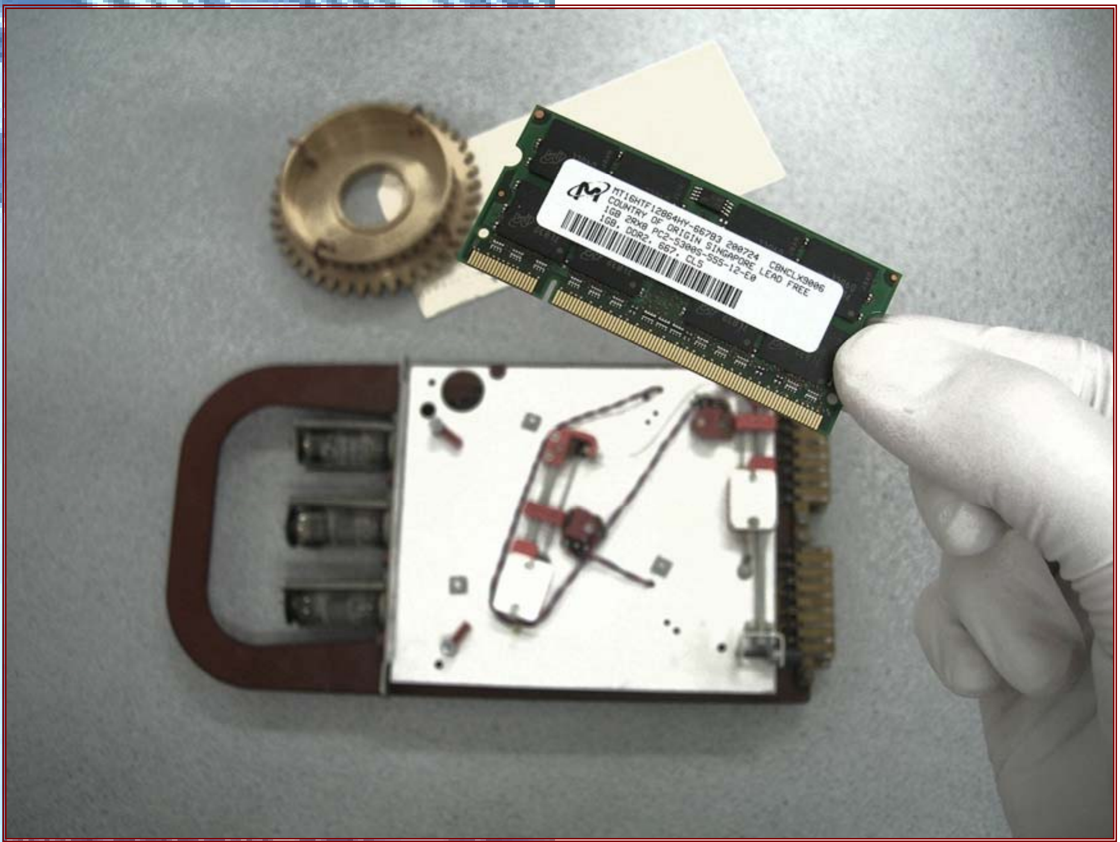
# An Archaeology of Computers:

## Material culture studies of the 19th and 20th century computing in the Science Museum, London



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A dissertation submitted to the University of Bristol in accordance with the requirements of the degree of MA in Historical Archaeology of the Modern World (1500-2000AD)

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**Word Count:14,014**

Cover:

Memory unit from the author’s laptop (Macbook, 2006) in front of delay-line memory unit (Ferranti-Pegasus), punched-card for Powers-Samas tabulating systems and cogwheel (gear) from the reproduction of Babbage’s Difference Engine No. 2. Photo by the author.

**Abstract**

This study examines computing material culture, as it was developed from the 19th century, onwards. A series of case studies on selected computing artefacts from the computing collection of the Science Museum in London, is creating the argument on the demonstration agenda that it is followed from technological museums, in preserving contemporary electronic artefacts.

The essay continues in the identification of social meanings that computing artefacts can hold in the opposition of an approach based on technological progression. The historic background of each artefact and the lives or their inventors are being examined for an interpretation which aims to be multi-dimensional and not always technology-oriented.

Other aspects such as the enchanting qualities created by the performance of obsolete technology contribute to a dialogue on the function and relative value of computing artefacts and the impacts of those aspects on computing devices that have become museum exhibits.

The notion of the authenticity of computing artefacts is also subject of discussion, as some of them that are subjects of this research, are reproductions, or placed in an artificial "authentic" environment.

All these topics raise the emergence of historical archaeology as part of the demonstrative agenda of the technological collections, in preserving human-oriented meanings of computers and a more critical approach to technology.

*Keywords*

Computers, Archaeology, Material Culture, Enchantment, Authenticity, Commodity Fetishism, Surveillance, Technological Museums

**Acknowledgements**

When I decided to make a research on computing material culture, I have never imagined how challenging the project would be. On the other hand, the opportunity to work as a member of the Conservation team of the Science Museum in London, made me able to access every possible museum resource and exhibits, in order to pursue this thesis. However, without the valuable support from all the colleagues of the Conservation and Curatorial department, this essay might never be completed. I would like to express my gratitude to Hazel Newey, Jannicke Langfeldt, Ian Miles, Richard Horton, Derek Brain, Rob Skitmore from the Science Museum, James Dixon from the University of Bristol and Dr. David Robinson, my academic tutor in this dissertation.

**Author's Declaration**

I declare that the work in this dissertation was carried out in accordance with the Regulations of the University of Bristol. The work is original except where indicated By special reference in the text and no part of the dissertation has been submitted for any other degree.
Any views expressed in the dissertation are those of the author and in no way represent those of the University of Bristol.
The dissertation has not been presented to any other University for examination either in the united kingdom or overseas.

SIGNED: DATE: 23/10/07

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## Introduction

Computing material culture constitutes an exciting and challenging category of contemporary artefacts. Computers find their way to museums after changing function several times, from scientific tools to collector's items and memorabilia. Being complex electronic devices, they are considered as research subjects for curators with specialisation in computing history than historical archaeologists or scholars of contemporary material culture.

This essay focuses on the examination of selected key-artefacts of one of the most important and detailed British computing collections, accommodated in the galleries of the Science Museum in London. The aim is to identify the museum's approach on demonstrating computers to the public and the possible meanings that these artefacts can evoke to the visitors of the museum.

Having as a starting point that the demonstration agenda does not contain historical archaeological principles, the analysis of the artefacts will focus to alternative and mainly social approaches instead of an emphasis to their technological specifications or capabilities.

The main advantage of this research is the author's ability of a close examination of the museum's computing artefacts, in a "behind the scenes" level. Being employed as a working objects conservator from the Science Museum, there was an opportunity of a hands-on approach to the artefacts, which can provide an effective evaluation of their demonstrative potential. In other words, this research is a theoretical approach supported in its material analysis with some gallery "fieldwork".

The fact that the research was undertaken in a public place that attracts large numbers of visitors everyday, cannot be ignored. After all, the selection of the computing artefacts for the case studies that they constitute this thesis was based on the public interaction and involvement with the displayed objects. The examined artefacts were chosen in terms of their visibility inside the gallery, the way the visitors experience them and their contribution to the computing technological progression, trying at the same time not to emphasize on the latter.

In terms of specifications, it would be difficult for an archaeologist to cover the wide technological background of a computing curator. Instead, it was decided to focus on the little things, such as personal accounts or incidents in the lives of the inventors of the computers that would justify the existence of specific social characteristics in the artefacts.

*Overview*

The research structure covers the history of computing from the early 19$^{th}$ century to the late 20$^{th}$ through a series of five case studies. In order to create an effective chronological sequence, five objects or categories of computing devices were selected, each one corresponding to a unique historical period.

The early19$^{th}$ century computing is examined through Charles Babbage's collection of artefacts consisted of portions and fractions of his original calculating devices, as well as enormous reproductions of his Difference Engine No 2. This case study attempts to challenge the general assumption of Charles Babbage being the early computer pioneer and to examine the reasons of his failure to complete any of his engines. The second part of the study aims to identify the possible meanings that the contemporary replica of Babbage's Engine can provide, along with an argument of the replica's contribution to a better understanding of 19$^{th}$ century's computing, or the technological potential of the Victorian period. The enchanting qualities of the operation of the Difference Engine when it operates in public is compared to a similar demonstration that used to happen from Babbage himself with a demonstrative trial of his engine. This comparison provides the ideological bedrock of the re-enchantment of technology and how it affects the public appreciation of computer artefacts.

The next case study is about the tabulation technology from the late 19$^{th}$ century until the first half of the 20$^{th}$ century. The authorities' financial support as the decisive factor to the computing development is being researched in the opposition to the individual contribution in computing. An archaeological research inside a diorama presentation of a punched-card office will argue on the importance of the presence of the human activity when displaying computing artefacts, while the potential of social meanings is being developed through a counter comparison of the demonstration of similar material culture in the Holocaust Museum in Washington DC.

Before proceeding to the next case study, a brief throwback of the rapid development of computer during the World Wars of the 20$^{th}$ century provides the necessary account of the dramatic acceleration of the computer technology as it took place during the war period, creating the essential link between mechanical digital computating.

Concerning the computing technology of the post-war period, the Science Museum holds the oldest operational computer in the world and there the third case study is dedicated to this artefact (Ferranti-Pegasus) and the computing background of the period. The Marxist theory of use-value and exchange value remonstrates the display pattern of demonstrating computing artefacts as commercial products. Other possible approaches are based on the fact that Pegasus is still part of the living memory as well as a functional machine, which still performs in public.

The computer gallery of the Science Museum accommodates artefacts that follow a historical timeline until the introduction of the integrated circuit in the early 1960's. Nevertheless, more recent computing artefacts can be found on display in the "Making the Modern World" gallery, along with some distant 19th century computing ancestors. There, a Cray 1A supercomputer is the focus of the fourth case study that emphasises to the ingenuity of its inventor and how his personal fears for a nuclear destruction became an inspiration on creating the fastest computer of the period. An important aspect of computer technology, the contribution of aesthetics and elegance in creating effective technology is also part of the same study.

The final case study is an approach on the cultural phenomenon of the personal computer. The computing artefacts of the "Everyday Life 1968-2000" gallery draw up the guidelines of the fortuitous identity of personal computers and the utopian rhetoric that was adopted for their marketing promotion. The analysis on the aesthetics of computers continues in this study with the suggestion that the established patriarchal model in computing resulted to the marketing failure of elegant computing devices. Also, the dangers from selective demonstration dictated from commodity fetishism that can result to misleading appreciations of contemporary artefacts.

**Literature Review**

Many historians have made thorough research on the computing development in the last two centuries. Computers are usually the subject of historians and museum curators of technology. Their research provides an effective account, even if sometimes is difficult to follow, as many specifications and operation principles are being demonstrated as parts of their analysis. Concerning contemporary computing, Campbell highlights that historians are still reluctant to write a full account of computer development of the past three or four decades because of the general applied principle to avoid writing recent events that might lack a proper perspective (2004:207).

However, many other researchers, mainly from non-academic fields (usually journalists of technology), have published various books based on contemporary computing devices. Their approach differs than that of a computing historian. For example, Levy’s research on the Macintosh computer or the iPod is written in non-academic language, trying to emphasise to the devices’ impacts on people’s life instead their technical specifications.

The social analogies of computing have been also been part of studies published in a variety of design or scientific journals (Cox, 1998; Punt, 1998).

The anthropological approach on modern technology has created a vital and constantly growing literature. Researches based on the re-enchantment of Science, the computer non-revolution, the cultural and the social meanings of computers are creating a detailed account in human-computer co-existence. It is worth to highlight that the social studies of computing are based on the virtual landscape (cyberspace) and generally on the digital concept of computers. Thus, interesting approaches on virtual material culture have already been written by anthropologists (Hall, 1999; McGee in Pearce, 1997).

However, few resources have been found in terms of computer material culture with concern to the physical device, known as “hardware”. Christine Finn’s book “Artifacts: an Archaeologist’s Year in Sillicon Valley” is probably one of the few studies in computing through an archaeological perspective. However, Finns research is based on observation of the rapid landscape transformation in Sillicon Valley, comparisons between ancient and modern recycling of ferrous materials and modern artistic appreciation of traditional archaeology. At the same time, there is an interesting study on the relative value of computers, as they are changing function from computation to “memorybilia”.

Nevertheless, this study had to stay focused on the materialistic nature of computers and the aesthetic and enchanting qualities of computing artefacts. Also, the definition of authenticity it is applied in computer restoration or replication. A selection of material culture literature based on studies on excavated historical artefacts, was used in similar terms to approach computing artefacts (Hodder, 1991; Brauner, 2000; Holtrof, 2005).

The curatorial research on computing artefacts could not be ignored. Many studies have been written emphasising in the preservation ethics of computing artefacts, the effective use of simulation and display policies in the museum environment (Finn, 1965; Swade and Keene, 1994).

Finally, social studies on modernity and enchantment were applied to this essay along with Jon Agar’s study on the bureaucratic character of modern computing (Lawrence, 1999; Agar, 2001; Bennett: 2001).

**Methodology**

The research strategy included the following objectives:

- Locating the key artefacts in the Science Museum’s galleries from observations based on the spatial allocation of the artefact, the popularity of the artefact and the way that is being promoted through the museum’s webpage.
- Research in the museum archives for any relevant information concerning the useful life of artefacts, their acquisition and conservation record, along with their operating manuals.
- Operation of the objects when possible, in an effort of understanding their functional principles and to make observations from the public response to their demonstration.
- Further research in the museum storages in order to locate non-displayed computing artefacts that they could be useful for an alternative interpretation in the computing gallery.
- Research of the available bibliography and computing history in order to create an accurate account of the historical importance of the selected

artefacts, their placement to the computing timeline in the opposition to their location in the museum galleries.

- Retrieving oral information from the museum's curators of computing and the volunteers from the Computer Conservation Society who are able to provide an invaluable account of the computing practice in the 1960's.
- Observation of the reproduction procedure of Babbage's Difference Engine No.2 and discussions with the engineer of the project (R. Horton) concerning the capabilities of the Victorian technology and the historical integrity of the project.

**The Babbage Difference Engine**

Many historians have credited Charles Babbage as the pioneer of modern computing (Hally, 1996:xiii). A dedicated exhibition in the Computing Gallery of the Science Museum accommodates his drawings, notes and other manuscripts, portions of his calculating engines along with a part of his brain.

A portion of his original unfinished Difference Engine is on display in the Making of the Modern World Gallery, strategically located near a weird but true ancestor of the mechanical punched-card tabulation technology: the Jacquard's Weaving loom, a machine capable to produce weaving patterns repeatedly. The pattern was fed to the machine using perforated cards, a system that was later adopted by Babbage himself, Herman Hollerith (for his tabulating machines) and many early computers, before the introduction of the magnetic tape memory[1] and other storage mediums.

*Charles Babbage: a computer pioneer*

Charles Babbage was born in London in 1791, the son of a well-established banker. He entered Trinity College Cambridge in 1810 to study mathematics and he worked as a mathematician in his twenties. Although he contributed in many fields from astronomy to political economy, his main achievements were the design of the Difference and the Analytical Engines. The idea of an automatic calculating engine was already known from the 17$^{th}$ century (Ifrah, 2001:121) when Babbage angrily remarked while proofreading a set of mathematical tables[2] prepared for astronomical

[1] See Appendix.
[2] See Appendix.

calculations, that he wished to God these calculations had been executed by steam (Bromley, 1990:62).

The idea that steam could not only replace manual labour, but also eliminate human fallibility can be considered as the expression of the general optimism for the potentials of the technology and industry in the early 19th century (Lawrence 1999). Babbage was positive that mathematical tables could be executed effectively using machines and he spent a lifetime trying to build one. However, he failed to complete the Difference Engine, mainly because of his harsh personality, his perfectionism and his ineffectiveness as a project manager, which caused dispute with his engineer, Joseph Clement (Campbell-Kelly et al. 2004:50, Hally, 2005:xvii).

The tombstone for the Difference Engine project was Babbage's distraction by a far more ambitious calculating machine, which he called the "Analytical Engine". Shortly after the hiatus of the Difference Engine in 1833, he started the design of the latter and he never resumed the first machine, although it was near completion. (Agar, 2001:20).

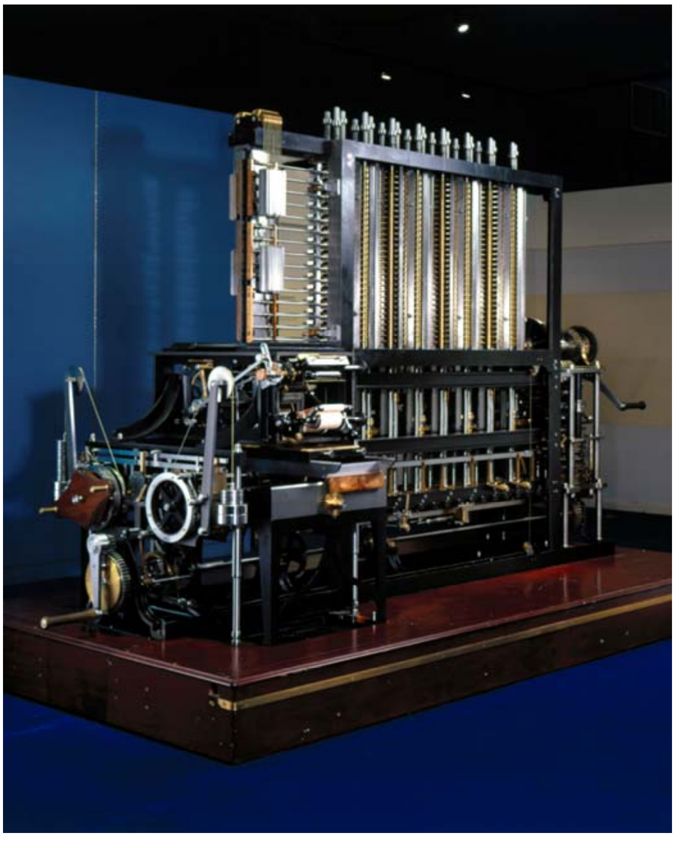

Fig. 01. Babbage's Difference Engine No.2.
Courtesy of the Science Museum of London.

*The Analytical Engine*

The concept of the Analytical Engine had followed the fundamental principles applied to modern computer development during the 20th century (Hally, 2005:253). Those principles were conceptualised for the first time by the British mathematician Alan Turing, in 1936. Turing introduced the theoretical concept of a calculating machine that could be programmed to compute every possible computation (Gelernter, 1998:46). Turing named this theoretical model Universal Machine. Babbage's invention was designed on a similar pattern:

The Analytical Engine would be equipped with a store unit, a kind of numerical memory for storing the results of the calculations and the arithmetic unit, in other words the processing software for executing the different calculations (id. at 191). In principle, the Analytical Engine can be considered as "the true ancestor of the present day computer" (Ifrah, 2001:189).

It seems yet unlikely that the Analytical Engine could ever be transformed from a theoretic concept to a functional machine. The kind of power to operate an engine like that, the undeveloped algorithms essential for programming and the depressing limitations of any form of mechanical memory to store programmable instructions, makes the creation of a pure mechanical computer a non-realistic task (id. at 195). Most importantly, the Analytical Engine served no purpose for anyone except its inventor (id. at 48).

*The construction of a contemporary Difference EngineNo.2*

A plethora of relics, bits and pieces from Babbage's inventions can be found in the Science Museum. However, the most breathtaking artefact of Babbage's Exhibition is a 20th century construction, an enormous functional replica of the Difference Engine No.2 which is on display next to another identical engine, still under construction by the museum's engineers. Nathan Myhrvold, a former Microsoft Chief Technology Officer, has funded almost the 2/3 of the project. The second replica will be part of his personal collection after a one-year display to the Computer History Museum in California (Finn: 2002:158).

Those replicas were the results of a six-year project on building a Difference Engine No.2 directly from Babbage's drawings. The first replica was completed on time for the celebration of the bicentennial year of its inventor's birth (1991). Doron Swade, the museum's curator of computing at the time, masterminded this exciting project.

The challenging construction of the five metric tons replica renewed the argument for the manufacturing potentials of the Victorian period.

*The Victorian Technology*

Before the construction of the Difference engine No.2, it was largely assumed that the main reasons for the failure of Babbage's inventions were the limitations of 19$^{th}$ century engineering (Hally, 2005: xvi, Swade, 2000:5). By the time that Babbage started to build his engine, there was no standardised metric system available for engineering. In order to achieve inter-changeability, a key to the successful construction of a machine with strict specifications and tolerance for thousands of identical parts, Babbage spent an astronomical amount for the period, much more that the available governmental support (Campbell et al, 2004:8). Even unfinished, the original Difference Engine was influential for the Victorian machine-tool industry. Joseph Whitworth, an employee of Clement's workshop developed a standardised thread system based on his experience from Babbage's project. (Bromley, 1990: 67)

*The Difference Engine No.2 as a museum exhibit*

Moving from the Difference Engine's historical background and approaching it as a museum exhibit, further argument can be developed. It seems that its inventor can be considered as a computing pioneer, not for the practical applications of his achievements but for the introduction of the fundamental principles in computing. Yet, those principles were captured when designing the Analytical Engine, which was the main reason that Babbage lost his interest for the Difference Engine.
The coordinators of the construction of the contemporary Difference Engine No.2 were well aware that they were building an enormous "number cruncher"[3] than a mechanical computer ancestor. Swade and Bromley had realised that a construction of an Analytical Engine would be an extremely difficult task, not only financially but also technically, as Babbage never designed the Analytical Engine as a defined entity. On the contrary, the Difference Engine No.2 was elegantly designed to avoid the imperfections of the Different Engine No.1 and it was well archived through a series of detailed drawings in the Science Museum's library. Thus, the successful

[3] See Appendix.

reconstruction would act as the materialisation of Babbage's general computing thought (Swade, 2000:224-5).

Although the project of the reconstruction of the Difference Engine No.2 resulted to the display of a non-genuine artefact in the Science Museum's computer gallery, it was beneficial in other ways.

First of all, it can be seen as the embodiment of Babbage's ingenuity. Apart from some minor alterations in the original drawings,[4] the finished complex machine works perfectly, as its inventor intended it to.

It also debunked the theory that Babbage's projects failed because of the engineering limitations of the Victorian Period. Although, Bromley had already reached this conclusion after comprehensive archival research and measurements of the original parts, the physical construction of the engine confirmed what the historical research suggested:

> "There seems no basis for the common belief that Babbage's machines could not have been made with the technology available in his day, though doubtless it would have been expensive" (Bromley, 1990:81).

This statement demonstrates the close relationship between economic principles and technological innovation, which led to criticism of the historical integrity of the project. Ifrah argues that building a contemporary replica served no purpose "unless …*the Difference Engine was…*a historical one, for the concept has since not only been put in action by mechanical…means, but also superseded by the Analytical computing offspring" (2001:197). Yet, even if the Difference Engine No.1 was a viable task within the capabilities of early 19$^{th}$ century engineering (Agar, 2001:20), it was more affordable for the government to hire an army of human computers[5] to do the calculations of the mathematical tables than to invest on a new machine (Campbell et al, 2004:51).

In opposition, Ifrah agrees that the theoretical model of the Analytical engine was based on the principles of modern computing (2001:197) while Swade and Bromley are more sceptical to the perception that Babbage's machines are directly related to modern computing.

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[4] Babbage's original drawings contain errors, which are believed to be a precaution against industrial espionage (Swade, 2000:237).

[5] See Appendix.

> “Babbage’s influence on modern computing may not be as strong as popular perception would have us believe” (Swade 2000:309).

Before them, Wilkes went even further implying that Babbage actually delayed computer evolution; his failure discouraged others from attempting building mechanical computers and made British government reluctant to support such efforts (according to Swade, 2000:310-3). Babbage’s failure might be the reason that the automatic calculating machinery, although feasible from 1914, became widespread decades later (Bromley, 1990: 97).

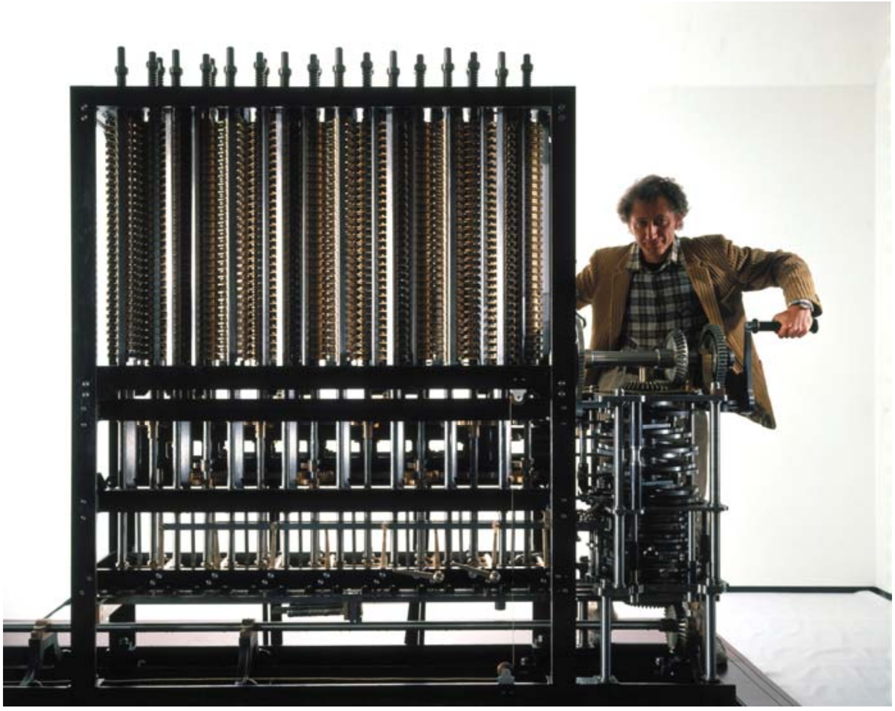

Fig. 02. Doron Swade operating Babbage’s Difference Engine No.2.
Courtesy of the Science Museum of London.

*Re-enchantment: now and then*

Another aspect of the demonstrative concept of the Difference Engine is the enchanting sensation that evokes to the public. Swade recalls the effects of the first demonstration of the finished engine when five hundred bright machine-finished bronze cogs moved with a ‘rhythmic clanking” calculating a series of mathematical calculations. The Difference Engine managed to capture the attention of an audience with no engineering or mathematical expertise; “the visual spectacle of the engine works its magic.” (2000:305)

The historical archives suggest a similar awe on Babbage’s audience when demonstrating the finished portion of his Difference Engine No.1. Babbage, being a member of the Victorian elite was famous for his Saturday soirées. There, with his calculating engine as main attraction, he used to make dramatic demonstrations as a proof of the non-existence of miracles. (Swade, 2000: 75-78) His efforts of disenchanting the audience using the mathematical rationale of the Difference Engine resulted to a transportation of the enchanting qualities from the spiritual to the technological level. Years later, Ada Lovelace, inspired from the concept of the Analytical Engine, wrote:

> "We can say that the Analytical Engine will weave algebraic patterns, just as Jacquard looms weave flowers and leaves." (as cited in Ifrah, 2001:190)

Following Bennett's thesis that enchantment can be found in the most unexpected places, computing technology seems to have created such enactment from its very beginning (2001).

*Alone, against a growing bureaucracy*

Babbage's engines can be viewed as the epitome of the innovation of the 19th century and at the same time as the technological dead end of mechanical computing. They also depict the first problems caused by the growing capitalism of the new industrial era. Mathematical calculations became suddenly an impossible task for humans, as the need for effective data manipulation increased (Cortada, 1993:44). As Agar highlights, the Analytical Engine was born from the crises of industrialization (2001:24). Babbage tried to solve the problem using for this purpose the cutting edge technology of his period. He adopted the Jacquard loom cards and he even managed to capture the modern computing principle. However, as a member of the Victorian elite, he inherited the notion that the accomplishment from one person of such ambitious project was possible (Swade, 200:74).

The Difference Engine No.2 standing in its uppermost mahogany case in the computing gallery of the Science Museum conveys valuable meanings for the potential of the person, the capabilities of the Victorian polymath and the weakness of the one against the increasing bureaucracy.

Fig. 03. Jacquard Weaving Loom.
Courtesy of the Science Museum of London.

## The 1930's Punched-Card Office

The Punched-Card Office is a representation of a business office as it was supposed to be in 1930. According to the exhibit's title, the main attraction is the Punched-Card, a perforated paper medium that was used for data storage. Before continuing in the analysis of the exhibit, it is necessary to juxtapose the historical concept of the punched-cards and the subsequent tabulating technology.

> "Tabulating gear has always been the heart of data processing's pre-computer history and it is the computer's direct ancestor." (Cortada, 1993:44)

As mentioned before, Charles Babbage's concept of a computing device consisted exclusively of mechanical components was not applicable. Nonetheless, the medium that Babbage used in order to "store" the various mathematical formulas that would make his engine able to perform a variety of computations, found widespread application for more than a century. Babbage used an improved version of the Jacquard loom perforated card. The punched-card was developed in a similar principle and it became the ultimate storage medium for mechanical calculations (Ifrah 2001:185-7).

The Punched-Card medium was used in a wide range of applications from statistical analysis to scientific calculations. The first computer forerunners such as the Harvard Mark I were still depended from codes printed on perforated tapes (Campbell-Kelly et al., 2004:63). The impact of the punch card technology was so influential that decades after the introduction of genuine computers, they co-existed in weird machinery combinations (Cortada, 1993:45). The commercial market preferred them because they were cheaper and available in a period that computers were still at an experimental level (Ceruzzi, 2003:20).

### *Herman Hollerith, census and tabulators*

The Punched-Card machinery was firstly developed for statistical analysis due to the increasing state demands for effective knowledge of the increasing industrial population (Agar, 2001: 31). In the United States, from as early as 1790, this knowledge was attempted through the organisation of the censuses. It was not until a century later when the usually 10-year long painful procedure was simplified with the introduction of the punched-card technology known as tabulation. The first machine was a manual key punch[6] that was invented by Herman Hollerith, a young technician of the U.S Bureau of Census. With this first rudimentary equipment, an operator could punch holes to a unique card per person, corresponding to data gathered from the individual. Then, an electrical device (sorter) could count and sort the cards, collating and analysing the data. This method accelerated the 1890 census and the results were available in two years (Hally, 2005:xix, Ifrah, 2001:183). Soon, Hollerith left the Bureau and he expanded his business to the commercial market as a "one-man act" (Cortada, 1993:52). By 1905 due to the strict monopoly tactics of Hollerith, other inventors such as James Powers entered as competitors the tabulation industry, which had already become a significant sector of the economy (Campbell-Kelly et al. 2004:37). Eventually, Hollerith's company merged to become the International Business Machine (IBM), in 1924. It is still one of the most successful computing companies of the 20th century introducing important innovations in the tabulating field (Ifrah, 2001:183). Powers remained the main competitor in punched-card machinery and companies such as Remington and Rand or Powers-Samas in the United Kingdom, awarded and continued his patents (id. at 184).

*Punched-card technology on display*

The 1930's office stands next to Charles Babbage gallery and the Ferranti-Pegasus installation, is a replica of a "typical" mid-war workspace. According to a rough demonstration draft written from an unknown curator and found accidentally in one of the office's drawers, the only compromise to the historical integrity was to "squash" the punched-card device due to the spatial limitations of the gallery.

Indeed, apart some nostalgic reminders of the old machinery together with the dark wooden furniture and the dim light, this 1/1 scale diorama is an utterly functional punched-card office.

The majority of the punched-card machines were acquired from Prudential Assurance Ltd. where they served their useful life. According to the object technical files, the office replica was designed and installed in 1974. The museum used to make regular public demonstrations of punched-card machinery, at least once a month, until 1978,

[6] See Appendix.

as indicated in the demonstration archives found inside the office filing cabinets. It is not clear under which circumstances the public demonstration stopped.[7]

Nowadays, there is an effort from assistant curator Rob Skitmore in cooperation with the conservation team for re-establishing this event.[8] Indeed, it seems a quite difficult task to explain the tabulating process without physical demonstration and function of this machinery to the public, providing that the operation of the machinery will satisfy the conservation ethics and their historical integrity.

The possibility of a future re-demonstration resulted to an off-the record short operation of the office's machinery. It was also a good opportunity for some internal research in the records of the 1970's public demonstration that was stored in the replica's filing cabinets.

Fig. 04. 1930's Punched-Cad Office
Courtesy of the Science Museum of London.

The demonstrative material remains intact from 1975 and according to the draft, the first step required to punch some blank punched-cards in the Powers-Samas 45 column-card automatic key punch. A 45-column card offers 450 different positions of

[7] The policies applied to working exhibits in the Science Museum can be found in Mann, Peter R., (1989), Working exhibits and the destruction of evidence in the Science Museum, International Journal of Museum management and curatorship, 8 (1989), pp. 269-387.

[8] The author will participate to this project as the conservator of metals/engineering in the Science Museum

holes. Each hole has to be correlated with specific information before starting the procedure. Every card has to be verified for its accuracy. The verification requires the key punch to be set to the "verify" position. When punching the same sequence of numbers on the same card, the result is a perforated card with slightly larger oval holes. Two round holes in the same column mean that the card contains data errors. A sorting machine that is not included in the office can separate the correct cards and reject the faulty ones. Then, the cards are fed to another sorter which sorts them by "reading" the punched holes in every column. The demonstration proceeded with a purpose-made set of 300 cards in ten different colours fed to the sorter. In a few seconds, they were sorted by colour. Although the tabulator seemed to be in good working order, it was decided not to operate it, as its maintenance record hadn't being examined thoroughly.

*Digging the office*

This demonstration shows at first hand, how powerful the material culture of the computing past can be when it is set up to perform for public.

Even though it was an unofficial and non-advertised event, in the few minutes that the punch machinery worked, it had captured the attention of every visitor in the computing gallery again demonstrating the enchanting power that these objects can hold.

The examination of the filing cabinets, binders and drawers of the replica office resulted to the identification and recording of a variety of objects and archive material:

- Electrical equipment, such as an unused electric bulb found inside a binder. Also, old type power sockets and electrical components, remains from early 1970's.
- Stationery probably from the same period, left untouched on a tray onto the historic desk.
- Operating manuals and internal mail containing information on demonstration and maintenance dates together with supportive information on objects acquired for the office presentation. For example, there is a document providing the loan details of the historical telephone device of the office, which is not in the official museum database.

- A large quantity of unused cards, probably from the stock of Prudential Assurance Ltd together with pre-Punched-Card sets for demonstrative purposes.
- Spare parts, accessories such as sealed ink ribbons for the tabulator and other bits and pieces necessary for the routine maintenance of the equipment.
- Chads remain inside the key punch and a branded (Powers) ashtray- like glass receptacle.

Fig. 05. Chads remain inside the key punch and a branded (Powers) ashtray- like glass receptacle. Photo by the author.

*Card meanings…*

As Ian Hodder had aptly put it "the relationship between material culture and people who produce it is a complex one" (1991:2). This complexity applies even when people are experiencing material culture in unproductive ways, such as the relationship between the museum personnel and the office artefacts in the computing gallery. The above collected evidence does not come from the historical use of the objects but through the 1970's demonstrative sessions of machinery inside the museum, without necessarily restricting archaeological evidence of the object's business period. The purpose of the demonstration is to show the application and use of Punched-Card technology in business and industry. In this respect, the office demonstration works effectively, especially during a public performance. However, the office looks empty of human activity, apart the most recent one from the museum personnel, which their routine can be traced far more accurately than that of its original workers.

In order to understand the potential of meaning, some alternatives in the interpretation of punched-card machinery using in one occasion relevant material culture displayed in a different context, are examined in the following paragraphs.

*…and alternatives*

The social role of the tabulation technology had been extensively researched by many computer history scholars, mainly emphasising to the impact in the female labour. In the first decades of the 20th century, punched-card machinery was operated in the vast majority by women operators. Already from the second half of the 19th century, many workshops and offices employed women for the first time (Ifrah, 2004:187). ICT, the company that continued the Powers-Samas patents since 1959, depicts this transformation in its "Basic Punching Instructions and Reference" manual, found in one the replica office drawers. In the first page, a woman operator of a key punch demonstrates the correct chair adjustment. [9]

The wider social impact of the development of punched-card machinery extends beyond the advantages that tabulation offered to the economic, industrial or scientific fields of the 20th century society. As mentioned before, tabulation was born inside the American government agency to solve problems related with population census. According to Ifrah,

> " (mechanography) opened the way to new relations between states, society and individuals, by making it possible to create large databases on different sectors of the population and thereby enabled various kinds of social action" (2004:187)"

The above statement implicates that government control as part of social action became more effective with the mechanical manipulation of personal information. Thus, rather than an exhibition of the potentials of technology and capitalism, punched-card technology can be used for a more critical approach of the impacts of the surveillance automation to the individual.

*The role of Punched-card machinery in the Holocaust*

In order to make an approach focused on the impacts of the tabulation technology to society, the curators of the Holocaust Museum in Washington DC decided to display an IBM tabulating device in 1991. It was an effort to highlight the involvement of IBM in the German census organisation during the Nazi regime (1934-1945) that led to identify and gradually exterminate Jewish and other populations in Europe (Black, 2001:14). In the mid-war period, the German statisticians were on the verge of

[9] The manual was found inside a drawer in the desk of the 1930's Punched-Card office.

understanding the limitless potential of mechanography to social policy (Luebke et al. 1994:27). Until this date, only a few scholars with the exception of Aly Götz and Karl Heinz Roth had explored the role of the mechanical tabulation technology in the process of racial persecution in the German region (as cited in id. at 25). The controversy caused from displaying a static tabulating machine with the IBM brand name on it, led to more comprehensive research on the subject. Edwin Black's volume "IBM and the Holocaust" was a rough accuse to IBM stating that:

> "IBM, primarily through its German subsidiary, made Hitler's program of Jewish destruction a technological mission the company pursued with chilling success." (Johnson, 1999:92)

Both Black and Luebke/Milton agree that despite the fact that the Holocaust was accelerated by the availability of advanced census-taking technologies, it would have happened even with pen and paper prosecution (Black, 2001: 14; Luebke et al. 1994: 36). The point is that tabulation analysis made state control a viable possibility. This possibility can be seen in Dehomag's (the IBM German subsidiary) director Willy Heidinger's

> "vision of totalitarian future in which every resident would be monitored and manipulated in a system of comprehensive surveillance." (Luebke et al. 1994:34)

This vision was graphically pictured in a 1934 Dehomag poster, where a surveillance panopticon is operating through Hollerith Punched-Cards.

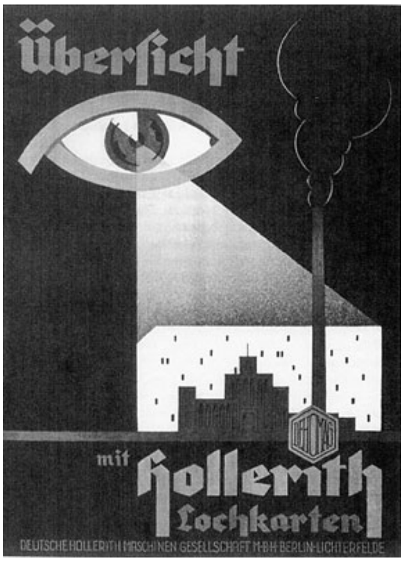


Fig. 06. Dehomag's poster. Surveillance with Hollerith cards. Source Black, 2001.

*A holistic interpretation*

However, the implication that the tabulation technology acted as a dehumanising factor leaves no questions for the failure of the human ethics of the period. (Davis, 1974) It could be more productive to approach technology in interconnected contexts rather than making technology as a scapegoat of the human misery using isolated views. The study of the punched-card technology and the counter comparison between different museum approaches illustrates the complexity of the meaning of things. A multidimensional approach can highlight to the human factor from the individual inventor to the labour preserving at the same time the capitalistic perspective or the social ethics of the historic period.

## The Ferranti-Pegasus computer

*20$^{th}$ century warfare and computing technology*

Between electromechanical calculation such as the tabulating systems and immiscibly digital computers such as the Ferranti-Pegasus for which this case study is about there has been more than 50 years of continuous scientific research and development in computing. At the same time, the burst of two world wars in the first half of the 20$^{th}$ century was the breaking point for the technological boost of computing.

Already from the beginning of the heavily industrialised World |War I the tabulation industry became a victory factor as the demands for military data processing, increased dramatically (Cortada, 1993:58).

Without a doubt, the burst of the Second World War accelerated the passage from electromechanical to electronic computation:

> “Without the six-year conflict at the heart of the century.... the history of many technologies would look radically different.” (Agar, 2001:39)

When the war broke out, there was an instant emergence for further development of computation and analytical calculation in key military fields such as cryptographic analysis, aircraft industry, gun aiming, simulation and radar technology (Ifrah, 2001:210-11).

The German army had successfully developed Enigma, an electromechanical device which provided robust encryption in telecommunications. The Enigma code was impossible to break from any mechanical device (Ceruzzi: 1990:232 and Murray, 1997:9).

In the opposition, the Allies and especially the British Division, perfected a machine called Colossus, an electronic circuits device consisted of 1500 valves, designed exclusively to compare encryption patterns (Ceruzzi, 1990). Although Colossus had some limited programmability, it could not be considered as a true computer, not following the principle of the Universal Machine. (Agar, 2001:111)

A more sophisticated calculator was ENIAC, which was developed to solve ballistic problems for the American Navy. However, ENIAC was completed too late to contribute to the final victory (id. at 84) and in the true sense of the term, it was a general-purpose analytical calculator than a real programmable computer (Ifrah, 2001:222).

The machine that is accredited as the first with Universal capabilities (at least in the United States) was the IBM-funded Harvard Mark I, which was developed in 1943. The American media responded with great enthusiasm, referring to it as the "Harvard's robot Super-Brain" (Campbell-Kelly et al., 2004:64).

In terms of structure, those first analytical electromechanical calculators such as the ENIAC and the Harvard Mark I (both of them non self-controlled devices[10]) were closely related to Babbage's Analytical Engine (Ifrah, 2004:222).

In summation, the experience gained from the military projects led to the birth of the first stored-programmed computers such as the UNIVAC. By mid-1951, six US and five UK computers had already run their first programs (Lavington, 200:6-7).

*A 1950's vacuum tube computer*

The computing gallery of the Science Museum gives an accurate historic account of the computing development in the first half of the 20th century, in addition to some rare artefacts like fractions from Colossus and ENIAC. There is even a German Enigma machine in the telecommunications gallery.

However, the most important representative of early computing in the Science Museum is Pegasus, a British-designed computer produced in 1956 by the United Kingdom Company Ferranti Ltd. Although it looks enormous compared to modern computers, it occupies the space of a normal office room; On the other hand, ENIAC required 1000 sq feet of space.

[10] See Appendix.

Like most of its contemporary machines, Pegasus is made up of cabinets of electronics divided into sections known as bays. It also has an operating console that includes paper tape input/output equipment. Alternatively, punched-card equipment could be attached as an input, due to the demands for this popular medium from the business community (id. at 25).

Pegasus is a vacuum tube computer. That means that instead of chips or even transistors, its control unit (CPU) consists of thermionic valves, which require 7KW of electrical power that needs to be brought up slowly in order not to impose thermal shocks to the valves. Nickel delay-line units each one with capacity of 42 digits are shaping a 128-word total memory size. This is equivalent of 25kbytes of modern RAM. The "hard drive" of the computer is a magnetic drum with a capacity of 5120 words (42 digits) and it runs at a clock frequency of 333 kHz. It is interesting that in the Pegasus Programming Manual (1962), the arithmetical unit that "can operate on numbers from the store (magnetic drum) and send its results back to the store" is described as "mill", a term originated from Babbage's days (Agar, 2001:24).

*The mind behind Pegasus*

Pegasus was designed by Christopher Strachey (1916-1975) who turned from a former schoolmaster to an NRDC[11] consultant and he contributed in Pegasus' system architecture (Campbell-Kelly, 1985). It is unknown how influential Strachey's educational background was in computer programming. His main contribution to the Pegasus system is what in modern computer terms is described as user interface. The term describes a user-friendly computing environment and his idea of general-register set architecture[12] is still applied to modern personal computers (Lavington, 2000:57).

*The oldest working computer in the world*

Pegasus is exhibited in the Science Museum, following different demonstrative principles from the previously described computing exhibits. Its respectful size makes it a highly visible artefact together with the fact that it is fully functional. It is advertised in the museum's webpage as the "oldest working computer in the world" and there is a public demonstration of its use by the members of the Computer

[11] The National Research and Development Corporation was a post-war UK agency that supported several computing projects leading to the development of commercially available computers (Lavington 2000:8).
[12] See Appendix.

Conservation Society, fortnightly. Pegasus' restoration and exhibition shaped the principles of displaying computing material culture in the Science Museum. The launch of the Pegasus eventually led to the announcement of a "Collecting and Conserving Computers" Conference in 1993 which finally did not take place due to internal transformations of the organisation. Nevertheless, the conference papers can still be found in the library of the museum and they provide interesting views of the ethics on preserving and interpreting historical computing material culture, in the early 1990s.

*The restoration of Pegasus*

The restoration process was co-ordinated by Tony Sale, then Computer Restoration Project Manager. The project had two aims: the design of a simulator compatible with modern personal computers (386 IBM PC at the time) and the physical rehabilitation of the machine. As Sale has put it,

> "This is thought to be a world first in restoring such an early computer and is providing such a detailed simulation of it running in a modern PC. It is a major step forward in interpreting early computers to the wider public." (Sale, 1993)

This rather optimistic approach of the beneficial use of simulation is evident to the exaggerated expectations of the newly introduced computer-graphics technology in museums in the early 90's. Undoubtedly, the simulator was a useful project, which in one occasion even detected some "bugs" on the original 1950's software (ibid). However, as Swade had already predicted in 1993, the contemporary medium that carries the simulator, soon became obsolete and incompatible with the rest of the museum's displaying media.

Nonetheless, the simulation of Pegasus designed as supplementary tools with no intensions to replace the "real thing".[13] The conservation team's efforts to restore Pegasus in its functional condition finally came to fruition in 1990.

*Pegasus performing*

Despite the fact that Pegasus is probably half a million times slower that a typical personal computer, the combination of the vacuum tubes, the twin radar-type

[13] However, "many users have commented that they really get the "look and feel" of operating the real Pegasus (Lavington 2000:34).

monitors and the switches and push buttons on the operating console give the feeling of an individual entity, an intriguing machine that acts in an evocative if not enchanting way to its audience. As an artefact with the advantage of still being part of living memory, the most valuable achievement, is its bimonthly demonstration from the veteran engineers of the Computing Society. Pegasus' operation provides an invaluable and rare live record of the application of the commercial computing of the post-war period. According to its operators, they are able to understand Pegasus' good operation, just by listening to its whirr. This incessant sound is also one of the factors that make this particular exhibit so important to the visitor. It can be viewed as a live organism from the past, an authentic piece of history, even if there might have been alterations, repairs and replacement of parts, in order to make it work.

Fig. 07. Pegasus operation from the members of the Computer Conservation Society. A 386 personal computer is running the simulation software. Photo by the author.

*Museum Interpretation*

It is notable that the curatorial efforts when dealing with computers are focused on the ethical issues of the preservation of the physical structure of the computing device as well as the software, essential to operate a computer. Without overlooking the importance of the historical accuracy when preserving functional artefacts, it is worth to stay in the interpretational challenges of early computers like the Ferranti Pegasus. Taking as guidelines the supporting visitors information labels, the approaches to the computing past of Pegasus are focusing on:

The physical capabilities of an early computer in comparison with a familiar personal computer. The devastating differences in specifications between Pegasus and an early 486 pc, which are inversely proportional to their physical size, led to underestimations of the post-war technology.

The importance of computing calculations in aeronautics is well presented but the conceptual absence of the 1950's background in addition with the limited multimedia capabilities of Pegasus, results to a confusing understanding of the necessity of a computer in a variety of fields. Pegasus I & II found several business and industrial applications. Forty Pegasus were built and sold from 1956-1962 to a variety of industrial, government and educational organisations. From a total of 40 Pegasus, 11 were purchased from aviation companies, three from banks, six from research laboratories and universities, one for military research, three from computing companies, six from business corporations and five from industrial or government organisations (Lavington, 2000: 46). It is clear that an early computer was mainly a research tool essential for scientific, industrial and military needs, far from any possibility for personal use, which was introduced decades later.

The museum advertises Pegasus as a domestic computer with the advantage of its functionality. That gives the impression that the United Kingdom computing industry was dominant rather that endangered from a better funded North American Industry. (Ceruzzi, 1998:11) The fact that Pegasus was a medium-performance computer even in its time has been discreetly avoided for an approach that emphasises to the legendary British computer industry. Even though it would be unfair to criticise this decision, the social background of computing in England and subsequently in Europe in the beginning of the cold-war period, remains untouched in the computing gallery.

*Alternative Approaches*

A common approach of computing material culture is the comparison with contemporary devices in terms of memory capacity, CPU speed, physical size and in the case of Pegasus, production cost. According to Lavington, the average cost of a Pegasus computer "delivered and erected" was (£42,000). At the same time (1962), a

four- bedroom terrace house in Manchester could be bought with £1200 and a four-door family saloon car about £700 (2000:42). This statement in an effort to commodify Pegasus seems unrealistic, as early computers could not be viewed as widely available products. Also, it would be interesting to compare Pegasus' price with equivalent computing equipment in order to have a clear picture of its real market price. Thus, the IBM 650, a technically inferior system which was delivered in 1800 units in the Britain from 1956 to 1962 (Burton, 1995) cost approximately $115,000 (almost £41,000).[14] The above examples can indicate two things:
Firstly, computer value in the mid 1950's was mostly based on use and not on exchange. In terms of exchange value, Pegasus could cost as much as 37 houses. Thus, exchange value turns unequal things to equal, a process, which Marx presented as "sinister" (as cited in Bennett, 2001:117). It is not sinister because of the violation to the artefacts themselves. Any comparison between cars or houses with Pegasus carries the possibility of stripping the computer of its specificity and turning it to transactional good (id. at 117).
Secondly, Pegasus cost almost as much as its main competitor, the IBM 650. However, the British computer failed to establish its position in the domestic market. It was a user-friendly, technologically superior, easy to maintain and elegant machine, having little in common with its bulky predecessors. An elegant characteristic of all Pegasus computers was the very good quality finish of their bodywork. The same company that carried out the bodyworks for Rolls Royce and Bentley cars was responsible for the blue-grey gloss 10-coated finish and the Rolls Royce clucks of the doors (Lavington, 2000:26). This perfectionism shows that Ferranti ltd produced Pegasus with ambitions to make it widespread to an even larger commercial market and it tried with Pegasus' successors until 1963 (id. at 56).

**Towards modern computing**

Except their sequence in the computing development timeline, the artefacts of the previous case studies have other things in common. Not only are they functional exhibits, they also have a significant size, a common characteristic of early computers, until the appearance of the first minicomputer along with the mini car and

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[14] BRL report no.1115, March 1961 <http:// ed-thelen.org/comp-hist/BRL61.html#TOC>. Currency conversion from US$ to GBP according to <  http://fx.sauder.ubc.ca>, retrieved on September 2007.

the miniskirt in the 1960's. They occupy the biggest part of the computing gallery, showing the evolution of computing material culture, until roughly the first half of the 20th century. The evolution from electronic tubes to discrete transistors and then to integrated circuits is also presented as well as a working DEC PDP-8 which was the first small sized computer ever produced and coined the above mention term from the fact that it could fit on a desk (Ceruzzi, 1998:135). However, for more contemporary computing equipment the visitor has to continue his trip in the "Making the Modern World" gallery, located in the ground floor. There, the computing timeline from the 1970's till the early 1980's and the introduction of the personal computer is presented with static exhibits. Thus, the next case studies do not follow the pattern of interpretation through functional demonstration. Instead, the displayed artefacts are examined on their value and appreciation as representative computing material culture of the modern world.

The chosen artefacts are also ideal for an analysis of the aesthetics of the computers and how some of those machines became symbols of the popular culture.

*Cray 1A and Supercomputing*

In the last section of the "Making the Modern World" gallery, facing the Apollo 10 command module - an impressive high-tech exhibit from the Cold War era, lays an extraordinary computing artefact. The museum's webpage provides the following information for the nature of what looks more like a high-tech circular leather couch:

> "Cray 1A super computer, weighting five and a half tons, made by Cray Research Inc, USA. The Cray 1A supercomputer was twice as fast as its predecessor, the Cray CDC 7600. The Atomic Weapons Establishment (AWE), Aldermaston, UK, took delivery of the example shown here (serial number 11) in 1979. The last of the Cray 1As was taken out of service on 27 January 1989."

Supercomputer is a term coined to describe a scientific computer capable of complex and time-consuming calculations. Gibbs gives a brief description of the capabilities of a supercomputer using as an example the Blue Pacific at Lawrence Livermore National Laboratory (U.S.). The fastest supercomputer in the world (1999) needed 173 hours to complete a simple turbulence simulation of a detonating nuclear bomb, a procedure that could take 16 years from a 600-megahertz Pentium II PC (2001:5). Supercomputers until their crash in the early 1990's, were essential for a variety of industrial and military projects, they cost several million dollars and the supercomputer companies dominated the computer industry. The development of the microprocessors turned the supercomputers from vector architecture[15] to highly tuned computer clusters that use commodity processors found in personal computers, combined with custom interconnects (Murray, 1997:217-8). The significantly lower cost of this arrangement made vector supercomputing obsolete.

*Seymour R. Cray: the father of supercomputing*

Cray 1 was a revolutionary and relatively compact computer, having less in common with its predecessors (the CDC family). The mastermind behind them, Seymour Cray, is a legendary figure among the computing circles.

Seymour Cray was an engineer that participated or coordinated some of the early supercomputing projects from 1950-1970. For many, Cray is the individual who created the supercomputing industry. He started his career in a former U.S. Navy lab (ERA), which continued post-war codebraking research. When ERA merged with Sperry-Rand's UNIVAC division, he established himself to the scientific computing field. In 1957 left ERA and he created Control Data Corporation along with other 4 colleagues. He is credited for the design of CDC 1604, the first fully transistorised computer. Shortly after the commercial success of CDC, Cray started to become annoyed from the corporate management interference, which wanted to increase profits with low risk projects. In 1972 he left CDC and founded Cray Research Inc., in order to accomplish a more ambitious project. The result was the exhibit with inventory number 1991-159 in "Making the Modern World Gallery".

Its inventor whom his fellow computer engineers could not decide whether to call him the "Albert Einstein of supercomputing", the "Thomas Edison of supercomputing" or the "Even Knievel of supercomputing" was an extraordinary and even eccentric engineer whose inventions continued to empower some of the most secret U.S. military projects during the Cold War era (Murray, 1996:5). His fear for a forthcoming nuclear blast (he had a nuclear shelter built under his house)[16] was probably a strong motivation for the development of the fastest computers in the world. His was so dedicated to his vision that he volunteered to work under the minimum possible wage before leaving the company (CDC) which had made profits

[15] See Appendix.
[16] Murray, 1996:81

of one billion dollars, mainly from the computers he designed. Struggling always from managerial bureaucracy and reluctance in funding, he continued to create the most elegant and fastest computers until his death in 1996.
Looking at Cray's achievements it is easy to understand why Cray 1 is one of the displays of the specific thematic gallery and not installed in the computing gallery in the second floor. For many computing scholars, the story of commercial minicomputing starts from Seymour Cray, although he never designed a personal computer (Ceruzzi, 1998:125).

*Integrated circuits*

Previously, in the late 1960's the challenge in computer development was the adoption or rejection of integrated circuits.[17] This was a not so new technology, as circuits had already been employed from the United States military several years before in a variety of projects, such as the Apollo space program (Murray 1996:129). Cray 1A was a revolutionary and at the same time, a non-evolutionary computer incorporating for the same time the integrated circuits technology in its core. Cray's decision of using a new technology was not as radical as it seems. Actually, he avoided the use of integrated circuits for nearly six years. This conservatism, made Cray able to avoid critical mistakes in adopting technology in its early stages of development. Over time the incorporation of integrated circuits became a hallmark of Cray's design wisdom. (Murray, 1997:128-9).

*Inside Cray 1A*

A more careful look at the Cray 1A supercomputer can reveal some of its avant-garde technological and highly aesthetically innovations that made it the fastest computer of its generation, an outsold product with more that 80 units delivered at a price of $5 million to $8 million. The computer mainframe consists of 12 wedge-shaped columns placed in a polygonal arc. The C-shape was chosen in order to keep the wiring distances sort and to increase the signalling speed but it is also Cray's initial, a kind or personal form signature. Finally, a Freon cooling system protects the vector processor from overheating. In Cray's latest models, the Freon was replaced by a liquid originally used as artificial blood in humans whose allergies or religious beliefs

[17] See Appendix.

cannot accept a blood transfusion (id. at 20). The frames are covered with in coloured leather as well as the arc, giving Cray 1 furniture than a typical computer appearance.

Fig. 08. Cray 1A supercomputer in the “Making of the Modern World” Gallery, opposite the Apollo 10 space module. Photo by the author.

*The aesthetics of Cray*

Cray 1A can be seen as is the materialisation of clear thought, creativity, use of new but proven effective materials and technological innovations, efficient architecture and state-of-the-art elegance all in one computing package. Most of all, it carries the personal vision of its inventor making it distinctive between its contemporary machines.

In his study on the aesthetics of computing, David Gelernter suggests, “the machine beauty is the driving force behind technology and science” (1998:8). In this respect, the most important discoveries in computational history happened from their inventor’s subconscious sometimes lust for beauty and elegance. Beauty in technology acts in different ways and not as design form, even if the latter is also important. In most occasions simplicity and power are the keys used to create beautiful technology and Seymour Cray seemed to understand this fact better than anybody of his competitors.

In one of his few interviews in 1995, when asked about his aesthetic objectives of his computers, Cray replied:

> "In the work that I had done I've always been interested in the aesthetics, the appearance of computers. So many computer products are rectangular boxes and don't seem to have any aesthetic appeal as I viewed it. (Cray 1) was my first opportunity to deal with the aesthetics, spend an extra 5% money perhaps to make something visually intriguing and so clearly this particular product was different than the rectangular boxes that were available from everyone else. I think it enhanced the early marketing opportunities for the machine. There is some emotional content even in buying large scientific computers and something that looks different and intriguing can sometimes sell a machine over competitors' square box" (as cited in Allison, 1995:19-20).

This "symphony of tight design" (Murray, 1996:142) is probably the most notable link between Cray's supercomputers and personal computers. After all, Cray never liked microprocessors (as cited in Allison, 1995:10). Few years after, Apple Inc. made personal computers available to the public, building elegant machines in Cray's aesthetic footsteps. A popular, yet not definitely confirmed, oft-told tale suggests that Steve Jobs, co-founder of Apple Inc., was the first and the only Cray's walk-in customer; when he arrived unannounced at Cray headquarters asking to buy a supercomputer to design his next Macintosh, Cray thought for a bit and replied that it seemed reasonable, since he was using a Macintosh to design the next Cray![18]
Finally, Cray 1's contribution was essential in a different field, equally important, that of Computer Generated Imaginary (CGI). In 1982, a Cray 1 was leased to help in the digital rendering of the movie TRON, the first computer animated film (Hoffman 1983). [19] Cray 1 became a pop culture icon and CGI grew to a large industry with applications from entertainment to scientific visualisation (Pool, 1989, Cox, 1998).

*A meaningful interpretation*

Cray 1A provides a canvas of equally important interpretations that cover a wide range, from aesthetics to science. As an exhibit in a technological museum, the

[18] < http://www.tafkac.org/faq2k/compute_76.html>, retrieved on September 2007.
[19] In honour of the Cray's contribution to the film, it had a cameo sequence in the film. A Cray-1 was used in a scene shot at Lawrence Livermore Laboratories in California (where many of the other parts of the film were shot). <http://www.digibarn.com/collections/systems/crays/cray1/Cray-In-Tron/index.html>, retrieved on September 2007.

displayed meaning focuses on its scientific application and the subsequent social impact.

First, Cray 1 can be viewed as a relic from an era when the American Nation dedicated some of 5% of its federal budget in space race and a world haunted from the possibility of a nuclear explosion. The Apollo 10 command module which stands opposite Cray 1A is the outright remain of this investment along with an extensive use of an early form of microcomputers inside the module (Tomayko, 1985:9). The fastest computer of the 70s could be the materialisation of Seymour Cray's personal fears of the disastrous potential of the atomic development. This assumption can be supported from the artefact's service life (Atomic Weapons Establishment (AWE), Aldermaston, UK), which can be applied to the majority of its contemporary supercomputers. Despite the fact that many high performance applications can be characterised as "scientific", the vast majority of Cray computers were employed in the Defence industry. (Hoffman 1983) High performance computers were under export permits from the Special Nuclear Export Committee and in many cases supercomputing sales outside the U.S. was restricted (Stork, 1990).

At the same time, academic researchers had to rely on a "beggar's status", using defence supercomputers subject to lease and availability (Waldrop, 1985). In other words, it seems that supercomputing was more oriented to the industry. This is of course not a surprise. Cray's obsession with speed was except it's possible emotional engagement, a clever entrepreneur's choice. He was carefully developing his products, based on his customer's need for speed. "Rapid growth was almost an obsession even in 1960*"* (Murray 1996:75*)* and Cray's goals were not exceptional.

Without a doubt, Cray 1A deserves its placement in the Science museum not only for its impressive computing capabilities but also as a carrier of modern aesthetic values. In this respect, his inventor's personality is much more obvious than raw computing performance. The unexpected or even accidental contribution of supercomputing in fields that weren't included in the product's specifications, is another exciting and intriguing achievement of computing.

### Personal Computer: an accidental machine

The last case study of this essay is about the role of ordinary users in defining computing and its products. This contribution was epitomised with the commercial innovation of the personal computer. Like many other hybrid technologies, the desktop computer was born in the PARC an establishment of Xerox, a leading corporation of the xerographic[20] industry. (Levy, 1994:50-3) The scientific team eventually developed in 1973 a minicomputer with the code name Alto, a strange for the period device that incorporated all the features found in a modern personal computer (Gelernter 1998: 69). Those features suggest a monitor, an alphanumeric keyboard[21] and a pointing device known as mouse.[22] However, Alto never became commercial product because nobody was quite sure of what to do with it. Although the project was born in a highly valued scientific circle, it was not believed that it could make a breakthrough (Levy, 1994:72).

In contrast, a small community of hobbyists named as the Homebrew Computer club, found the idea of a personal computer extremely attractive. Soon, one of the Homebrew members, Stephen Wozniac, designed a circuit board, mainly to impress his colleagues (ibid). This first circuit became the Apple I, the first commercial personal computer (Linzmayer, 1999:2).

When the two Steves, Wozniac and Jobs, founded Apple Inc. in a garage (as the computer mythology faulty demands) changed a previously widely accepted appreciation about computers. Suddenly computers were not just big number crunchers, billing machines, defence appliances or obscure scientific instruments. They were accessible to everybody, even if their exact use was not yet clear. Personal computers had the significance to be invented before a definition of their use (Punt, 1998:61). Starting as a hobbyist's obsession, computers became essential to the market because of software applications and uses that they were introduced afterwards.

*PC's as museum objects*

The Personal Computer (PC) in the Science Museum is represented by a variety of artefacts located in the section "Everyday Life 1968-2000" in the ground floor. The visitor can see an Apple II desktop computer, a software package of Windows 3.1 a Sinclair ZX80 and a Grid "Compass" laptop. Also, there is an Apple I strategically placed between Cray 1A and the Apollo 10 command module that is advertised as

[20] See Appendix.
[21] See Appendix.
[22] See Appendix.

> “the first computer from a company which became one of the fastest growing in history, launching a number of innovative and influential computer hardware and software products”

Despite the importance of the Sinclair ZX80 especially for the British personal computer history and the contribution of the Grid laptop to the military field, this study is focusing on the corporate phenomenon of Apple Inc.


Fig. 09. The Apple II personal computer on display with other computing artefacts in the “Everyday Life 1968-2000” gallery in the Science Museum. Photo by the author.

It is desirable to appraise the impetus that drove the Science Museum as well as other technological and art museums to acquire personal computers under the Apple brand for their collections. It is clear that those computing artefacts have not place in the museum’s showcases for the demonstration of technological progression.  The museum’s computing storage in Blythe House holds a vast number of artefacts that they could be equally if more eligible for a strict technological timeline. An Altair 8800 as the first hobbyist computer, an IBM PC as the first mass consumed PC and many others. The two Apple computers on display are certainly not the first of their kind, neither the most bestselling. Apple I sold approximately 200 units and Apple II had to compete with IBM pc and Commodore 64 domination in the market (Linzmayer 1999:11). They don’t even satisfy the aesthetic status and the elegant industrial design of Apple’s later models, which eventually led to the exhibition of some of its products in the collections of the Museum of Modern Art in New York.[23]

[23] <http://www.moma.org/collection/>, retrieved on September 2007

*Apple I & II*

The first Apple computer was a little more than a circuit board to which customers were expected to add a case, power supply, monitor and keyboard (id. at 2). The Science Museum's Apple I exhibit has a custom made wooden case and the whole concept hardly reminds a personal computer. The Apple II is a more compact device consisted of a beige plastic enclosure in the universal shape of a typewriter with a bulky monitor built in.

What is most important is that the first Apple computers were also the first pioneering efforts of marketing and commodifying a computer, making it available to "the rest of us" (Levy 1994:8).[24] A lot of consumers bought the Apple II because it was the only computer that it could run VisiCalc, the first spreadsheet program (Gelernter, 1998:60-61). These facts can justify the selection of the Apple I & II as personal computer representatives in the Science museum, the model I as the first commercial product and the model II as the medium of the first "killer-app", a computer program, worth to spend $1298 (for the computer) in order to run it (Levy, 1994:134; Punt 1998:73).

Fig. 10. Apple I, the first commercial personal computer displayed in the "Making of the Modern World" gallery in the Science Museum. Courtesy of the Science Museum of London

*The Macintosh: a computer for 'the rest of us"*

The introduction of the Macintosh in 1984 was influential for the development of the personal computer, from the shape of the device to the user interface (GUI)[25] and the

[24] "The computer for the rest of us", from the Apple advertising campaign c.1984.
[25] See Appendix.

way that people would appreciate personal computers in the years to come (Levy 1994:140).

Unfortunately, there is not a Macintosh model on permanent display. Nevertheless, a variety of Macintosh models, from the first 128k (1984) to the SE/30 (1989) and other portable models (laptops) are being held in the computing storage, for future exhibitions, or a computing gallery update.

Fig. 11. The Apple Macintosh 128K personal computer (1984). Courtesy of the Science Museum of London

The Macintosh computer epitomises the principle of Alan Turing's Universal Machine. It was originally created from Jef Raskin (1943-2005) a Human-Computer Interface expert, whose vision was the creation of a computer that would be a modest, yet essential tool, like a Swiss army knife (id. at 111). Even when the Macintosh project was taken over from Steve Jobs, the user-friendly interface remained the main objective. In terms of technological innovation, Macintosh was the first successful computer that adopted a mouse pointing device, a bitmap display[26] that followed the "What you see is what you get" principle and most importantly, windows environment for graphical user interface (GUI)[27]. Macintosh's predecessors and contemporaries were equipped with operation systems like MS-DOS[28] or BASIC[29]. For example, in order to retrieve a file in non-windows system, the user had to type the file's name in a one-dimensional computer screen. If he mistyped the name of the file, then the computer assumed that the user intended to create a new one, with the

[26] See Appendix.
[27] See Appendix.
[28] See Appendix.
[29] See Appendix.

typo as its title. The user had to wait until the new file was created, then to erase it and start over again. In the opposition, Macintosh's illuminated white screen had a graphical visualisation of any file. The user could click on that in order to open it, drag it or deleted. It was a groundbreaking development, universally adopted in later computers, especially after the introduction of the Microsoft Windows operating system in the early 90's (Levy, 1994; Gelernter, 1998:77).

*Commercialising the personal computer*

The marketing promotion of Apple's Macintosh was also a computing historic event. Until 1984, computer marketers avoided science fiction style commercials fearing that the American public would make the connection between computers and the Orwellian nightmare of Kubrick's 2001.[30] IBM's efforts to advertise associate its PC with the charming picture of Charlie Chaplin, didn't manage to improve the cold and aloof picture of the company (Friedman 2005). Apple chose the opposite way, launching a 500,000$ spot during the third quarter of the Super Bowl on January 22 1984, creating the term "event marketing" in advertising.

The ad opened with a technological nightmare of a grey tube-like network where bald-headed feckless humans marched down to a cavernous auditorium. In a giant TV screen, a Big Brother figure was making reality Orwell's fears for total control. Suddenly, an athletic female figure wearing a white T-shirt with the Macintosh "Picasso" logo and chased by armoured guards hurled a sledgehammer and shattered the TV image.

As the screen exploded and a blinding light rushed, in 43 million people's screens that watched the Super Bowl, a message appeared:

> "On January 24th, Apple Computer will introduce Macintosh. And you'll see why 1984 won't be like 1984." (Levy, 1994: 170; Friedman 2005).

The ad implicated the role of IBM or ate least any conglomeration of centralized power as the Big Brother, when Apple adopting the female model was the alternative solution, that of a company that promoted a computer available to everybody, above gender or information restriction. According to Friedman,

[30] 2001: A Space Odyssey is a 1968 science fiction film directed by Stanley Kubrick, written by Kubrick and Arthur C. Clarke. The film deals with themes of human evolution, technology, artificial intelligence, and extraterrestrial life, and is notable for its scientific realism, pioneering special effects, and provocatively ambiguous imagery and sound in place of traditional narrative techniques (source: <http://www.imdb.com>, retrieved on September 2007

"Casting IBM as a monolithic threat to freedom allowed Apple, already a $500 million company at the time, to present itself as a lone underdog by comparison. Apple may present itself as a smaller, kinder, gentler corporation, but it operates by the same rules of the marketplace as everybody else…that doesn't much affect the underlying inequities of capitalism". (2005)

Fig. 12. Apple Commercial (1984).
Source: Wikipedia

*Commodity Fetishism*

During the following decades Apple's corporate root continued the idealistic principles of decentralisation, democratic autonomy and the restoration of nature, along with a range of elegant products, tight locked software and operating system which discouraged any efforts from third-party developers to clone the Mac[31] phenomenon (Pfaffenbergen 1988:44). Soon the market was dominated from standard computers of the business oriented IBM and the instantly successful Microsoft Windows[32], which incorporated a suspiciously similar to the Mac user-interface. Columnist John Dvorak gave a radical explanation of Apple's failure to dominate the computer industry. In 1984, he stated that a DOS-equipped IBM PC was «a man's computer designed by men for men» (as cited in Gelernter, 1998:36). In simple words, technology and especially computer technology was a man's world with no place for ideas of beauty. There are many examples in the technological world that elegant and user-friendly innovations were eventually adopted under the label «ladies aid», such as the electric starter in automobiles (id. at 37). Another important factor was the reluctance of Apple's executives to sell their products in more competitive prices in the early 1980's when the company had still the chance to be the leader in

[31] Shortcut for "Macintosh"
[32] See Appendix.

the personal computer market. «We make Hondas, we don't make Yugos» was the corporate slogan until the late 1990's (Levy, 1994:233). This decision along with problems in the company infrastructure led to a shrinkage of Mac percentage in the computer market in a poor 4% in 1997, when the company was 90 days behind bankruptcy (Levy 2006:230).

Nevertheless, even with minor sales comparing with the global computer market, which is still dominated by IBM PC clones and Windows Operating system, Apple survived the infertile 1990's, while creating a small but fanatic Macintosh market. The elegance of its products in combination with the strong ideological pattern of the only resisting company to Microsoft's totalitarianism contributed to the formation of a brand identity that became strongly related to creative communities and a healthy suspicion of corporate conglomeration (Punt, 1998:70). In other words, Apple Inc. while being a several million dollars company remained a "pirate" of the industry, while its customers turned from consumers to members of a very special community. The museum galleries contributed in their own aspect to the Mac fetishism. In many computing galleries across the world, putting an Apple product on display it just feels right. After all, Apple's engineers viewed themselves as artists "spawned by the protean nature of the computer" (Levy 1994). Museums on the other hand, are commonly related with art incorporation in their collections. Many museum scholars have detected the dangers of interpreting artefacts with aesthetic terms; still, the temptation is always present (Finn 1965:77; Dark, 1969:1130).

Recently, a research for a possible donor of a first generation Apple iPod (which can be described as a limited miniaturisation of a personal computer) attracted the media attention and a number of people voluntarily donated their mp3 players. An iPod with its owner's personal music library will be displayed as the ultimate music player of the 21st century. Rob Skitmore, member of the curatorial department of the Science museum emphasises the fact that

> "The iPod will then become part of the Science Museum's historic collections and be conserved and preserved for future generations."[33]

The iPod acquisition could be a characteristic example of a modified commodification, which in many cases responds to injustices or misinterpretation in existing patterns of consumption (Bennett, 2001:114). iPod might be a bestselling

[33] <http://shop.ipodworld.co.uk/weblog/archives/2007/06/museum_searchin.html>, retrieved on September 2007

device in the United States and Europe, but the sales statistics do not include low-range music players that being produced from unknown brands and having little exchange nor aesthetic value. The portable audio experience in the end of the 20th century will be probably represented to the future generations through the iPod, unquestionably and with no archaeological evaluation, as it is already part of many museum collections.

## Discussion

### *The concept of the Universal Machine*

The previous case studies were part of an effort to examine computing material culture particularly in the concept where artefacts continue their useful life as exhibits. Five generations of computing technology were unveiled having in common the idea of the Universal Machine, a device that would be able of any mathematical computation (Campbell-Kelly et al., 2004: 46). An approach of computers in the concept of technological progression would be less intriguing if not strictly technical. There was inevitably a technological evolution in terms of incorporation of new materials, improvements in performance, reduction of physical size and multiplication of possible uses. Meanwhile, the computing principle remained unaltered from the time that Babbage was trying to capture the universal calculation using mechanical methods. According to this principle, any computer can compute every computation from mathematical calculations to the complex algorithms of a digital video file, regardless the time it would take. (Gelernter, 1008:47) in the interim, there are alternative meanings in computing, that connect material culture from a period of two hundred years.

### *The individual thought*

Already from Babbage’s days, the role of the Universal Machine, which was materialised in a form of electronic machines, was mainly political. The only difference is that during the Victorian period, the public service could satisfy the demand for universal applications effectively and affordably (Agar, 2001:142-3). At this point, the government turned Babbage’s project down because there was no reason to invest. As the industrial population dramatically increased and multiplied the demand of state social action, Herman Hollerith as an individual, provided the appropriate computing solution. Computing might have accelerated social control, but its technological progression was mainly a product of individual thought, along with sufficient government funds. In the occasions that the individual creativity slipped from well-defined computational demands, inventors had to struggle with corporate bureaucracy and in most occasions they failed. The exception to this norm was the personal computing industry as it can be viewed through relevant artefacts on display in the “Making the Modern World” gallery in the Science Museum.

The material culture of computing shows that their inventors had developed a close relationship with their creations although in some cases these creations were technological dead-ends. Babbage’s excursive creativity resulted in the abandonment of the viable Difference Engine, engaging him with the design of the Analytical Machine, a device that few of his contemporaries could understand and even less could find usable. Seymour Cray is considered as the classic individual and ultimate engineer of the computer age (Hoffman, 1983). He once stated “it is hard to do it (computer design*)* as a group activity” (Allison 1995:7). In the end, his obsession in the vector architecture which was his personal contribution in supercomputing, misled him from the simplest approach of parallel processing, which made high-speed computer more affordable and thus widespread in the scientific laboratories. Computers always carry some of the individual aura of their inventors. Pegasus computer comprehends Strachey’s intelligence in its infrastructure. It was one of the first computers to be designed with a human-interface aiming to be user-friendly. Steve Jobs the co-founder of Apple Inc. chose a more straightforward way to patronise his revolutionary personal computer. The first Macintosh computer was something more than a machine with a distinctive aesthetic form. In order to emphasise to the technological importance of their product, the Macintosh Division signatures were moulded on the inside of the Macintosh’s case, in a place that only authorised technicians could access.

*The social impetus of computing*

The people behind computing worked on their perfection driven from scientific interest, visions and posthumous fame. However, the key factors in the rapid technological development of computers were the industrialisation of the society from the 19$^{th}$ century along with a subsequent growing capitalism. Also, the 20$^{th}$ century warfare made the need of powerful computing inevitable. In this concept, computers can be seen as the materialisation of bureaucracy, corporate and government control.

Agar asks the implicit question "Why Computers fit so well into the managerial corporations and public government departments in the 20th century?" and he instantly replies, "Because computers were made in their image" (2001:149). Computing became a reality only when agency realised its potential and incorporated its applications. This one-dimensional approach led to dehumanising practices and worked sometimes against the vision of the inventors. In one occasion Steve Jobs described his mixed feelings of awe and contempt, when he watched a classified military tape that he was not supposed to see. He realised that every tactical nuclear weapon in Europe operated by American personnel, was targeted by an Apple II computer. (Linzmayer, 1999:14) His utopian rhetoric for a democratic machine that would oppose the totalitarian use of computing was collapsed from the implications of free distribution. The military had simply purchased the machines from the retail market.

*The fortuity of computing*

Computers became a cultural phenomenon beyond the expected limitations of the agency. Once again, the individuals found applications that extend the use of computing above any imagination. The large centralised computers were and continue to be agents of authority while the corporate organisations like IBM invested extensively to this model (Pfaffenberger, 1988: 42). It was the ability of the consumers in generating new needs in an apparent endless series that led to the transformation of computers from a strict scientific and government tool to an attractive medium for entertainment, creativity and access to information resources (Campbell, 1997:37). Thus, the personal computer was not invented as a whole idea and at least in the beginning their developers did not have a defined application agenda. They were simply worked on a previously constructed idea of the extension of human memory, as it was envisioned from Vannevar Bush in the late 1940's. According to this vision, the collective memory and scientific research could be easily accessible to everybody. Clearly the materialisation of this Vannevar's dream to what nowadays is known as the World Wide Web was never intended to be a public network (Punt, 1988:64). Hence, in archaeological terms, computing artefacts correspond in a way with the Marxist theory that material culture is a reflection of dominance and resistance in the class struggle (Miller et al., 2000:1).

*Authenticity and Enchantment*

With its functional exhibits or the replicas that have been examined in the case studies of this essay, the Science Museum provides the ideal canvas for a discussion on the notion of authenticity. Cornelius Holtorf describes authenticity as a notion of Western Cultural history, originated in antiquity. According to this thesis, authenticity can be assumed as a condition that is being formatted during the life cycle of an object and cannot be artificially created. Thus, authenticity has been commonly used as a criterion of the material integrity of the object itself. The conservation ethics have been based on this theory, following the principle "Conserve, do not restore" with minor alterations.

On the other hand, authenticity has become a cult, where virtually every object is to be conserved in its "authentic" form. Holtorf argues that the conceptual confusion of the actual meaning of authenticity results to an appreciation of the genuine not only in material terms, but in spiritual as well. In other words, the experience of authenticity can be described as the experience of the aura of the original. Accordingly to Michael Shanks, Holtorf cites that aura distinguishes the original from the reproduction. Hence, aura is the form in which age and authenticity can theoretically be sensed from the object itself. (Holtorf, 2005: 112-129)

To develop further on this thesis, aura can be easily described as a phenomenon that contains enchanting qualities. The case studies of the computing artefacts in the galleries of the Science Museum, clearly demonstrate that computing artefacts can enchant, despite the status of their material integrity. The Difference Engine No. 2 can be equally carry the same aura of the authentic portion of the Difference Engine I (or even more, as it is fully functional), provided that the audience do not know it as being a replica. In equal terms, the 1930's punched-card office can be certainly described as authentic, because it is based on the "typical" romantic representation of the 1930's era.

> "In a way…exhibitions are not consequences of existing …artefacts, but …artefacts are consequences of existing …exhibitions". (Holtorf, 2005:121)

Holtrof concludes that the problem appears when we ignore the role of the archaeology in determining which objects do or do not have aura (id. at 116). Concerning that the majority of the technological museums do not include archaeologists in their personnel, the danger of misinterpretation of the displayed objects is prominent.

*Aesthetics and commodity fetishism reconsidered*

Gelernter's study on the aesthetic of computing demonstrates the close relationship between "beautiful technology" and computing development.  On the other hand, the examined artefacts such as the Cray 1A or the iPod are generally considered as objects with high aesthetic value, that makes them eligible to be displayed in museums of modern art.

In equal terms, according to Bennett's study on commodity fetishism, the high exchange value of an object can lead to a misunderstanding of its user-value, having subsequent impacts when the object is placed in a museum collection. Christine Finn in her archaeological journey in Silicon Valley gives an accurate account on the anomalies in the exchange value of computers, which in many ways depends on its social function.

Thus, the exchange value of a Cray 1A in 1976 was approximately $8 million.[34] This figure did not only represent the years of research and computing development. Along with is technofunction, Cray 1A acted in a sociofunctional way, being the fastest computer of its era, indicating the scientific superiority of the organisation that could purchase it. John Rollwagen, the sales manager of Cray Research Inc., emphasized in the sociofunction created an unprecedented auction between the two most important a American research laboratories (Los Alamos National Laboratory and Lawrence Livermore Laboratories) for the privilege to be the first of having a Cray 1A (Murray, 1997:144).

Two decades later, a Cray supercomputer could be purchased for as less as $10,000, mainly because of its ferrous materials. Nonetheless, it did not take long for a re-evaluation of Cray 1, based this time on its ideofunction. Being a collectors' item, an original memory board has a much higher exchange value. (Finn, 2000:163).

The problematic of this cycle of functional change and exchange value transformation is that computing artefacts as contemporary objects without archaeological evaluation can be acquired and displayed in museum collections, containing artificial meaning.

[34] Finn mentions a cost of $19 million. However, the majority of the other sources are closer to a figure of $8 million.

## Conclusion

Undoubtedly computing artefacts constitute a significant range of material remains of the contemporary past. Their social impact in the last two centuries created the emergence of their collection and demonstration in a variety of museums and institutions. The vast majority belong to technological collections, and their usual interpretation of meaning is that of technological progression.

However, the role of archaeology in the demonstration of their social meaning is still ignored. This essay shows that despite the rich available historic resources and documentation, comprehensive recording and classification of computing artefacts, their social role is awaiting for further research.

The anthropological approach of the digital computing environment restricts the social significance of computers in their application and not on their material form.. The vision of the people who contributed in the computing development along with the role of the ordinary consumers or amateurs can transform the displaying principles of computers in exciting and non-imagined directions. The emergence of historical archaeologists in the computing collections of the technological museums is inevitable in order to create a vital understanding of what computer meant to the 20th century society. The physical preservation of computing material culture can be also benefited from the contribution of the historical archaeology, in an effective application of the conservation ethics with respect to the historical integrity of the artefacts.

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## Appendix: Computer Terminology

| | |
|---|---|
| BASIC | acronym for Beginner's All-purpose Symbolic Instruction Code, which refers to a family of high-level programming languages. The original BASIC was designed in 1963, by John George Kemeny and Thomas Eugene Kurtz at Dartmouth College, to provide access for non-science students to computers. |
| Bitmap display | a computer output device where each pixel displayed on the monitor screen corresponds directly to one or more bits in the computer's video memory. Most modern personal computers and workstations have bitmap displays, allowing the efficient use of graphical user interfaces, interactive graphics and a choice of on-screen fonts. |
| CPU | central processing unit (CPU), or sometimes simply processor, is the component in a digital computer capable of executing a program. |
| Graphical User Interface (GUI) | a type of user interface which allows people to interact with a computer and computer-controlled devices which employ graphical icons, visual indicators or special graphical elements called "widgets", along with text, labels or text navigation to represent the information and actions available to a user. The actions are usually performed through direct manipulation of the graphical elements. |
| Human Computers | Before mechanical and electronic computers, the term "computer", in use from the mid 17th century, literally meant "one who computes": a person performing mathematical calculations. Teams of people or human computers were used to undertake long and often tedious calculations. The work was divided so that this could be done in parallel. |
| Integrated circuit | a miniaturized electronic circuit (consisting mainly of semiconductor devices, as well as passive components) that has been manufactured in the |

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| | surface of a thin substrate of semiconductor material, usually silicon. |
| Key punch | a device for entering data into punched cards by precisely punching holes at locations designated by the keys struck by the operator. Early keypunches were manual devices. Later keypunches were mechanized, often resembled a small desk, with a keyboard similar to a typewriter, and with hoppers for blank and punched cards. Some key punch models could print at the top of columns, the character punched in each of those columns. The small pieces punched out by a keypunch fell into a chad box, or (at IBM) chip box, or bit bucket. |
| Magnetic drum memory | an early form of computer memory that was widely used in the 1950s and into the 1960s, invented by Gustav Tauschek in 1932 in Austria. For many machines, a drum formed the main working memory of the machine, with data and programs being loaded on to or off the drum using media such as paper tape or punch cards. Drums were so commonly used for the main working memory that the machines were often referred to as drum machines. Drums were later replaced as the main working memory by core memory, which was faster and had no moving parts, and which lasted until semiconductor memory entered the scene. |
| Magnetic tape: | a medium for magnetic recording generally consisting of a thin magnetizable coating on a long and narrow strip of plastic. Nearly all recording tape is of this type, whether used for recording audio or video or for computer data storage. It was originally developed in Germany, based on the concept of magnetic wire recording. |
| Mathematical tables: | Logarithmic and trigonometric tables with use in astronomy, navigation, life insurance, civil engineering etc. (Campbell et al, 2004:3-4). |
| Microsoft Windows | the name of several families of software operating systems by Microsoft. Microsoft first introduced an operating environment named Windows in November 1985 as an add-on to MS-DOS in response to the growing |

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| | interest in graphical user interfaces (GUIs). Microsoft Windows eventually came to dominate the world's personal computer market, overtaking Mac OS which had been introduced previously. |
| Mouse | In computing, a mouse functions as a pointing device by detecting two-dimensional motion relative to its supporting surface. |
| Mp3 player | a portable, handheld digital music player that stores, organizes and plays digital audio files. The most popular format for a digital audio is named Mp3. |
| MS-DOS | an operating system commercialized by Microsoft. It was the most commonly used member of the DOS family of operating systems and was the dominant operating system for the PC compatible platform during the 1980s. It has gradually been replaced on consumer desktop computers by various generations of the Windows operating system. |
| Nickel delay line memory | a form of computer memory used on some of the earliest digital computers. Like many modern forms of electronic computer memory, delay line memory was a refreshable memory, but as opposed to modern random access memory, delay line memory was serial access. Information introduced to the memory in the form of electric pulses was transduced into mechanical waves that propagated relatively slowly through a medium, such as a cylinder filled with a semi-viscous liquid like mercury, or a magnetorestrictive coil, or a piezoelectric crystal. |
| Number Cruncher: | a slang term used in Computer engineering to refer to any computing operation that requires a large number of arithmetic operations (adding, subtracting, multiplying and dividing) - as opposed to (for example) memory reads and writes, accesses to disk drives or networking operations. By extension, a Number cruncher is either a computer that is dedicated to that kind of processing because of its role in some organisation - or a computer CPU that is especially designed to be good at arithmetic |

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| | operations (typically at the cost of being worse at other things). |
| RAM | a type of computer data storage. It takes the form of integrated circuits that allow the stored data to be accessed in any order — that is, at random and without the physical movement of the storage medium or a physical reading head. |
| Vacuum tubes | electronic components able to modify an electrical signal by controlling the movement of electrons in a low-pressure space. They enabled the development of electronics technology, leading to the development and commercialization of such technologies as radio broadcasting, television, radar, high fidelity sound reproduction, large telephone networks, modern types of digital computer, and industrial process control. Many of these technologies pre-dated electronics, but it were electronics that made them widespread and practical; analogue computers such as slide-rules have become almost extinct due to electronics. |
| Vector processor architecture | A vector processor, or array processor, is a CPU design that is able to run mathematical operations on multiple data elements simultaneously. This is in contrast to a scalar processor which handles one element at a time. The vast majority of CPUs are scalar (or close to it). Vector processors were common in the scientific computing area, where they formed the basis of most supercomputers through the 1980s and into the 1990s, but general increases in performance and processor design saw the near disappearance of the vector processor as a general-purpose CPU. |
| WYSIWYG | acronym for What You See Is What You Get, used in computing to describe a system in which content during editing appears very similar to the final product. |
| Xerography | Know also as electrophotography, is a photocopying technique. |