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Reverse engineering and the archaeology of the modern world

Gabriel Moshenska

UCL Institute of Archaeology

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).

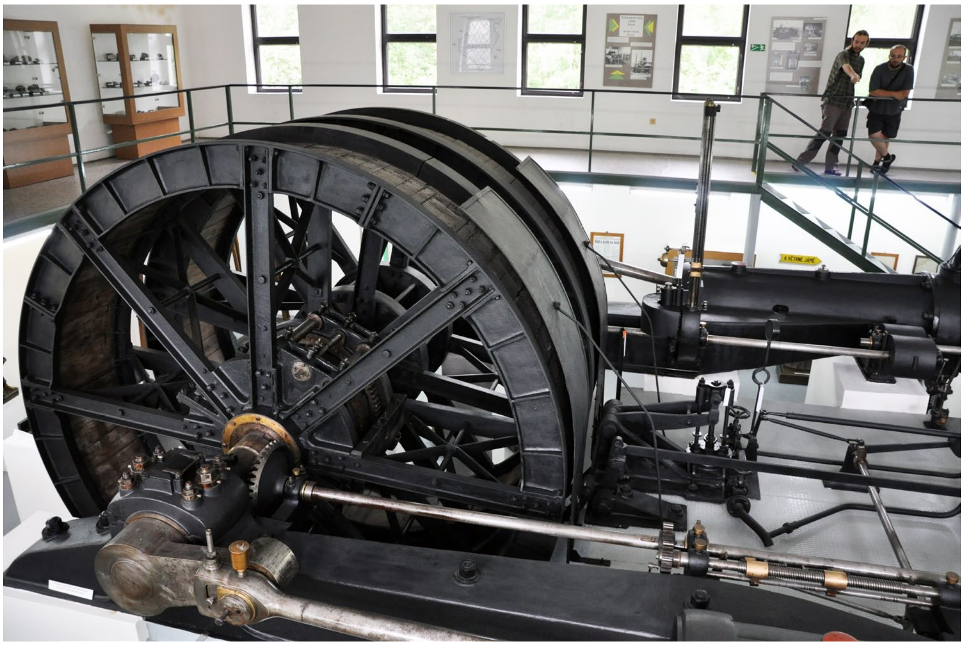

Figure 4: Industrial heritage in a mining museum, clean and out of place by Ben Skála (source: Wikimedia Commons).

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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