reverse engineering and the archaeology of the modern world": a response

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Moshenska draws a convincing parallel between reverse engineering of obsolete technology and archaeological inference. Interestingly, many of the arcane experts in orphaned software and discontinued machinery themselves recognize this parallel with their cooption of the term 'archaeology' (they are 'digital archaeologists' and perform 'software digs'). What is not clear from either their appropriation or from Moshenska's summary is whether archaeology itself works as 'tacit knowledge' of past know-how. Also left unresolved is whether we could take a more ambitious step of inference from 'how things work' to 'how society works.' The suggestion that the logic of archaeological inference could be tightened up with deployment of the methodical problem-solving techniques of forensic engineers is intriguing. Perhaps I am more hopeful than Moshenska, who shrugs his shoulders at the end of the paper and says, "I remain uncertain" about the paper's contribution to the field. Like the *chaîne opératoire* mentioned, is there a map for a *chaîne logique* that we could follow, or what used to be taught in required philosophy courses as 'formal logic'? As he also suggests, the parallel to processual archaeology, with its deductive modeling and fixation on material prime movers, comes to mind. But processual archaeology, in its heyday, was rarely interested in questions of political power (except as always, already evident in monumental structures) or the informal beliefs and practices of daily life that we awkwardly call culture. Thus, the possible retrofitting of old logics to newer questions holds promise. This writer, for one, does sometimes become weary of the loose poetics of much archaeological writing today in which the links between argument and evidence are hazy at best. Reverse engineering seems to offer a standard of precision that the field may just now need.

In terms of the larger theoretical stakes, the paper points towards Marxism, and makes a critical complaint about outmoded ideas about modernity, but ultimately there are some spare parts left over. Some major claims in the paper made me scratch my head. They regard the problem of the 'inhuman' and the nature of 'modernity.'

Moshenska says, "In this paper I have tried to show that the vision of modern industry as an inhuman, technological edifice was always to some extent an Oz-like illusion maintained by skilled human beings." It is unclear who maintain this characterization of modernity. Certainly, popular anxieties about industrialization were expressed during the machine age, perhaps most beautifully by Fritz Lang in the 1927 film *Metropolis*. However, it is no coincidence that Lang's influential film found its first audience during a global peak of socialist sentiment and Marxist membership, just before those political waters were poisoned by Stalin and Hitler in the 1930s. Lang's critique is not about a modernity in which machines have replaced humans but about one in which the needs of machines justify a futurist form of slavery. In the paper, some unintentional elision may exist between the 'inhuman' environment and Marx's idea of the alienation of labor. It is entirely common to have humans and machines operate as an integrated unit, or a relationship of interdependency. The result of Fordism is that workers are deskilled -- performing repetitive, mindless operations *like* the machines to which they are shackled. 'Fordism' is a reverse anachronism; the practices it describes really date to the early English textile mills of the early 19th century, so familiar to Marx and Engels.

To get an idea of how this principle could drive a downward spiral of conditions in which the worker's needs were subsumed to those of the machine, let me quote from an archaeological report on a New Orleans cotton mill I wrote many years ago, summarizing first-hand accounts from newspapers and testimony from an 1894 strike:

> *New Orleans' subtropical heat and humidity were amplified by the friction of thousands of machines and radiation from steam-powered motors. Temperatures inside the mill during the summer went well into the 100s. The noise of millions of machine parts clanking, spinning, whirling, pumping, and humming all at once must*

> *have made conversation at a normal tone impossible. The heat and noise exacerbated fatigue from 10 to 12 hour days spent doing repetitive tasks in a standing position. Workers were responsible for keeping a certain group of machines constantly running, so that lunch breaks were only possible if or when workers were able to get ahead of the machines' need to be loaded, threaded, and adjusted. (Dawdy and Ibáñez 1997:42)*

This is the 'dehumanization' that most people probably have in mind when they think about mechanized modernity. *Metropolis*, not *Wizard of Oz*. Moshenska's argument is weakened by not better setting up the 'dehumanization' thesis he wants to counter (despite his protests, it remains a ghostly straw man), but a second problem of an evidentiary nature leads to an interesting insight. That is, the counterexamples he uses are of extremely complex (even hand-built) technologies that were produced in low numbers by highly skilled workers – a.k.a, nuclear bomber planes. This type of technology (akin to the massive, temperamental Corliss steam engine that powered the cotton mill's moving parts) requires a different kind of human relation than does a row of identical spinning spools. Thus, one of the most powerful, though hidden, implications of this paper is that we need to find a way to talk about different species of machines and the different human relations they required for their creation, operation, and repair. One size does not fit all, even in the era of laser-cut mass production. What if we let machines be as variable in their character as their human interlocutors, rather than trying to come up with theories that lump all historic technologies into a single scrap heap of analysis?

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Reverse engineering and the archaeology of flowing materials. A response to Gabriel Moshenska's paper

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Reverse engineering and the archaeology of flowing materials. A response to Gabriel Moshenska's paper

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First of all, thanks to Gabriel Moshenska for raising such interesting questions regarding the relationship between reverse engineering and archaeology. His paper does an excellent job in setting out similarities and alignments between the two sets of practices, opening up the topic for further discussion. The author takes us a certain distance along a path of comparison, equips us with some well-honed ideas to carry with us, and then leaves it up to us to make of them what we will, or take them in whatever direction we choose. In picking up the challenge thus laid down, I will argue that archaeologists do indeed reverse engineer after a fashion, and that this not only has important implications for our understanding of archaeological inference: more than that, reverse engineering has potential to be of practical use to archaeologists in their investigation of specific types of material evidence, which I will go on to discuss.

Reverse engineering might at first seem to be most applicable to artefacts or machines, sometimes quite complex ones like the Antikythera Mechanism or Vulcan bombers. This leads Moshenska to consider the relevance of reverse engineering mainly with regard to industrial artefacts in a post-industrial age. But as he rightly points out, such things can be so complex, their maintenance and operation so bound up with tacit expertise and embodied rationales, that there are practical limits to what reverse engineering can realistically achieve.

Of all the examples given by the author, however, the one that strikes a chord for me is Pettigrew's unravelling of the Egyptian mummies. The mummies in question are neither mere artefact nor machine. Nor are they of modern date. In unrolling the layers of bandages and flesh, Pettigrew acquires insights which inform his own embalming practices. He unwraps the body of the ancient other in order to acquire the necessary bodily expertise, so he can then physically wrap the bodies of contemporary others with appropriate skill. He does not have access to the tacit knowledge of ancient Egyptian embalmers, but through engagement with their handiwork he learns much about materials used, techniques deployed, and intentions put into practice.

What Pettigrew does in unraveling Egyptian mummies, it seems to me, is essentially what archaeologists do in their archaeological investigation of sites and landscapes. It is not so much artefacts or complex mechanical devices that archaeologists reverse engineer, however – nor bodies for that matter - but sequences of strata. The landscape is seen to be layered, with later accretions / truncations above or cutting into earlier ones. We excavate layers in opposite order to that in which they were laid down – latest first, earliest last, so that the processes through which they have accumulated can be understood. This is broadly akin to Messler's account of reverse engineering as 'taking apart to learn'. The object of reverse engineering, then, does not have to be a technological artefact in the narrowest sense of the term: we can include sites and landscapes as well as portable tools and machines in that description.

Of course there is an art to fieldwork and the archaeologist acquires his or her own layers of embodied expertise, so to speak, in the process of investigating sites. To unravel a site is to do much more than seek to understand the physical traces of past human actions / intentions. There are biological and geomorphological forces to take into account too, and the physical traces of these are intermeshed with those of human forces in complicated ways that are hard to disentangle. But this does not render the comparison between archaeological fieldwork and reverse engineering unviable. Far from it - it actually makes the comparison more appropriate.

Reverse engineering has always been about physical engagement with materials, taking things apart with the hands as well as the mind, as much to do with the interaction between humans and other material flows and forces as about abstract reasoning alone. That is what is intriguing about it. It cuts through dualisms inherent in much discussion on forms of scientific inference, and moves us beyond polarities of mind and matter, ideas and things, practice and theory. The sheer physicality of dismantling an engine and putting it back together, or unraveling the bandages of an Egyptian mummy, is significant. Reverse engineering is a practical and physical process as well as a mental one. It is a wrestle with materials as well as with ideas, even if it overtly accords primacy to the latter by its over-emphasis on the importance of the original design.

Moshenska defines reverse engineering as 'the process of reasoning backwards from a technological artefact to the initial problem or design specification it was created to solve or fulfil'. But we are already beginning to take that definition apart, dismantling its main components one by one, so we can put it together again in a slightly different way, broadening it out in the process.

We should make clear for example that by 'reasoning' we are referring to *practical* reasoning as well as to *analytical* reasoning. Not all reasoning takes place solely in the brain, but is somehow distributed throughout action fields where hands and brain are used in unison, in deployment of appropriate tools of the trade on problematic materials. In postulating the existence of an initial preconceived 'design', we should entertain the alternative possibility that there could have been no original plan as such. Past human agents and artisans must often have proceeded by flexible and creative processes of trial and error, learning from the materials that they were engaging with, developing ideas in response to practical problems encountered, working out designs as they went along (Ingold 2013).

Matter is not just a passive recipient of the force of human intentional agency, and does not always submit compliantly to the constraints of preconceived designs. Materials being assembled or disassembled have a quality of vibrancy and liveliness (Bennett 2010) which disrupts even the best laid plans, and should therefore be considered as active participants in the political ecology of manufacture and design. With this in mind, it becomes clear that what one is working back in reverse engineering may be an interactive process rather than a plan - or ideational-material engagements rather than conceptual entities alone.

There is a good reason why I have sought to broaden out the concept of reverse engineering beyond its original specifications. I see it as being especially applicable and relevant to one particular field of research in which I have a longstanding interest, and that is the archaeology of flowing materials. Here we are necessarily talking about landscapes (or flowscapes) as much as about technological artefacts, and how these have been shaped in part by human beings alongside other material agencies. Working out the techniques and rationales employed by people in the past – attempting to reconstruct something of the content of their former expertise - has real relevance for future policy and practices. Yet in many cases all that survives for inferences to be based on are the derelict structures themselves – ditches, channels, levees, sluices, weirs, dams, staunches, drains, leats, qanats, terrace walls, etc - in their landscape setting and stratigraphic context.

Reverse engineering is applicable here because of certain basic realities that both people in the past and archaeologists in the present must respect. One is the fundamental principal that water and other flowing materials are subject to the force of gravity and tend to flow downhill (other things being equal). This provides a useful baseline around which deductions can be made, and in terms of which reverse engineering questions can be framed. We might ask, for example, how past peoples have made use of or modified landscape topography in order to harness or resist the energy of gravity-driven flows, and what were they trying to achieve in doing so?

Such questions can be addressed archaeologically. Let us suppose for instance that beneath a Neolithic house a series of interconnecting drains are discovered during the excavation of the site. An obvious technique to use would be to survey and map the drain system, recording heights along the floor of each drain. The resulting plan would show the gradient or slope of the drains and thus the direction of flow, revealing which drains flowed into which, where the water was channeled from and where it was channeled to, which drains were bringing flow into the house and which were taking it away, and so on. Since the drainage system in this case did not arise naturally but was a skilled accomplishment, involving integrated expertise in thought and practice, something can be usefully said about the intentions of the makers of the drain system.

Similar techniques can be used on much larger scales. The Anglo-Saxon town of Wallingford is surrounded by impressive enclosing defensive rampart and ditch, known to have held flowing water. To try and understand how this water management system worked, levels were taken along the floor of the ditch to ascertain gradient and therefore the direction of flow. Such data facilitates not just a description of the physical form of the monument, but also something about the intentions of the Saxon hydraulic engineers (for that is effectively what they were) who constructed it. any map showing direction of flow is also a map of their enacted intentions, modified in practice to take account of the many material challenges the local topography must have presented (Edgeworth 2011: 88-91).

A third example of where reverse engineering can usefully be deployed is provided by the various kinds of terracing which are to be found over large areas of terrestrial surfaces of the Earth, especially in the Far East. Terraces support the production of food on a vast scale. Such structures modify local hydrology and prevent erosion. Indeed, it seems that in many cases the intention behind them (to use a loaded term) is to make use of the gravity-driven flow of materials precisely by resisting it, trapping the downward moving water-borne sediments behind the terrace walls to create fields of fertile soil. Yet many of these terraced fields are of ancient origin, and knowledge of the techniques of construction has been lost in many cases. Reconstructing such knowledge from archaeological investigation of the stratigraphy of terraces, by means of a kind of reverse engineering (which takes account of the material as well as the conceptual forces at work), could be of immense value in informing future policies of soil conservation and sustainable agriculture.

In short, as a field archaeologist with an interest in the archaeology of flowing materials, I find the concept of reverse engineering both problematic and inspiring. It has archaeological potential. Of course it is important to be critical of aspects of it, and to adjust its methods to suit archaeological purposes. But one thing is for sure. The next time I carry out a project on the archaeology of rivers or water management, it will be in part an experiment in archaeology as reverse engineering.

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Comment on Gabriel Moshenska: Reverse engineering and the archaeology of the modern world

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Comment on Gabriel Moshenska: Reverse engineering and the archaeology of the modern world

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The author's summarised definition of reverse engineering, "the process of reasoning backwards from a technological artifact to the initial problem or design specification it was designed to solve or fulfill," brings to mind an example from the Old World, and what might be described as the old way of doing archaeology. But one which, more recently, has been interpreted by artists.

The example is from Sir Leonard Woolley's excavation at Ur, Mesopotamia. I quote it from the account published online at https://archive.org/details/urexcavations186385join, a process which is, in itself, one of recovery prompted by the paper's suggestion to reason backwards.

Woolley's access to lost artifacts, in this case a lyre, came from his reasoning that the absence of the object defined its presence.

The Plaster Lyre, U. 12351, from PG/1151 [...]

The manner in which a plaster cast was made of this instrument, of which the woodwork had completely disappeared, has been described [before]; only the copper calf's head and shell plaque … are original, all the rest being the modern plaster…. In the photograph …, taken while the cast still rested in the ground against the cut face of the soil, the outline is less distinct because (a) large lumps of plaster remain at the tops of the uprights where it was poured in and the superfluous plaster congealed; (b) when the earth on the near side was cut away in order to expose the cast it was found that the plaster had not quite filled up the channel representing the cross-bar or the sound-box….

Taking the better preserved side…, it will be seen that the uprights are particularly slender; they are mortised into the sound-box presumably by tenons, and the lines of the joints are clearly visible. The sound-box has a flat top for about half of its length which definitely overhangs the table, but this is less evident at the back where the strings were. … At the back end of the sound-box there is a raised ridge which may possibly be the bridge. When the soil between the uprights was cut back we were astonished to see very thin lines…of very light white fibrous dust which were the remains of the actual strings; judging from the texture of the dust they had been of gut or sinew. There were ten of these.

And so it was, with the recovered artifact being rendered well enough that 20th century copies could be made, the music the lyre made brought to life through this re-fitting and further articulated into the digital age (I made a BBC Radio 4 programme, "Ghost Music", about this in 2011, still online www.bbc.co.uk/programmes/b010dp0s).

The recognition of the lyre - or rather the space it represented - as an instrument which could be re-animated links to the tacit knowledge discussed in Gabriel Moshenska's paper. Hearing a lecturer describe the process Woolley used, my undergraduate response was not about the evidence of the culture per se, but the ingenious way he had brought the various sensations back to life. The material science evoking, later, the haunting sound, one still recognisable as the lyre is still played as a musical instrument. By a similar process of recovery, the artist Rachel Whiteread made her name as an artist working with spaces, where the abutting of material defines not just the lost object, but how the fit works.[1] It is a retro-fit of sorts, which is also a form of salvage.

1 www.tate.org.uk/art/artists/rachel-whiteread-2319

The author's description of reverse engineering as applied to contemporary technology - "a frankly terrifying daily reality" - chimes with my earliest (and ongoing) excavations in Silicon Valley (Finn 2001), which illuminated, in a more positive way, the place of tacit knowledge. The accelerating rate of change means that artifacts in the technology museums have a bonus source of tacit knowledge, from the researchers, developers, makers, and early adopters who are still - on the whole - around to put story and object together. One of my first interviewees was a man I traced from a note he wrote to go with a small detail from chip manufacture, a piece of metal accessioned into Intel's in-house museum. It was gratifying that this link in the evolution of smaller, faster, cheaper memory was not in any fragile digital format, but a note written by hand on a piece of paper, placed with the object, detailing what it was, and what it did.

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Das Cookie Monster und sein iPhone - Bemerkungen zum Beitrag von Gabriel Moshenska über reverse engineering and the archaeology of the modern world

Ulrich Müller

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Das Cookie Monster und sein iPhone - Bemerkungen zum Beitrag von Gabriel Moshenska über reverse engineering and the archaeology of the modern world

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Das Cookie Monster der Sesamstraße war und ist für viele ein echter Typ, ein Original, welches intern den Namen Sid trug.[1] Das Stofftier mit seinen anarchischen Zügen und seinem individuellen Habitus ist zugleich ein Produkt einer globalen Unterhaltungs- und Bildungsindustrie. Auch wenn Krümelmonster alias Sid handgefertigt war, so ist es eine Marke und seine zahlreichen Umsetzungen auf Tassen, Rucksäcken, Schlüsselanhängern, Puzzeln usw. ein Ausdruck kapitalistischer Massenproduktion. Ebenso wie übrigens das iPhone, das seit seiner Einführung nicht nur Apple ungeahnte Gewinne bescherte, sondern hilft, das soziale und kulturelle Kapital von Taschentelefonaten bis heute zu erhöhen. Apple als Marke ist cool und irgendwie auch anarchisch - so wird es gerne kolportiert und dies mag erklären, warum auf die Frage an Siri, den Sprachassistenten des iPhones, "Was ist Null geteilt durch Null?" als Antwort ein philosophischer Diskurs zu Keksen und der Traurigkeit des Krümelmonsters folgt.[2]

Gabriel Moshenska fragt nach einem anderen Sid. Jenem Sid, den man in Gebäude 9a der Versorgungsbasis der RAF (Royal Air Force) kontaktieren muss? In einem Betriebshandbuch, das bei der Fertigung oder dem Austausch bestimmter Komponenten des Blackburn Buccaneer den TechnikerInnen mit Rat und Tat zur Seite stand, wird in einer Randnotiz jener Sid genannt. Er allein scheint über Expertenwissen zu verfügen. Der Eintrag in dem "instruction manual" eines britischen Kampfflugzeugs aus der Zeit des Kalten Krieges wird zum Ausgangpunkt der lesenswerten Überlegungen von Moshenska, um den Begriff und das Konzept des reverse engineering für die Archäologie auszuloten.

Moshenska geht es in seinem Beitrag im wesentlichen darum, die Zusammenhänge von reverse engineering und Archäologie vor allem in Bezug auf industrielle und post-industrielle Gesellschaften zu untersuchen, aber auch danach zu fragen, wie Archäologinnen und Archäologen mit technischen Artefakten dieser Zeit eigentlich umgehen. Ein Ausgangspunkt seiner Überlegungen ist dabei Sid, der im konkreten wie übertragenen Sinne für das Handlungswissen menschlicher AkteurInnen auch in den scheinbar dehumanen industriellen und post-industriellen Gesellschaften steht. Insbesondere bei der Analyse von Werkzeugen und Geräten, Techniken und Technologien, die ein zentrales Thema einer Archäologie des 20. und 21. Jhs. sind, darf nicht allein auf technische oder ergonomische Prozesse geschaut werden. Standardisierte Produktionsketten von der Küchenmaschine über das iPhone bis hin zu Flugzeugen sind zwar ein Merkmal kapitalistischer und industrieller Produktionsweisen, aber auch in Zeiten der Produktion 4.0 bleibt der Mensch der nicht immer blinde Uhrmacher. Dies führt Moshenska zu der kurzen Auseinandersetzung mit den Konzepten der Moderne und Supermoderne in der Archäologie, die er insbesondere anhand der Deindustrialisierung diskutiert.

Zunächst aber einmal - was ist reverse engineering? Im engeren Sinne ist reverse engineering, im Deutschen aus als Nachkonstruktion bezeichnet, ein Vorgang, um "aus einem bestehenden, fertigen System oder einem meistens industriell gefertigten Produkt durch Untersuchung der Strukturen, Zustände und Verhaltensweisen die Konstruktionselemente zu extrahieren"[3]. Etymologisch verrät das Wort seine Herkunft aus den Ingenieurswissenschaften. Reverse engineering ist stark in der Informationstechnologie verbreitet, wo es über die Hardware hinaus um die Rekonstruktion von Software (Quellcode) geht. Schließlich wurde und wird reverse engineering auch in den Lebenswissenschaften eingesetzt. Stichworte sind hier Gentechnologie, Medikamentenentwicklung oder das groß

1 http://muppet.wikia.com/wiki/Cookie_Monster, Stand: 17.02.2016.

2 http://www.cosmopolitan.de/geniales-verstecktes-apple-feature-siri-erklaert-euch-mit-dem-kruemelmonster-was-0-geteilt-durch-0, Stand: 17.02.2016.

3 https://de.wikipedia.org/wiki/Reverse_Engineering, Stand: 17.02.2016.

angelegte Projekt eines reverse engineering des menschlichen Gehirns, für das der Microsoft-Gründer Paul Allen ab 2003 dreistellige Millionenbeträge bereitstellte.[4]

Reverse engineering erfolgte zunächst klassisch durch die Demontage und eine genaue Dokumentation der Arbeitsschritte sowie der Bauteile, wurde aber zunehmend durch non-invasive oder nicht-mechanische Verfahren erweitert. Moshenska benutzt hier die Begriffe “black box” und “white box”, Verfahren, die letztlich dem software engineering entstammen. Über die Verwendung des reverse engineering-Konzeptes in Ingenieurs-, Informations- und Lebenswissenschaften hinaus ist der Begriff inzwischen auch auf anderen Feldern wie im Management oder den Wirtschaftswissenschaften präsent (z.B. Gelain et al. 2015). Um reverse engineering für die Archäologie zu nutzen, bedient sich Moshenska einer “Definition” von Eldad Eilam (2005, 3), der davon spricht, dass reverse engineering sämtliche von Menschenhand geschaffen Dinge betrifft. Dies wäre sicherlich zu diskutieren. Vor allem aber ist festzuhalten, dass E. Eilam primär das software engineering und hierbei MS Windows-Systeme behandelt und die Definition der Einleitung (S. 3) entstammt. Ganz ähnlich ist dies bei Robert W. Messler (2014), dessen Konzept Moshenska ebenfalls zitiert. Auch er arbeitet mit einem sehr weiten Begriff, der es einerseits ermöglicht, vergleichende Betrachtungen anzustellen, andererseits aber aus meiner Sicht immer noch rein ingenieurwissenschaftlich geprägt ist.

Gewinnbringender wäre es gewesen, den Weg des Begriffes in die Medien- und Kulturwissenschaften zu verfolgen (Friesinger und Herwig 2014). Reverse engineering wird unter anderem als ein Konzept für eine demokratische, digitale Wissensgesellschaft verstanden, in der jede und jeder Zugang zu Information hat und diese beliebig verändern darf (Fugléwicz-Bren 2014). “When we practice ‚Reverse Engineering’, we do not want to destroy technology as the luddites did... We want to make it democratic and therefore deconstruct its capitalist ideology of exclusion and exploitation that has found entrance into its blueprints and a concise articulation in the encasings” (Schneider und Friesinger 2014, 14).

Im Kern ist und bleibt reverse engineering ein Produkt der industriellen Sphäre. Es umschreibt Techniken und Methoden der Exploration. Produkte von Wettbewerbern werden in ihre Einzelteile zerlegt und funktional überprüft mit dem Unternehmensziel, Informationen über die verwendeten Technologien und Fähigkeiten der Konkurrenten und unter Umständen Erkenntnisse für die eigene Forschung und Entwicklung sammeln kann. Reverse engineering kann damit auch Teil des sog. enterprise enginnering sein und es ist an bestimmte ökonomische und gesellschaftliche Konfigurationen gebunden, die im vorliegenden Text allerdings nicht weiter diskutiert werden. Das ist schade, denn es geht ja im Kern um postindustrielle Gesellschaften. Dieses Vorgehen von Moshenska verdeutlicht ein allgemeines Dilemma der Archäologie, wenn es um die Übernahme von Begriffen und Konzepten aus anderen Wissenschaftsbereichen geht. Ich hätte mir hier eine kritische Analyse gewünscht. Bevor der Begriff für die Archäologie als gewinnbringendes Konzept eingeführt wird, sollten seine Genese und die Mechanismen seiner Übernahme in andere Wissenschaftsbereiche näher beleuchtet werden.

In den Abschnitten “Archaeology as Reverse Engineering” und “Reverse Engineering as Archaeology” geht es um die konkrete Anwendung. Das ist nicht völlig neu, denn Greg Urban (2010, 210ff.) benutzte das Konzept bereits vor rund sechs Jahren zur Analyse von sozialen und materialen Beziehungen. Die Analyse von Prozess- und Verfahrenstechnologien, aber auch Nutzungsabläufen als chaîne opératoire, als ergologische Analyse, experimentelle Archäologie oder im Sinne des Aktor-Netzwerkes von Bruno Latour ist ein zentrales und etabliertes Anliegen der archäologischen Wissenschaften. Die im folgenden angeführten Beispiele überzeugen nur auf den ersten Blick. Die Arbeiten von Thomas Joseph Pettigrew (1791–1865), der als “Mummy Pettigrew” in die Forschung einging, liegen am zeitlichen Rand des Übergangs von der Vormoderne zur Moderne. Der Chirurg und Antiquar wurde u.a. bekannt, weil er vornehmlich im Rahmen privater Veranstaltungen Mumien entrollte und für die Unterhaltung seiner Gäste obduzierte. Das hierbei erworbene Wissen, das vielleicht schon im Entrollen einer Mumie als reverse engineering bezeichnet werden kann, hat nicht nur zu einem tieferen Verständnis der Einbalsamierungstechniken geführt. Es ermöglichte ihm auch, seinen Gönner, den Herzog von Hamilton, nach seinem Tod 1852 zu mumifizieren. Der Mechanismus von Antikythera, ein der späteren Astronomischen Uhr vergleichbares Gerät aus dem zweiten vorchristlichen Jahrhundert, von dem 82 Fragmente erhalten sind, fasziniert nicht nur durch seine Komplexität. Da er unvollständig erhalten und nicht mehr funktionsfähig ist, fordert der Fund die Wissenschaft nach wie vor heraus. Am vorläufigen Ende der Kette der Rekonstruktionsversuche steht das 2002 initiierte “Antikythera

4 http://www.engineeringchallenges.org/challenges/9109.aspx, Stand: 18.02.2016.

Mechanism Research Project".[5] Tony Freeth und Alexander Jones (2012) virtualisierten jüngst das Gerät. Ein letztes Beispiel bilden die archäometrischen Analysen an Funden aus Oberstockstall, einem frühneuzeitlichen Alchemistenlabor in Niederösterreich. Der Versuch, die Rezepturen des dort tätigen Alchemisten zu ergründen und mit der modernen anorganischen Analytik in Einklang zu bringen, offenbarte allerdings kaum dessen geheimes Wissen. Es zeigte - und das verleiht dem Beispiel eine doppelte Semantik - dass der "Chemiker" in Oberstockstall als Bediensteter seines Herren über die Transmutationschemie hinaus handfeste Analytik im Interesse der frühneuzeitlichen Montanindustrie betrieb (Sokup 2007).

Die gewählten Beispiele stammen aus der Antike, der frühen Neuzeit und der Wende zur Moderne. Die Versuche, Aussehen und Funktionsweise (Antikythera), die Rezepturen und Verfahren (Oberstockstall, Pettigrew) zu rekonstruieren, erfolgten im 20. und 21. Jahrhundert. Sie belegen eindringlich, wie mit neuen Techniken und Methoden Erkenntnisse über die Vergangenheit gewonnen werden und zugleich die Erforschung von Artefakten der Vergangenheit die Entwicklung der Archäoanalytik stimuliert. Auch wenn man reverse engineering nicht als bloße Technik oder Methode, sondern als Konzept versteht, erschließt sich mir der Mehrwert gegenüber etablierten Verfahren der Rekonstruktion von Verfahrens- und Prozessabläufen nicht unmittelbar. Im übrigen: hilfreich wäre es gewesen, Begriffe wie "Rekonstruktion" in Bezug zum reverse engineering zu klären.

Mir fällt zudem auf, dass Moshenska seine Überlegungen ausschließlich auf Artefakte gründet. Dies liegt nahe. Allerdings wäre es reizvoll gewesen, den archäologischen Formationsprozess als Ganzes oder zumindest Teile davon einmal unter dem Blickwinkel der reverse engineering zu betrachten. Stratigrafischem Arbeiten und der Rekonstruktion stratigraphischer Sequenzen ließe sich dadurch Neues abgewinnen. M. E. hätte es sich eher angeboten, konkrete Anwendungen des reverse engineering im archäologischen Kontext darzustellen und dadurch in die Diskurse über die Super- bzw. Hypermoderne einzusteigen. So könnte es um die Frage gehen, wie das 3D-Digitalisieren von archäologischen Objekten, die Aufbereitung dieser Daten zu einer Oberflächenbeschreibung und die Verwendung dieser Beschreibung für die rechnergestützte Herstellung (CAD; CAM) von Duplikaten, Replikaten und Restauraten eingesetzt werden. Hieraus ließe sich im übrigen ein Diskurs entwickeln, der über die technische Seite hinaus den Inhalt berührt: Die Frage nach der Authentizität eines Objektes in Zeiten der Virtualisierung. Die Traditionen des Römisch-Germanischen Zentralmuseums (Mainz) sind hier ebenso zu nennen wie die #Unite4Heritage-Initiative der UNESCO, via Laserscanning virtuelle Kopien potentiell gefährdeter Kulturgüter herzustellen.[6] Was macht die Authentiziät von Vergangenheit aus und wie wird diese in postindustriellen Gesellschaften dargestellt?

Angesichts der postulierten Wahlverwandtschaften von reverse engineering und Archäologie (bzw. bestimmten archäologischen Techniken und Methoden) ist es konsequent zu fragen, ob denn reverse engineering auch als Archäologie betrachtet werden kann. Wenn von "Software Archaeology" bei der Rekonstruktion von Quellcodes oder im "lunar orbiter recovery project" von "Technoarchaeology" gesprochen wird, so zeigt mir dies zunächst die metaphorische Verwendung des Archäologie-Begriffes. Verlorenes, Verschüttetes oder Unbekanntes wird ausgraben, wiederentdeckt und der Vergangenheit entrissen - Begriffe, die seit Beginn der Archäologie nicht nur mit dieser verbunden wurden, sondern stellvertretend für den Umgang mit Vergangenem stehen. Nicht umsonst hat Michel Foucault ja bereits 1969 von der "l'Archéologie du savoir" gesprochen. Und hier genau scheint mir das Problem zu liegen. Das reverse engineering-Konzept ist und bleibt nämlich im Kern eines der Ingenieurswissenschaften. Wenn es um den Faktor Mensch geht, um das implizite Wissen der humanen Akteure, wäre ein Rückgriff auf wissenssoziologische Ansätze vielleicht hilfreicher gewesen.

Mit den Ausführungen zur Archäologie eines Nuklearbombers, dem Avro Vulcan, kommt Moshenska letztlich auf den Anfang zurück. Der Avro Vulcan Bomber wurde in den 1950er Jahren entwickelt und die letzten Modelle 1984 außer Dienst gestellt. Der Kampfjet ist ein frühes Beispiel für die Stealth-Technologie, denn er war als Deltaflügler schwer vom gegnerischen Radar auszumachen. Bei der Entwicklung spielte im übrigen ein gewisses rapid prototyping eine Rolle, die Moshenska nicht thematisiert. Die Firma Avro baute zunächst drei Maschinen im Maßstab 1:3, um bis dato nicht erprobte aerodynamische Merkmale zu testen. A propos Kapitalismus und Krieg: Die Avro Vulcan Bomber besaßen nur Schleudersitze für die beiden Piloten, während die übrige Besatzung im Falle eines Absturzes auf sich gestellt war.

5 http://www.antikythera-mechanism.gr/, Stand: 18.02.2016.

6 http://www.unite4heritage.org/index.php, Stand: 18.02.2016.

Wie manches militärische Großprojekt war die Fertigung immer wieder Veränderungen unterworfen, die sich auch aus dem konkreten Einsatz ergaben. Gerade Militärische Großprojekte zeichnen sich - aus welchen Gründen auch immer - häufig durch eine erhöhte Fehleranfälligkeit aus und sind im Vergleich zur zivilen Massenproduktion in ihrer Anzahl beschränkt. Dies - und hier ist Moshenska zuzustimmen - macht es nicht einfach, die erhaltenen Exemplare als "Typ" vorzustellen und sie zu restaurieren.

Moshenska stellt zu Recht die Frage, ob wir es bei ausgemusterten, restaurierten und teilrekonstruierten Exemplaren mit einem "archaeological artefact or an archaeological site" zu tun haben. Damit betritt er ein zwar spannendes Feld, das über die Archäologie des 20. und 21. Jhs. hinaus von grundsätzlicher Bedeutung ist, doch m.E. wenig mit der Frage nach dem reverse engineering zu tun hat. Unabhängig vom reverse engineering belegt das Beispiel die Probleme einer Archäologie des 20. Jhs., Großobjekte zu erhalten - doch dies ist eben ein anderes Thema. Ergänzend zu den Analysen von Moshenska ist zu erwähnen, dass die Avro XH558, 2007 erstmalig bei einer Flugschau wiederbelebt wurde und ein ehemaliges Besatzungsmitglied zur Crew gehörte, welches seinerzeit an der „Black Buck"-Mission (Falkland Islands 1982) teilnahm.[7] Im Sinne eines archäologischen reverse engineering Konzeptes wäre es interessant gewesen, zu erfahren, wer an der Restaurierung und Teilrekonstruktion denn beteiligt war, wie diese Vorgänge abliefen und wie das Verhältnis von implizitem Wissen, tradiertem Wissen und den verschiedenen Wissensformaten war.

Mehr oder minder direkt greift Moshenska dann eines der großen Themen des ausgehenden 20. und vor allem des 21. Jhs. auf - die Deindustrialisierung. Damit sind in der Umkehrung zur Industrialisierung Prozesse sozialen oder wirtschaftlichen Wandels gemeint, die vor allem durch die Transformationen im industriellen Sektor angestoßen werden. Deindustrialisierung hat auch ihren Eingang in die Archäologie gefunden, und sie wird für Moshenska zum Ausgangspunkt für Überlegungen über die Konzepte von Moderne und Supermoderne. Die archäologischen Diskurse um "modernity" und "late-modernity", die z.B. von Rodney Harrison und ohn. Schofield angestoßen wurden, stellt er dem eher postkolonialen Ansatz von Alfredo González Ruibal entgegen. An dieser Stelle möchte ich nicht weiter auf die Argumente für und wider eingehen, aber doch darauf hinweisen, dass Moderne als ein Konstrukt der westlichen bzw. kapitalistisch-industriellen Welt schon lange vor dem archäologischen Diskurs einer kritischen Revision durch die Kultur- und Sozialwissenschaften unterzogen worden ist - Hybridität und Transkulturalität seien hier nur als Schlagworte genannt. Aber auch die Konzepte der Super- und Hypermoderne, die Literaturwissenschaftler wie Terry Eagleton oder Philosophen wie Gilles Lipovetsky als neue Konzepte einführten, lassen sich häufig nicht voneinander scharf abzugrenzen und werden innerhalb der beteiligten Wissenschaften kontrovers diskutiert. Abschließend beleuchtet Moshenska das Konzept der "non-lieux" kritisch, das von dem französischen Ethnologen Marc Augé entwickelt wurde. Nun ist die Idee der non-lieux auch in den Kulturwissenschaften nicht völlig kritiklos aufgenommen worden, denn Transiträume wie die "non-lieux" zeichnen sich durch eine Vielzahl von Interaktionen aus. Die spannende Verbindung liegt indes darin, das hinter den "non-lieux" stehende Konzept, auf jene "lost places" zu übertragen, die als physischer oder sozialer Raum im Zuge der Deindustrialisierung entstehen. So spannend diese Ausführungen von Moshenska sind und ich ihnen auch folgen kann, so undeutlich bleibt der Bezug zum reverse-engineering.

Ist das Wissen von Sid aka Cookie-Monster aka Siri nun intuitiv oder nicht verbalisierbar? Entzieht es sich einer Formalisierung oder ist es erfahrungsgebunden? Was - so fragt Moshenska zu Recht - bedeutet dies für archäologisches Arbeiten? Seinem Argument, dass die Rekonstruktion von technischen Anlagen oder Prozessen im Besonderen und von Vergangenheit im Allgemeinen von Akteuren mit implizitem Wissen abseits von rational choice abhängig ist, kann ich folgen. Doch ich frage mich, ob aus kulturwissenschaftlicher Perspektive nicht offene Türen eingerannt werden. Anstelle des reverse engineering-Konzeptes, das mir in einer sehr engen Auslegung in der Archäologie kaum anwendbar erscheint und in einem weit gefassten Verständnis zu schwammig bleibt, hätte es sich angeboten, mit Ansätzen der science and technology studies bzw. der Wissenssoziologie zu operieren. Diese bieten in der Untersuchung des alltäglichen Zusammenspiels von Wissenschaft, Technologie und gesellschaftlicher Ordnung implizit Zugänge. Wenn reverse engineering über die rein ingenieurswissenschaftliche Verwendung hinaus als ein Konzept der Wissensreproduktion verstanden wird, sollte die Auseinandersetzung auf dieser Ebene erfolgen. Sie zeigt uns dann, dass Sid ein individuell agierender Mensch ist, dessen Handlungsoptionen und Handlungslogiken aber zugleich in Strukturen eingebunden sind.

7 http://www.vulcantothesky.org/, Stand: 18.02.2016.

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The Cookie Monster and his iPhone – a comment on Gabriel Moshenska's contribution "Reverse engineering and the archaeology of the modern world"

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The Cookie Monster from Sesame Street is for many a real "buddy," an original who was known by insiders as Sid.[1] The stuffed animal with its anarchic traits and individual habits is at the same time a product of the global entertainment and the education industries. Even though Cookie Monster, alias Sid, was originally handmade, it is also a brand with numerous incarnations on mugs, backpacks, key rings, puzzles, etc. In short, it is an expression of capitalist mass production. That makes it similar to the introduction of the iPhone, bringing unimaginable profits to Apple, while simultaneously helping to increase the social and cultural capital of cell-phone calling. The brand Apple is cool and somehow also anarchic – at least that is how it is peddled. This may explain why Siri, the voice assistant of the iPhone, responds to the question, "What is zero divided by zero?" with a philosophical discourse about cookies and the sadness of the Cookie Monster.[2]

Gabriel Moshenska's inquiries concern another Sid. That Sid whom one has to contact in building 9a of the Royal Air Force (RAF) supply base. In an operations manual that supplied technicians with advice on the manufacture or replacement of specific components of the Blackburn Buccaneer, that Sid is mentioned in a marginal note. He alone seems to have the necessary expert knowledge. The note in the instruction manual for a British fighter plane from the time of the Cold War is the starting point for Moshenska's interesting reflections on the concept of reverse engineering for archaeology.

Moshenska's principal goal is to investigate the relationships between reverse engineering and archaeology, with a primary focus on industrial and post-industrial societies. But he also asks how archaeologists deal with technical artifacts. Sid stands both in reality and figuratively for the practical knowledge of human actors in seemingly de-humanized industrial and post-industrial societies. However, especially for the analysis of tools and equipment, techniques and technologies, all central themes of an archaeology of the 20th and 21st centuries, it is important not to restrict oneself to technical or ergonomic processes. Standardized production chains, from the food processor to the iPhone to airplanes, are a feature of capitalist and industrial modes of production. But even in times of production 4.0, human beings do not always submit to technology like blind watchmakers. This leads Moshenska to a brief discussion of modernity and supermodernity in connection with de-industrialization.

But what is reverse engineering? In a narrow sense it is what is called in German Nachkonstruktion, a process to "extract the construction elements from an existing, installed system or a mostly industrially manufactured product by examining its structures, conditions and behaviors."[3] Etymologically the phrase "reverse engineering" betrays its origin in the engineering sciences. It was initially developed in mechanical engineering, with reference to the analysis of mechanical, but increasingly also electrical or electronic systems. Reverse engineering is widespread in information technology, where it goes beyond hardware to deal with the reconstruction of software (source code). Finally, reverse engineering was and still is used in the life sciences. The keywords here are genetic engineering, drug development, or the large-scale project of reverse engineering the human brain, for which Microsoft co-founder Paul Allen has made hundreds of millions of dollars available since 2003.[4]

1 http://www.unite4heritage.org/index.php

2 http://www.cosmopolitan.de/geniales-verstecktes-apple-feature-siri-erklaert-euch-mit-dem-kruemelmonster-was-0-geteilt-durch-0

3 https://de.wikipedia.org/wiki/Reverse_Engineering

4 http://www.engineeringchallenges.org/challenges/9109.aspx

Reverse engineering first proceeded by dismantling and accurately documenting operations and components, but it was increasingly extended by means of non-invasive or non-mechanical methods. Moshenska uses the terms "black box" and "white box," which ultimately originate from software engineering. Beyond the use of reverse engineering in engineering, information and life sciences, it is now also found in other fields such as in management or economics (e.g., Gelain et al. 2015). To use it for archaeology, Moshenska draws on a definition from Eilam (2005, 3), according to whom reverse engineering concerns all human-made things. This is certainly debatable. It should be noted that Eilam primarily treats software engineering and the Microsoft Windows systems (the definition is taken from his introduction), similar to Messler (2014), whose concept Moshenska also cites. Messler, too, uses a very broad concept that increases its comparability but is still in my view completely dominated by engineering sciences.

It would have been preferable to follow the development of reverse engineering in media and cultural studies (Friesinger / Herwig 2014) where it shows up – among other things – as a concept for a democratic, digital knowledge society in which each person has access to information and may change it as desired (Fugléwicz-Bren 2014). "When we practice 'reverse engineering', we do not want to destroy technology as the Luddites did ... We want to make it democratic and therefore deconstruct its capitalist ideology of exclusion and exploitation that has found entrance into its blueprints and a concise articulation in the encasings" (Schneider / Friesinger 2014, 14).

At the core reverse engineering remains a product of the industrial sphere. It outlines techniques and methods of exploration. Products from competitors are broken down into their individual parts and checked in functional terms against a company's objectives, information about the technologies used and competitors' capabilities. In certain circumstances findings are gathered for research and development. Reverse engineering can thus be part of so-called enterprise engineering, and it is tied to economic and social configurations which are not discussed further by Moshenska. This is a pity, because this principally concerns post-industrial societies. Moshenska's approach illustrates a common dilemma in archaeology when it comes to the adoption of notions from other disciplines. I would have liked to see a more critical analysis. Before the term reverse engineering is introduced into archaeology as a productive concept, its origins and mechanisms of its transfer among other scholarly disciplines should be examined more closely.

Moshenska's sections "Archaeology as reverse engineering" and "Reverse engineering as archaeology" deal with the concrete application of the concept. This is not entirely new, as Urban (2010, 210ff.) already mobilizeed it several years ago for the analysis of social and material relations. The analysis of processing and manufacturing technologies, but also of use, in the form of chaînes opératoires, ergological analysis, experimental archeology or in the sense of Bruno Latour's actor-network approach, is a central and established concern of archaeology. The examples given below are only convincing at first glance. The works of Thomas Joseph Pettigrew (1791-1865), who became known as "Mummy Pettigrew," stand at the transition from pre-modern to modern times. The surgeon and antiquarian was known among other things because he unrolled mummies primarily in the context of private events and did post-mortems for the entertainment of his guests. The knowledge thereby acquired, which perhaps because of the unrolling of a mummy can be referred to as reverse engineering, did not only lead to a deeper understanding of the techniques of embalming. It also enabled him to mummify his patron, the Duke of Hamilton, following his death in 1852. The Antikythera mechanism, a device comparable to the later astronomical clock from the second century BCE, of which 82 fragments remain, fascinates not only because of its complexity. Since it is incomplete and no longer functional, it continues to pose a scientific challenge. At the provisional end of the chain of reconstruction attempts is the "Antikythera Mechanism Research Project" initiated in 2002.[5] T. Freeth and A. Jones (2012) recently virtualized the device. A final example is the archaeometric analyses of finds from Oberstockstall, an early modern alchemist laboratory in Lower Austria. Trying to fathom the formulations of the alchemist there and to reconcile them with modern inorganic chemistry revealed little of his secret knowledge. It showed - and this gives the case a double meaning - that the "chemist" in Oberstockstall, as an obedient servant of his master, carried out goal-oriented analyses in the interest of the early modern mining industry that went above and beyond his transmutation chemistry (Sokup 2007).

These examples all stem from ancient times, the early modern period, and the transition to the modern age. The attempts to reconstruct appearances and functions (Antikythera), formulations and methods (Oberstockstall, Pettigrew) succeeded in the 20th and 21st centuries. They demonstrate vividly how knowledge about the past can be

5 http://www.antikythera-mechanism.gr/

obtained with new techniques and methods. At the same time, the study of artifacts from the past stimulates the development of an archaeological analytic. Even if reverse engineering is understood as more than a technique or method, i.e. if it is seen as a complex approach, I do not see its surplus value over established methods of reconstructing processes and procedures. Furthermore, it would be helpful to clarify terms such as “reconstruction” with respect to reverse engineering.

It also strikes me that Moshenska bases his ideas exclusively on artifacts. This is understandable. However, it would have been interesting to consider the archaeological formation process as a whole, or at least parts of it, from the perspective of reverse engineering. New insights could be extracted from the reconstruction of stratigraphic sequences. In my opinion it would have been important to present concrete applications of reverse engineering in an archaeological context and thereby enter into the discussions on super- or hyper-modernity. One could ask how the 3D digitizing of archaeological objects, the processing of these data for a surface description, and the use of this description could be employed for computer-aided production (CAD; CAM) of duplicates, replicates and restored objects. That could be a starting point to develop a discourse that goes beyond the technical aspects to touch on content: the question of the authenticity of an object in the age of virtualization. Work of the Römisch-Germanisches Zentralmuseum (Mainz) or the #Unite4Heritage initiative of UNESCO are both efforts to make virtual copies of potentially endangered cultural objects using laser scanning.[6] What constitutes the authenticity of the past, and how is it represented in post-industrial societies?

Given the postulated elective affinity of reverse engineering and archaeology (or certain archaeological techniques and methods), it is logical to ask whether reverse engineering can be considered to be archaeology. When we talk about “software archaeology” in the case of reconstructions of source code or of “technoarchaeology” in the “lunar orbiter recovery project,” this indicates to me primarily a metaphorical use of the term archaeology. The lost, buried or unknown is excavated, rediscovered, and snatched from the past - terms that have not only been connected but also represent dealings with the past since the beginning of archaeology. It is in this sense that Michel Foucault spoke already in 1969 of l’archéologie du savoir. And exactly here, it seems to me, lies the problem: reverse engineering remains at its core an engineering concept. When it comes to the human factor, the implicit knowledge of human actors, recourse to the sociology of knowledge would perhaps be more useful.

With the remarks on the archaeology of a nuclear bomber, the Avro Vulcan, Moshenska returns to where he began. The Avro Vulcan was developed in the 1950s. The last models were decommissioned in 1984. The fighter jet is an early example of the stealth technology, a delta-wing aircraft that was hard for enemy radar to identify. A kind of rapid prototyping played a role in its development, something that Moshenska does not address. The company Avro initially built three machines at a scale of 1: 3 to test the until-then unexplored aerodynamic characteristics. To return to capitalism and war: the Avro Vulcan bomber had ejection seats only for the two pilots, while the rest of the crew was on its own in case of a crash.

Like other major military projects, the completion of the Avro Vulcan was repeatedly subject to change which also arose from its deployment. Major military development projects, for example, of planes are often distinguished - for whatever reasons - by an increased susceptibility to error. Production numbers are limited when compared to civilian mass production. I agree with Moshenska that this does not make it easy to imagine the specimens as a “type” or to restore them.

Moshenska rightly raises the question of whether we are dealing with an “archaeological artifact or an archaeological site” when considering decommissioned, restored and partially reconstructed complex objects. In doing so he steps into an exciting field that is of relevance well beyond the archaeology of the 20th and 21st centuries. However, in my opinion, it has little to do with the question of reverse engineering: problems of preservation of large and complex objects is a different topic. It should also be mentioned that the Avro XH558 was revived for the first time at an air show in 2007 with a former crew member on board who had taken part in the “Black Buck” mission in the Falkland Islands in 1982. For the purposes of archaeological reverse engineering, it would have been interesting to know who was involved in the restoration and partial reconstruction, how these procedures were conducted, and what the relationship was between tacit, traditional, and other knowledge formats.

In sum, Moshenska engages more or less directly with one of the major themes of the late 20th and especially

6 http://www.unite4heritage.org/index.php

of the 21st century deindustrialization. These processes of social and economic change constitute a reversal of industrialization and are triggered mainly by transformations in the industrial sector itself. Deindustrialization has also found its way into archaeology, and it is for Moshenska the starting point for reflections on notions such as modernity and supermodernity. He sets the archaeological discourse on “modernity” and “late modernity,” initiated by R. Harrison and J. Schofield, in contrast to the postcolonial approach of González-Ruibal. I do not want to dwell on the pros and cons, but rather point out that modernity, as a construct of the western or capitalist-industrial world, underwent a critical revision in the cultural and social sciences long before its introduction into archaeological discourse – I mention as keywords hybridity and transculturation. But also the concepts of super- and hypermodernity, which literary critics such as Terry Eagleton or the philosopher Gilles Lipovetsky introduced, are not sharply distinguished from each other and are hotly debated within the relevant disciplines.

Finally, Moshenska engages critically with the concept of “non-places,” developed by the French anthropologist Marc Augé. The idea of non-places has not been taken over without criticism in cultural studies, because transit spaces as “non-places” are characterized by a variety of interactions. An important task would be to link the concept of “non-places” to those “lost places” that arise as physical or social spaces from de-industrialization. Interesting and creative as these ideas of Moshenska’s are, the reference to reverse-engineering remains unclear.

Is the knowledge of a Sid aka Cookie Monster aka Siri intuitive or something that cannot be verbalized? Is it impossible to formalize it? Is it bound to experience? What - as Moshenska rightly asks - does this mean for archaeological work? I follow his argument that the reconstruction of technical equipment or processes in particular and the past in general is dependent on actors with implicit rather than formal-rational knowledge. But I wonder if from a cultural studies perspective this is not tantamount to preaching to the choir. Instead of the reverse engineering concept, which in its narrow sense does not seem to me to be applicable to archaeology and in a broad understanding remains too vague, it would have been better to work with approaches from Science and Technology Studies or the sociology of knowledge. They offer implicit access via the investigation of everyday interactions between science, technology and social order. If reverse engineering is understood as a concept that goes beyond a purely engineering application to include the reproduction of knowledge, the engagement with this notion should be at this broader level, showing us that Sid is an independent actor whose options and logic of action are at the same time integrated in larger structures.

Comment on Gabriel Moshenska: Reverse engineering and the archaeology of the modern world

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Comment on Gabriel Moshenska: Reverse engineering and the archaeology of the modern world

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Gabriel Moshenska sets out an argument for the utility of applying the theories and practices of "reverse engineering" to archaeological work. Reverse engineering involves taking objects apart in order to understand the design processes that were in play to create the object. Within contemporary industrial production reverse engineering allows product replication. When a product comes to market, competitors can reverse engineer it in order to design their own versions. It is, therefore, a key practice of market competition. In this article Moshenska is interested in the ways in which reverse engineering might reveal some of the human and more-than-human messiness of these processes, in the never-smooth tacit knowledges at play. His contention is that similarities in the aims, methods and intended outcomes of archaeology and reverse engineering make it a productive space in which to work with and understand, in particular, modern technological artefacts.

It is always useful for disciplines to open up new avenues in which to think otherwise about their questions and materials. Archaeology has been the focus of multiple minor conceptual thefts across the arts and humanities that either marginalize archaeology as "mere" digging or hijack its material practices altogether in the mapping of genealogies. Moshenska seeks to work through other possibilities for archaeology, and he frames familiar examples from Science and Technology Studies (STS) in terms of re-introducing the agency of specific, individual humans to moribund stories of techno-scientific modernity. Specifically, Moshenska echoes the focus of STS scholarship when he argues for the utility of approaching archaeological analysis through reverse engineering, arguing that such an approach reveals 'the specific and frequently idiosyncratic mechanisms through which the technologies of modern society operate' (p. 18).

Moshenska points towards Lucy Suchman's pioneering work that emerged out of her long career at Xerox in California. In *Plans and Situated Actions: The Problem of Human-machine Communication* (1987), Suchman detailed the entangled relationships between humans and other-than-humans in her case study analysis of the design and installation of a large, interactive photocopier. Suchman contests the planning model of action and design to argue that plans are "formulations of antecedent conditions and consequences of action, which account for action in a plausible way" (1987: 4). However, Suchman critiques the underlying logic of reverse engineering as she suggests that "plans systematically ignore the necessary *ad hocness* of situated action in favour of an account of the action as in accord with the plan" (4). While he concludes his paper on a more optimistic note, Moshenska himself raises doubts early on about the abilities of reverse engineering to illuminate the *ad hoc* and situated action of people in production processes (p. 17).

While I had not before considered contemporary industrial archaeology in the specific context of reverse engineering, and while I can recognize its potential as method, I was left with several questions as I read Moshenska's discussion. If the application of reverse engineering is to reconstruct production processes and to explore the connections between humans and other-than-humans in those processes, then I am unsure why this is best applied to "modern technological artefacts such as vehicles, computers and industrial machinery" (p. 17). If no corner of the contemporary landscape, from Blackfriars Bridge in London to the Cowley Business Park in Oxford (Penrose 2010) to the remotest forests of northern British Columbia, is untouched by industrialization and deindustrialization, why restrict reverse engineering only to artefacts such as vehicles, computers and industrial machinery? Moreover, with the tantalizingly brief question in the section on the Avro Vulcan as to whether artefacts might be considered sites, might reverse engineering itself not be extended to consider the interpolation of these modern technologies and their associated sites to question where and how the boundaries between the two are enacted?

If, as Moshenska argues, reverse engineering's focus on "re-constructing the function of obsolete technology or technologies for which the documentation has been lost…describes the entire archaeological record" (p. 19), then is he simply arguing for it to be adopted as method for all archaeologies of the contemporary world? As Penrose argues in her paper on Cowley, " archaeological memory becomes a methodology for materialising; for materialising that which escapes us" (ibid: 176). Reverse engineering as an archaeological memory practice holds the potential to do this, certainly. Yet, do we run the danger of having to all be reverse engineers now (*pace* Holtorf 2015)? Or were we always already, in which case the distinction between archaeology and reverse engineering is dubious from the outset? Moshenska attempts to address how we might distinguish archaeology from reverse engineering by aligning archaeology with the pursuit of knowledge for its own sake whereas reverse engineering is more directly economic (p. 21). I suggest that this might not be the clear distinction that it appears to be. In his later critique of archaeology's use of Marc Augé's concept of the non-place, Moshenska rightly points to the ways in which the abstraction neglects the real experiences of the people who work, travel through and occupy such spaces. Similarly, developer-funded archaeology, archaeological work carried out in museums and heritage contexts and archaeological teaching to fee-paying students connect archaeological practices directly to economic activity. This would seem to apply equally to prehistoric archaeology and the archaeology of deindustrialization.

There are other considerations that might cause the reader to hesitate around the application of reverse engineering to archaeology as a conceptually productive framing. Where the situated action model developed by Lucy Suchman shines a light on how people and machines interact in the processes of planning and use, understanding objects (whether as artefacts or as sites) through their dismantling potentially produces an overly linear history. This has been one of the critiques of media archaeology, a field that could also be framed in terms of reverse engineering (see papers in the *Journal of Contemporary Archaeology*, 2015 Vol 2.1). Media archaeology lab practices are seen to move away from an artefactual focus to explore operationality as a performance-based epistemology that attempts "to open up ways of knowing the world from a technological perspective" (Parikka 2015: 11). In both media archaeology and reverse engineering, the focus on dismantling as a form of revelation sediments the idea that we must return to the point of original production in order to understand subsequent operation.

However, on balance, the crux of Moshenska's argument is that the processes of reverse engineering offer the potential for archaeologists to work on (post)industrial sites and artefacts without rushing either to the romance of ruin and loss or to a celebratory modernism. In the absence of the ethnographic eye observing the production process, reverse engineering attempts to access industrialization's ad hoc, messy human-to-human and human-to-other-than-human relationships. Moshenska's conclusion that it is at "the point in a process of reverse engineering where our reconstruction stumbles or fails…where we might infer human agency or tacit knowledge" (p. 25) and assertion that reverse engineering attempts to breathe the human back into technological artefacts and processes clearly articulate the value of this exercise in imagination. It is here that Moshenska's arguments appear to echo Louis Althusser's aleatory materialism:

> *Every encounter is aleatory in its effects, in that nothing in the elements of the encounter prefigures, before the actual encounter, the contours and determinations of the being that will emerge from it […] No determination of these elements can be assigned, except by working backwards from the result to its becoming, it is retroaction (Althusser 2006: 193).*

Here, Althusser's materialism and, by extension, Moshenska's reverse engineering, might suggest Walter Benjamin's take on Paul Klee's Angelus Novus in "Theses on the Philosophy of History" (1968 [1937]). Because every encounter in the here-and-now produces random effects, sense-making can only happen in reverse. Yet, with each passing moment that sense-making is reshaped. With reverse engineering, the contours and determination of the being of artefacts is similarly subject to unforeseen losses, breakages, bodged repairs, and so much depends on at which point the process of reversal begins.

Reverse engineering, with its focus on practice and on imaginative rear projection, is also very close in spirit to reenactment. Moshenska refers in passing to experimental archaeology techniques and how these relate to reverse engineering. These points of connection are interesting and warrant further conversation, particularly as they intersect with his opposing of knowledge-for-knowledge's-sake and knowledge that is directly economically framed. As historian Vanessa Agnew suggests, reenactment is a "body-based discourse in which the past is reanimated through physical and psychological experience" (2004: 330). Reenactment, from the pioneering kitchen to the

Avro Vulcan, involves the reverse engineering of technologies and then their reanimation through experience and operation. It is also a field in which both knowledge for knowledge's sake and the economic pertain.

Moshenska's paper, particularly the concluding section, offers much to those of us with interests in the archaeology of the contemporary world. After several readings, I remain intrigued by the conceptual and methodological work that the term 'reverse engineering' can do for archaeologists. What might referring to my fieldwork as reverse engineering do for the research that simply referring to it as archaeology might not? Does it more concretely link archaeological interests in industry and technology to the design and manufacturing sectors that produce the things we look at? Does reverse engineering produce new ways of understanding human and other-than-human relationships? Moshenska ends in an admirably humble style, suggesting to his reader in the final sentence that all of this has been offered as food for thought, an opening into a much longer conversation. I very much look forward to hearing more.

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Reverse engineering and the archaeology of the modern world: Response to comments

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Reverse engineering and the archaeology of the modern world: Response to comments

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It is a humbling experience to reach the limits of one's scholarly imagination, as was the case with my opening paper, which I fiddled about with and revised for more than five years with valuable input from friends. To solicit formal responses from respected colleagues seemed the optimal way to carry the concept of archaeological reverse engineering further in new and interesting directions, and to correct errors that I might have introduced. I am extremely grateful to the authors of the responses and to the editors.

One of the most valuable critiques of my paper was that it was insufficiently archaeological, as Piccini asked, 'why restrict reverse engineering only to artefacts'? This point is also noted by Edgeworth and Müller who raise the possibility of reverse engineering archaeological site formation processes and the layering of strata in a landscape. Edgeworth suggests that reverse engineering could and perhaps should move swiftly beyond industrial-age or technological artefacts – ditching the methodological training wheels – to become a form of archaeological reasoning. My first, last and main hope for archaeological reverse engineering is that it might serve as a thinking-tool, a sandbox for exploring archaeological reasoning and praxis: this was taken up by several of the respondents, and by Piccini in particular, who links reverse engineering and experimental archaeology to the more playful world of re-enactment. The concept of re-enactment and its inherent performativity offer another viewpoint on reverse engineering, linking reasoning with action in the process of tinkering with things, turning them in one's hands, fiddling about, taking apart and reassembling. Re-enactment is a fiddling about with entire material assemblages, sites, buildings and landscapes: a window on to reverse engineering beyond the industrial artefact.

Several of the responses push the model of reverse engineering where I was perhaps too timid: out of the factory gate and into capitalist society as a more wide-ranging socio-economic critique, as Dawdy says, "from 'how things work' to 'how society works'". Here I am particularly interested in Müller's notion of archaeological reverse engineering (in its digital forms at least) as a mode of activism: a blending of anti-capitalism and hacker culture, demanding a democratisation of technology. I don't own an iPhone, the foremost symbol of modern technology as Müller notes, but two recent news stories touch on some of the practical, ethical and commercial complexities of reverse engineering. In one, Apple created a software update that 'bricked' any iPhone that had been opened or repaired by a non-Apple technician (Brignall 2016). In the other, Apple is fighting the U.S. government through the courts against an order that they decrypt a secured iPhone belonging to a dead terrorist (McLaughlin 2016). Protecting against reverse engineering is good security and good business. In iPhone archaeology a democratizing approach to reverse engineering might involve 'jailbreaking' or 'rooting' the phone, opening it up to non-approved software and hardware additions, based on the idea that a phone you can't hack isn't truly yours. Archaeological hacking would add an ideological layer to reverse engineering: from understanding to openness as the basis of freedom and participatory democracy. Or we might reverse engineer Pandora's box and end up by opening it by accident. Either way, the historical archaeology of the iPhone will be a story worth telling one day.

Some of the harsher and most valuable critiques concern my criticisms of notions of modernity in the archaeology of the modern world. Both Dawdy and Müller note the over-simplicity of my models of modernity: Müller suggests rightly that there are far subtler conceptualisations outside of archaeology. This slightly misses the point, which is that the concept is treated simplistically within contemporary archaeology, but I pulled my punches, and what Dawdy noted as a straw-man is also the ghost of an *ad hominem*. Certainly this was one of the least well developed, unsubtle and grouchiest elements of my original paper.

Dawdy explores the organisation of technology and the notion that machines can ‘enslave’ their attendants, drawing a line from the mills at the birth of the Industrial Revolution through twentieth-century Fordism to Fritz Lang’s “Metropolis,” and sending me scurrying back to Marx’s *Capital* to explore instruments of labour. The machines and assembly lines that wove human labour and technology so tightly together were expressions and drivers of new social relationships, and Dawdy uses the passive voice: “workers are deskilled” and their needs “subsumed to those of the machine” – but by whom? The view of the factory as dehumanised is the view from the head office: everything looks cleaner and simpler from a distance. I would slightly dispute Dawdy’s suggestion that handmade technologies involve a qualitatively different human relation to the machinery of mass-production: my point is that all technologies, down to the microchips that Finn discusses, manifest quirks and oddities in their operation that become part of their attendants’ tacit knowledge of their job, which is never as straightforwardly deskilled as it might appear. But Dawdy’s principal point holds true: that an archaeology as reverse engineering could generate a more detailed and nuanced understanding of the ‘species’ of technology and the human-machine relations that they embody.

One of my enduring concerns in archaeology is the idea of outlining the unknowable: tracing the edges of darkness where the incompleteness of the record and the limits of our techniques force us to stop (or ought to). This theme of gaps – such as the inferred but unknowable human dimensions of technology – is taken up by Finn, who points out the ways in which archaeologists have filled material absences. Here perhaps is the chasm between reverse engineering the Antikythera mechanism on the one hand and the modern microchip on the other: in archaeology we are far more often reasoning backward from an incomplete material trace, an archive or object full of gaps. If archaeology is the art of reverse engineering from an incomplete artefact, we can perhaps revisit Piccini’s criticism that it could produce ‘an overly linear history’. Certainly the *chaîne opératoire* seems to imply linearity, but as Edgeworth points out, in archaeology we rarely deal with a straightforward human-material relation: “There are biological and geomorphological forces to take into account too, and the physical traces of these are intermeshed with those of human forces in complicated ways that are hard to disentangle.” In summary, archaeological reverse engineering is amongst other things:

- A disentangling of fragments and layers, embracing non-linearity
- A process of human-material interaction, embracing play, performance and embodied reasoning
- A study of parts as well as wholes, embracing absences and gaps

Once again my deepest gratitude to the respondents and I look forward to future developments around the idea of reverse engineering in, as and of archaeology.

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