Computer Conservation Society

Aims and objectives

The Computer Conservation Society (CCS) is a co-operative venture between the British Computer Society, the Science Museum of London and the Museum of Science and Industry in Manchester.

The CCS was constituted in September 1989 as a Specialist Group of the British Computer Society (BCS). It is thus covered by the Royal Charter and charitable status of the BCS.

The aims of the CCS are to

- Promote the conservation of historic computers and to identify existing computers which may need to be archived in the future
- Develop awareness of the importance of historic computers
- Encourage research on historic computers and their impact on society

Membership is open to anyone interested in computer conservation and the history of computing.

The CCS is funded and supported by a grant from the BCS, fees from corporate membership, donations, and by the free use of Science Museum facilities. Membership is free but some charges may be made for publications and attendance at seminars and conferences.

There are a number of active Working Parties on specific computer restorations and early computer technologies and software. Younger people are especially encouraged to take part in order to achieve skills transfer.

Resurrection

The Bulletin of the Computer Conservation Society

ISSN 0958 - 7403

Number 24

Autumn 2000

Contents

Editorial

Nicholas Enticknap

This issue has taken an unusually long time to put together. We apologise for the delay, and hope you feel it is better late than never.

Much has happened since the last issue. Your Society has a new chairman, Ernest Morris, and one of the first tasks of his reign will be to superintend changes necessary to the financing of our society.

The AGM authorised the Committee to introduce membership subscriptions should it become necessary. This is quite likely, as the Society's finances are at a low ebb at the moment — the Treasurer reported that there was just £120 in the kitty at the end of the financial year in April. For the time being though, the Committee is still inviting voluntary donations, especially from Society members who are not also members of the BCS.

Our outgoing chairman Brian Oakley recorded at the AGM our pleasure at the knighthood awarded to Maurice Wilkes. It was pleasant to see IT further recognised with the award of a knighthood to programming pioneer Tony Hoare and of a damehood to Steve Shirley.

Significant computing anniversaries are now following one another thick and fast. Following the celebrations for Manchester University's 1948 breakthrough and for the start of the world's first computing service based on Edsac at Cambridge University in 1949, the highlight this year has been the golden jubilee of the National Physical Laboratory's Pilot Ace, which we celebrated with a one day seminar in May. Sir Maurice Wilkes was inspired by this event to reflect on early computer circuitry, and the results of his thinking form our first feature article in this issue.

Output printing is today taken for granted, but it took many years for the pioneer designers to perfect an output device capable of matching the internal speed of the computer. In our second feature, Tony Wix describes the engineering difficulties involved from the perspective of a British designer working for ICL and its component companies.

The Internet is also taken for granted now, even though it has only been part of most of our lives for around five years. The World Wide Web itself dates back only to 1989, and that is later than the Domesday Project, which forms the subject matter of our third feature article.

News Round-Up

Brian Oakley has relinquished the chairmanship of the Society after four years at the helm. The AGM elected Ernest Morris as his successor.

- 101010101 -

Simon Lavington is looking for contemporary photographs of people involved in the design and development of Pegasus for use in his new booklet on this pioneering Ferranti computer. Photographers at the time concentrated perhaps naturally on the machinery, and the sung and unsung heroes and heroines of the project were neglected in comparison. Anyone who can help can find Simon's contact details on page 32.

- 101010101 -

Doron Swade and his team at the Science Museum completed assembly of the printer for the Difference Engine in April, in time for the launch of Doron's book "The Cogwheel Brain".

- 101010101 -

In December the Society will present a talk on early calculators, including the BTM 541, 542, 550 and 555 and the Powers Samas EMP, and associated early computers including the BTM 1201 and 1202, the Powers Samas PCC and the ICT 558. Hamish Carmichael would love hear from any member who has documentation of any of these machines — manuals, brochures, plugboard layouts and the like. Anyone who would like to contribute a talk on any of these machines at the meeting should likewise get in touch with Hamish.

- 101010101 -

The Science Museum's new Wellcome Wing was formally opened by HM The Queen at the end of June. Billed as "the world's leading centre for the public presentation of contemporary science", it features over 40 terminals linked in an intranet to a database that is updated daily.

- 101010101 -

As we were going to press we heard the sad news that Derek Milledge had died. Derek was an enthusiastic supporter and a leading light in the Pegasus Working Party, knowing more than anyone of the details of its programming and operation. He had been designing software since the early 1950s, and we will greatly miss his detailed knowledge of the pioneering times. We plan to publish a fuller appreciation in our next issue.

- 101010101 -

We regret to report also that Donald Davies died in May aged 75. Donald, whose work with computers started on the Pilot Ace in 1947 and who subsequently became best known for his pioneering work with packet-switching, was a good friend of the Society who often contributed to *Resurrection*. We publish a last letter from him in this issue.

- 101010101 -

Another who is no longer with us is the Earl of Halsbury, who died in January aged 91. Lord Halsbury was as managing director of the National Research Development Corporation from 1949 to 1959 a highly influential figure in the development of the British computer industry. A former president of the British Computer Society, he attended some of the earlier Society functions.

- 101010101 -

Paul Rojas of the Freie Universitaet Berlin tells us that he and his colleagues "have re-implemented in Java the first chess program ever written". The original author was none other than Konrad Zuse, who wrote it during the war in a high level language called Plankalkűl. No compiler was ever produced for this language until Professor Rojas and his team did so in February this year. Readers interested in the program can get at it at the Zuse Internet Archive at <www.zib.de/zuse>, using the button marked 'simulations'.

- 101010101 -

John Deane of the Australian Computer Museum Society is writing a history of Silliac, Sydney University's copy of John von Neumann's IAS computer. As part of this project John has compiled a list of all the machines inspired by and based on the IAS design, 18 in all. He is looking for information about the shutdown dates for all of these machines. Anybody who can help should contact John at <John.Deane@tip.csiro.au>.

- 101010101 -

Can any member give one, or even two, Philips minicomputers a good home? A P851, built around 1978, and a P854, probably a couple of years younger, are offered, complete with manuals for hardware, software and programming. For further details contact Ray W Clarke at <ray@clarke.demon.co.uk> or <rwclarke@iee.org>.

- 101010101 -

The Winston Churchill Memorial Trust has sent the Society details of an attractive offer. The Trust provides a number of Travelling Fellowships which are available to British citizens of any age and from all walks of life, irrespective of academic or professional qualifications. They enable their holders to travel overseas to undertake study projects related to their trade, profession or particular interest. Anyone interested please contact Hamish Carmichael.

- 101010101 -

The Committee is planning to make *Resurrection* available from our Web site in PDF format, instead of LaTeX, Word and ASCII as at present.

- 101010101 -

Readers who have general queries to put to the Society should address them to the Secretary at the address given on the inside back cover.

Members who move house should notify Hamish Carmichael of their new address to ensure that they continue to receive copies of *Resurrection*. This is because the CCS membership is different from the BCS list.

- 101010101 -

North West Group contact details

Chairman **Professor Frank Sumner FBCS**, Department of Computer Science, University of Manchester, M13 9PL. Tel: 0161 275 6196.
Secretary **William Gunn**: Tel: 01663 764997.
Email: bengunn@compuserve.com
Science & Industry Museum representative **Jenny Wetton**, Museum of Science & Industry, Liverpool Road, Castlefield, Manchester M3 4JP. Tel: 0161 832 2244. Email: curatorial@msim.org.uk

Recollections of Early Vacuum Tube Circuits

Maurice Wilkes

A remark made by one of the speakers during the Ace 2000 seminar brought back to me very vividly the climate of the late 1940s when the first stored program digital computers were being designed. It was to the effect that Ted Newman did not care for the circuits for a possible Pilot Ace that Harry Huskey had designed, and preferred to design the real Pilot Ace in his own way.

The early radio engineers were concerned with sine waves of various frequencies — radio, intermediate, audio — and nothing else. By the 1930s cathode ray tubes were coming into use and bringing with them new and strange wave forms, particularly time bases and strobes. Primitive analogue computing devices were also appearing. A new term, 'electronics', was coined for the new technology.

Electronic techniques were much to the fore in ionosphere research and in television. They were vigorously exploited during the war for radar and other applications and, by the end of the war, knowledge of electronics had become widespread.

The designers of the early digital computers felt entirely confident that electronic techniques would meet the challenge. In fact, electronics offered them an embarrassingly wide range of alternative techniques to choose from. The first thing they had to do was to decide on the best way to realise gates and flip-flops and to evolve a consistent set of principles for putting them together to make a computer. There was not time for a careful and exhaustive appraisal, and each designer made his choice largely on the basis of personal preference. Although their experience in other applications of electronics stood them in good stead, computer designers soon found they had to learn a few new tricks, such as how to handle non-repetitive wave forms.

There were three main approaches to the design of trees and gating circuits. One was by means of what were called Kirchov circuits, that is, resistor networks feeding amplitude discriminators. This was essentially an analogue approach. Another was to make use of pentodes with independent inputs applied to the control grid and to the suppresser grid. Thirdly, use could be made of diodes.

Obviously vacuum tubes would be used for amplifiers and this seemed straightforward enough. However, the output was at a much higher voltage than the input, and the inter-stage coupling circuits had to allow for this. The designer could either use capacitors or pulse transformers for inter-stage coupling, with diodes for zero restoration (otherwise called clamping), or he could use a resistor chain, perhaps with capacitors for frequency correction.

Having made his choice, every designer was firmly convinced that his way was the best. This was only natural. I myself was no exception to the rule. I would stand up stoutly for the superior merits, as I saw them, of the Edsac design philosophy. Likewise, it was inevitable that Ted Newman, an ex-EMI man and a disciple of Blumlein, should have no time at all for Harry Huskey's Eniac-style circuits.

Yet in spite of all the strong feelings, it was found, when the chips were down, that all the early computers worked with much the same degree of reliability. It was not that the doubts which had been expressed about pattern sensitivity, stability and so on were not well founded. What experience showed was that, if the engineering were carefully and competently done, most schemes could be made to work.

The chart (see overleaf) is intended to illustrate the great diversity that existed in the way selected circuit functions were implemented in the first wave of computers. It was constructed partly from memory and I make no great claim for its accuracy. Not all the functions required in a computer are included in the chart; for example, there is no mention of control logic.

Events moved fast in the first few years. Kirchov circuits dropped out and pentode gates became unpopular. Germanium diodes, which were not available when the Edsac design started, soon came along. At first, there were doubts about their reliability and recovery time, but confidence was soon established, and the Seac made free and elegant use of them. The merits of parallel architectures became recognised, one being that they opened the way to DC inter-stage connection. Finally, when all seemed set for a great future with vacuum tubes, transistors came along and we were all back at square one.

Blumlein died early in the war and we can only speculate as to what his approach to digital design would have been. He is famous for his insistence that a circuit should be designed on paper, with the expectation that it would work first time. This used to puzzle me, until I realised that he must have been referring to Kirchov circuits. How right he was! Anyone who has worked with such circuits will have found that to proceed without working out a properly toleranced design in advance is a good way to hang oneself!

Blumlein would have approved of one feature in the design of the Edsac, namely the use of cathode-coupled amplifiers. These are essentially long-tailed pairs, a special favourite of Blumlein's. If the tail is not made too long they have very good clipping properties and they do not invert the pulses. For this latter reason the Edsac contained no inverters.

	Eniac	SSEM	Edsac	Pilot Ace	Seac	Swac	IAS
Interstage Coupling							
Kirchov				⋆			
Capacitor and DC restorer			⋆	⋆			
Pulse transformer and DC restorer					⋆		
DC							⋆
Trees							
Kirchov	⋆			⋆			
Diode			⋆		⋆		
Adder							
Kirchov		⋆					⋆
Pentode	⋆	⋆				⋆	
Triode				⋆			
Diode			⋆		⋆		
Flip-Flops							
Static	⋆	⋆	⋆	⋆		⋆	⋆
Dynamic					⋆		

This chart shows the great diversity in the way in which circuit functions were implemented in first generation computers. The computers were: Eniac - Electronic Numerical Integrator and Calculator (University of Pennsylvania): SSEM - Small-Scale Experimental Machine (Manchester University 1948); Edsac - Electronic Delay Storage Automatic Calculator (Cambridge University): Pilot Ace - Automatic Computing Engine (National Physical Laboratory): Seac - Standards Eastern Automatic Computer (US National Bureau of Standards); Swac - Standards Western Automatic Computer (US National Bureau of Standards); IAS (called after the Princeton Institute of Advanced Study).

Obituary: John Grover

Leo pioneer John Grover has died. John played a principal part in the coding of the world's first routine business application on an electronic computer. The application went live in November 1951.

John joined Lyons, the catering company that built Leo, after service in the RAF. He was recruited as a management trainee, but was selected to work on Leo in the first trawl through the company's promising young people.

David Caminer, who was Leo's systems and programming manager at this time, has paid this tribute to John Grover. "John played an invaluable part in out very very small team. He followed the methodology that we laid down unswervingly and made it possible to get it firmly established as newcomers were drawn in. He was a fine trainer and many of the young men and women who were recruited learned the new discipline working under him."

John later joined the computer enterprise at EMI. When EMI was absorbed by ICT he was appointed to a senior sales management post in that company and subsequently within ICL, where he was re-united with several of his old Leo colleagues again.

CCS Web site information

The Society has its own World Wide Web (WWW) site: it is located at **http://www.cs.man.ac.uk/CCS/**. This is in addition to the FTP site at **ftp.cs.man.ac.uk/pub/CCS-Archive** (please note that these URLs are case-sensitive). Our Web site includes information about the SSEM project as well as selected papers from *Resurrection.* Readers can download files, including the current and all past issues of *Resurrection* and simulators for historic machines.

In the Footsteps of the Conqueror

Nicholas Enticknap

The 900th anniversary of the Domesday Book, William the Conqueror's great survey of all his domains, seemed a suitable occasion for the BBC to try to produce a modern equivalent. As things have turned out, 1986 proved to be a couple of decades too early, and the Domesday Project can be voted at best only a partial success. It did however provide the BBC with valuable experience which is today being used to create innovative historical Web sites.

William the Conqueror's audacious attempt to create an inventory of everything he owned in the whole of England still excites admiration, and the result is still invaluable to scholars. It was not until the 19th century that a comparable census of the population was taken, and not until the 20th Century that subsequent administrators assembled anything like as complete a picture of the country's economic assets.

As the 900th anniversary of the Domesday Book approached, it seemed to the BBC a good idea to celebrate the occasion by producing a modern variant. As a result the Domesday Project was born.

The idea was to create a similar survey of the whole country visually rather than verbally, by means of a series of layered maps. Starting with a map of the whole country, you could drill down layer by layer until, in some towns at least, you could reach a level of detail showing individual buildings. Each layer was accompanied by text and other materials explaining what could be seen.

Fourteen years later, the BBC hosted a presentation to the Society at the Science Museum describing the Project.

The story started in the late seventies and early eighties. At that time, the BBC had embraced computer technology in a big way, producing a variety of television programmes about computing in general, and following that up by joining forces with Acorn, at the time a major player in the computer education market, to produce the BBC micro. This led to a series of 'how-to-do-it' programmes, created by the lead speaker at the Society's presentation, George Auckland, who is now Head of Digital Media Presentation for the BBC Education Department.

The awareness of computer technology within the BBC generated by the BBC micro project led to the idea of the Domesday Project. Furthermore, as George Auckland said, "That machine had qualities which lent themselves to education". A most important feature was the Video Editing System chip within the machine, which had 32Kb memory of its own, a huge amount in 1983 when the Domesday Project started.

The initial idea was that the eventual end product should be sold as an add-on to the BBC system at a price of around £1000. But things did not work out quite like that.

Apart from using the BBC micro, "we had no idea of what technologies should be used", the main speaker, Professor Stephen Heppel, told the Society. Ultimately, the choice fell on LV-ROM video discs, the forerunner of today's CD-ROMs, with a capacity of 650Gb per side. They contained both moving sequences and programs written in BCPL. These programs were controlled via the BBC system's Video Editing chip, allowing you to jump from sequence to sequence via menu bars at the bottom of the screen.

For data gathering the BBC called on the assistance of the nation's schoolchildren. According to Heppel, "Children were given a 1km square to look after. They wrote about it, and photographed it." Writing about it was a harder task than it would be today, as that was before the days when every schoolchild learnt keyboard skills as a matter of course.

It was a massive logistical exercise, said Heppel, as "One million kids were involved. In places where there were no schools, we drafted in the WIs.

"The photographs were either commissioned or sent in by the schools. They were then mounted on walls in a virtual gallery. There were doors in the gallery leading to the outside world. There was the idea of a 3-D space you could explore: it would be a hot Web site today. Three photos only were associated with each square, because of limitations on storage space. But it would still take seven years to see it all on a 9-to-5 day basis."

Nonetheless the result, though an invaluable archive from the future historian's point of view, did not meet all its objectives. Part of the reason for that was the costs turned out to be much higher than foreseen, and so the price of the system was at £6000 rather too much for most individuals and even for many schools.

Heppel admitted that the Domesday Project, judged from the short term perspective at least, was only a qualified success.

“There were three fatal errors. First, it was very expensive - the price of a small family car at the time. Second it was jolly hard to find your way around - making the map layers work, for example. Third, it lacked extensibility. People were disappointed with what it said about them.”

Many of these limitations have been resolved with the passage of time. Storage space is much cheaper today, for example, so it would have been possible to add in many more pictures. Object-oriented programming technologies have also moved on apace, which would have made the provision of database navigation tools much easier.

The BBC itself has moved on, and now has its own history Web site, at <bbc.co.uk/history>. According to the BBC Education Department’s Chris Warren, this “is a top line generic site dealing with many different aspects of history. We are trying to build a history educational resource. It is aimed at everyone, primarily at adults but small children as well.”

Another current project is the History 2000 Web site, commissioned by George Auckland. “We are trying to create a live Web site. Our brief is broad. Others who engage in it have deep knowledge, and we want them to join with us in creating content. The Web was a perfect vehicle for getting this kind of thing going.”

Chris Warren described the History 2000 project. “History 2000 is a Millennium project to encourage audiences inspired by BBC programmes to find out more about history. We have 1000 partners around the UK providing content on the Web site. There is a calendar of events on the Web site.

“We want to encourage people to submit photos to the Web site so that we can publish them fairly quickly. It was launched in September 1999. It will be part of the National Grid for Learning.”

All of these initiatives can trace their origins back to the Domesday Project. As Chris Warren said, “The Domesday Project proved you can build a useful resource in partnership with the whole country. So the BBC site is the great-grandchild of the Domesday Project.”

Editor’s note: this is a report on the seminar hald by the Society at the Science Museum on 2 March 2000.

Bombe Rebuild Project

John Harper

Manufacturing progress has been excellent over the past few months. There is not enough space here to cover everything, so I will just pick on some highlights.

The Society of Model and Experimental Engineers has completed the machining of the main gearbox and clutch housings. This was a highly specialised operation requiring the use of precision machinery. The result is excellent and very impressive. Future machining is simple in comparison, so we treat this as a major step forward.

On the Bletchley Park site, but not directly associated with the Trust, is a Mechanical Engineering Apprentices College. We have met with the management at various functions arranged by the Trust, and as a result the apprentices are making intricate parts. In addition, the staff has been helping us by providing the use of CNC machinery. Examples of the parts that have been made are the steel cams that drive the Bombe carry mechanism. They were machined using computer files generated on our CAD systems. Another example of the College's work is the manufacture of tapered brass wiring pins. This work has started, but with 6000 required we still have a long way to go.

It might be worth mentioning here for those who have not seen it elsewhere that the Bletchley Park Trust has now signed the lease for the main part of the site. This allows the Trust to move forward at last, and to plan the future. The level of cooperation between the Trust and the Rebuild Project is very good, and is improving as BP plans develop.

While manufacturing has been progressing well, we have also been drawn into a diversion we very much welcome.

Many readers will have read Robert Harris's novel "Enigma". This novel is currently being turned into a major film, and the producers have gone to great lengths to have everything as accurate as possible. When it came to filming a Bombe room, we were asked to assist a film effects company to create 'prop' Bombes. The level of detail which these people are prepared to go to is amazing.

They used many of our AutoCad drawings to make the external parts. In some cases our drawings were taken as a file, converted to a suitable format and fed directly into a CNC machine. From this process, many parts were made ‘exactly to drawing’.

Having British Bombes appear in a major WW2 film will greatly improve our public awareness. However there is a great deal more benefit to both the Bletchley Park Trust and the Rebuild Project when these ‘prop’ Bombes go on display at BP. They will not just be static displays: they have been made so as to allow the drums to rotate. Our project is committed to motorise one Bombe such that the rotation and carry action of the drums is made to be as original. By the time this report appears in print, the Bombes should be on display at BP, with the motorising planned to be working in September.

Our requests for assistance in *Resurrection* issue 23 for people to help with drilling and tapping have produced an excellent response. We now have a team of retired Nortel people working away in the basement of the Conference Centre at Nortel Networks Harlow, and the work is progressing extremely well.

The cableforming is also making good progress in the same area, as mentioned last time. We have also had a good response to our previous cry for help in the area of hardening and grinding. A technical college is carrying out initial experiments with the grade of steel we have used, and we are optimistic about the ongoing processing.

Lathe work is perhaps our largest single manufacturing operation and literally hundreds of parts have been made. However, there are still very large numbers of parts that need turning, and further help would be greatly appreciated.

We are now looking for help in refurbishing and rebuilding our stock of Hollerith relays. We also need a quantity of coils wound from scratch. For this, we have a coil-winding machine available. This work could be carried out by one person or split if required. All help would be welcome, and knowledge of Hollerith relays would be a distinct advantage.

Readers who feel they would like to help our Project can find my contact details inside the back cover.

Impact Line Printers - an ICL Perspective

Tony Wix

Line printers were developed to produce computer output more quickly than the teleprinters and similar devices used with the early computers.

Line printers had to meet four basic and different requirements:

a) to print data onto preprinted or constant format stationery, such as payslips, invoices, orders and standard letters, where accurate and non-ambiguous printing was a higher priority than pure speed (often printing was concentrated into an area of a few lines over the full page width);

b) to tabulate scientific data (to a maximum width of 160 columns);

c) to produce standard personal letters, where print quality was more important than speed; and

d) to print characters that could be read by an OCR B reader.

Overall, line printers were expected to achieve quality printing over long periods with minimal operator intervention, maintenance and parts replacement, and to handle the output of high fanfold paper flow tidily.

The first computer printers were generally solenoid-operated typewriters and modified tabulator printers operating at speeds of up to 100 lines per minute (lpm).

A major advance was made in the late 1950s in the US when Shephard proposed and patented the principle of 'hit on the fly' line printing. He used a print drum made up of discs, each with 48 characters embossed around its periphery. They were clamped together to cover 120 horizontal print positions. Print speed was 150 lpm.

Line printer mechanisms

Impact printing involved the movement of mechanical parts under the control of electronics.

Embossed characters were presented serially to the printing area, either vertically (on a print drum with its axis parallel to the paper) or horizontally (by a chain, belt or train moving across the paper).

Print hammers, one for each column of print, were situated on one side of the paper with the ribbon and drum on the other side. Hammers impacted the paper and ribbon against the drum to transfer an inked character onto the paper.

Embossed (reversed) characters moved continually at constant speed. As a result, during impact there was always some degree of smear — vertical from drum printers, sideways from train printers. This effect increased with speed, and thus was a factor in limiting speed.

Designers attempted to minimise this smear effect by reducing the limb width of the embossed characters. They also minimised the period of impact by using high hammer speeds.

A print drum typically had a 64 character repertoire around its periphery, repeated up to a maximum 160 times to provide multiple print columns. A subset of 48 of the most frequently used characters was grouped together, so that a line shift could occur during passage of the other 16 characters on most occasions. When this happened, the printing speed equalled the print drum speed. Nominal speeds quoted used this 'synchronous' subset.

There were two principal types of dynamics for line printing: controlled penetration printing, and ballistic hammer printing.

The early line printers were all controlled penetration systems. A pivoted arm had a hammer head at one end and an armature at the other, the latter being attracted by an electromagnet. The hammer was further away from the pivot than the armature.

A front stop with adjustable screw was positioned between the hammer head and the pivot, and an adjustable screw backstop determined start position and flight time.

Energising the electromagnet caused the arm to hit the front stop, flexing and overtravelling slightly to hit the paper, ribbon and embossed character and then quickly whip away.

This fast rebound minimised smear. The front stop position determined the depth of the impact, and thus the print density. In theory, a front stop control should have given the crispest print because of the short dwell time; in practice, it was difficult to maintain the front stop position. A very small change in distance had a profound effect on ink transfer and thus on print density, and in the extreme could cause random wear on the faces of the embossed characters.

On the early printers, the front stop was closer to the pivot, with large overthrow, and it was difficult to set front and back stop positions because they interacted. Adjusting flight time varied the initial air gap, energy input, hammer velocity and impact energy. The time taken to settle the arm was one limitation on printing speed.

Later printers, such as the Anelex Series 5 from the USA, had the front stop much closer to the hammer and less overthrow, and so were relatively more stable. They achieved speeds up to 1250 lines per minute.

In linear ballistic hammer printers each hammer was a free item, constrained only by a settling spring and guides to keep it along the flight path, which was a straight line through the centre of the drum. The hammer head was shaped to match the print drum curvature.

An electromagnetic actuator was energised to move a hammer sitting in contact with the arm. The hammer travelled in guided free flight to impact the ribbon, paper and embossed character, then rebounded to settle under control of the return spring.

The print density was set by adjusting the electrical energy supply to the actuator, while flight time was set by adjusting the arm rest position when fitted in the printer.

Among the advantages of the ballistic approach were automatic compensation for variations in stationery weight and thickness, which was considerable when for example you changed from a single part set to a six part set with interleaved carbons. The hammer geometry automatically ensured that the curved face of the hammer exactly fitted the drum face, which avoided clipping of printed characters.

RCA, English Electric Computers and ICL all used linear ballistic hammers. There were many variants on the theme: for example, CDC used rotary hammers and Data Products used flexure mounted hammers.

Media and Paper Feed

Ribbons were loaded with sufficient ink to allow them to transfer a clear character without smudging, and to have an acceptable life at reasonable cost.

To start with, ribbons were made from silk, imported from China. Silk had mechanically stable fibres which did not distort under impact, retained ink well, and gave the best quality print.

Later suppliers became concerned about the continuity of supply from China, and put much effort into developing nylon ribbons. By optimising warp, weft and strand thickness they developed ribbons of lower cost which became the workhorse, with silk only used where the highest quality printing was essential.

Single pass melinex or mylar ribbons with a deposited ink coating were also developed for printing of highly defined characters. This development had to overcome tracking and spooling problems.

The paper used had to withstand the acceleration forces as it passed through the printer, and the hammer impact force at the time of printing. Printer design teams usually included a media section, with a brief to maintain and improve quality by testing and providing customer service.

Line printers used continuous fanfold stationery with sprocket holes punched down both sides. They engaged on the pintles of pairs of tractors, which moved print line by print line so the paper was nominally stationary during printing. The tractors were flat to have as many pintles in line contact as possible, to spread the load.

Early printers used only one tractor pair, positioned after the print station. Later, faster printers used two pairs, one before and one after the print station. Each tractor slid along a plain round shaft for lateral positioning, and was locked into place before printing. A rotating drive shaft passed through each tractor gear wheel to provide the drive to the continuous chain or belt on which the pintles were set.

The drive shafts were connected to an induction motor and flywheel through an electromagnetic friction clutch and brake system. In the early years friction clutch systems provided the best high torque, low inertia drive characteristic required for the fastest single line shifts and therefore the fastest print speed. Later magnetic particle clutches and printed circuit low inertia servo motors began to appear.

When the rotating print drum was under impact, the drum tended to grab the paper, moving it backwards and so misplacing some printed characters. Paper was held taut between the tractors to resist such movement but, since it was only held by the pintles, it could tear if it was too tightly stretched under acceleration.

When a print hammer impacted a character and the adjacent character was not to be printed, the paper and ribbon were drawn towards that character and a ghostly image of it could appear on the paper. Ghosting was minimised by the correct choice of character pitch and by guiding the ribbon and paper in the print area.

Control Electronics

Core memory was used on early line printers. A core store consisted of a matrix of, say, 120 print columns by 52 characters, giving a total of 6240 cores, each of which had a column wire and a character wire threaded through it. Coincidence of two currents in a core located the character to the column to cause a print out.

Later, single line buffers holding a line of character codes were used. As a row of characters moved opposite the hammers, detectors on a coded disc on the drum axis defined the current character code. The store was scanned through the line for that character code, and where coincidence was found, hammers were fired at the drum. When all characters in the store had been read, a line feed was initiated and the store refreshed with the next line of print.

Scanning could start with the drum in any position, so that printing all the characters on the drum took one complete revolution, which was followed by a line shift. The characters along the drum length were set in a slight spiral, to compensate for the time taken to read a character from store.

The clutch brake unit generated a signal for every $\frac{1}{6}$ or $\frac{1}{8}$ of an inch of incremental paper movement. A counter was set to the number of lines to be moved, and decremented by three pulses to zero, to stop paper motion.

ICT line printers to 1969

The first line printer developed by ICT was the model 600, which was introduced around 1962 for the 1301 computer. This was a controlled penetration printer with the front stop closer to the pivot, accentuating the overthrow. It had a 48 character set, 110 print positions, and a maximum speed of 120 lpm.

The model 600 used a print barrel constructed from a number of print wheels. The wheels were produced by pressure-rolling the wheel periphery backwards and forwards along a linear master, engraved along its length with the full character set and laid out on the bed of a milling machine: this process eventually cold formed the characters on the wheel periphery.

The 600 employed an interesting mixture of contemporary technologies: 3000 series Post Office relays, KT66 drivers, 2D21 thyratrons, thermionic valves, core stores and germanium transistors. Power consumption was in excess of 4.5 kilowatts. Paper line shifting used a wrapped spring clutch.

Next came the model 666, designed for the 1900 series. ICT's marketing team set a performance target of 1500 lpm, but ICT had no new printing dynamics to achieve this, so the company copied the Anelex Series 5 printer hammer module in the model 666. The Anelex device operated at 1250 lpm: ICT uprated the barrel speed to 1350 lpm, which sacrificed print quality for speed, so a 660 lpm option was included as well. The 666 had a repertoire of 64 characters and printed across 132 columns.

The design of the 666 concentrated more on production engineering aspects — the ability to produce printer components in-house at low cost — than on the development of printer technology. ICT had in 1965 invested heavily in factory automation, including expensive Milwaukee-matic computer-controlled milling machines and fine blanking.

ICT manufactured the 666 in quantity at its Letchworth factory from around 1966, both for the 1900 series and for the OEM market. The official ICL history states that the 666 was "the apple of ICT's eye".

ICT's last model was the 667, a low cost 600 lpm printer designed at Stevenage. A major feature was a new miniature front stop hammer module (MFSH) — ICT's advertising made much of the fact that it would fit inside a matchbox. It allowed a dramatic reduction in the mechanism size. A novel feature was the operator exchangeable print barrel.

The 667 was not a success. The MFSH overheated when in the packed conditions of a full hammer tray, and the magnetic circuits of adjacent units were so close that they interacted, causing distorted printing. Magnetic shields proved no solution, since they reduced efficiency, so more power input was required, which produced more heating.

To keep costs down, the paper feed path used only one set of tractors, set horizontally. But they were positioned after a right angle bend from the vertical, which compromised the control of paper between the print drum and the tractors, particularly on multipart sets.

In short, this project demonstrated that small is not always beautiful. When problems arise, there is no room for manoeuvre.

It also showed that basic development work should be proven before you commit to product design expenditure. After a large outlay on development, nobody dared stop the 667 project until some time after the formation of ICL.

One ambitious plan for the 667 was to fit it to 1900 series printers at 600 lpm as a cost reduction. This development project also continued for too long. One idea we tried was intricate forms of air blowing, but this cooled the print hammers differentially making the printed line unstable. In the end, 'Echo' Organ closed down both projects.

English Electric printers to 1969

English Electric Computers was formed in the early 1960s. This company eventually took over the computer businesses of Leo, Marconi and Elliott, changing its name several times in the process.

The company's first commercial computer, the KDP 10, was manufactured at Kidsgrove under licence from RCA. It used an RCA Series 500 printer, which was costly to support as components wore out quickly. English Electric improved the design and renamed it the model 1035. The modifications that were made significantly improved print quality and printer life.

The 1035 used ballistic hammers. The paper path was a horizontal table with the print drum above and the hammers below. The print drum, supplied by Mark Stamp Steel of the USA, was 120 columns wide, and was built from steel discs each of which was two columns wide and had 52 characters embossed by pressure rolling around the periphery.

The 1035 was further enhanced to become the 1040 in time for the launch of the first English Electric-designed computer, the KDF9. The 1040 was demonstrated at the Business Efficiency Exhibition at Olympia in 1963.

The 1040 featured new logic and diode gates and a range of plug-in printed circuit boards with higher packing density. English Electric used Mullard mesa transistors with low storage charge and higher speed, eliminating the need for speed-up capacitors, and employed a new high speed diode for the gating function, with faster rise times and good noise reduction.

For the System 4 computer (another product manufactured under licence from RCA), the same printer development team produced the model 4560, which operated at 750 lpm. It was introduced in 1966 and manufactured in English Electric's Winsford factory.

The 4560 employed a new mechanism with new hammer and actuator. The print repertoire was increased to 64 characters to include a lower case alphabet.

For this product English Electric turned to a different print drum supplier, Caracteres of Neuchatel, Switzerland. Caracteres had developed a new machining process which increased life by a factor of 10.

The drum was made up of two-column discs fixed in a slight skew around the shaft, to allow time to scan the core store sequentially as the shaft rotated. The top and bottom tractors were now linked by a belt. Paper throw rate was 26.6 inches per second.

Testing of the 4560 showed that the mechanism was capable of meeting the requirement for higher speed printing, at 1350 lpm. But time was needed to evaluate performance at this speed and to develop a high speed paper throw feature and a dynamic paper stacker.

So English Electric decided to buy time for the System 4 introduction phase by purchasing OEM mechanisms. Both ICT 666 and Anelex Series 5 mechanisms were examined in detail, and the choice fell on Anelex as that was the more established product. This was incorporated in a new printer known as the 4552: like the 4560 it was manufactured at Winsford and introduced in 1966.

The Anelex Series 5 print mechanism used front stop controlled penetration hammers with an eight segment print barrel. Each segment was 20 columns wide and had 64 characters around the periphery. The rated speed was 1250 lpm at 48 characters.

English Electric was ready to introduce the 1350 lpm version of the 4560 in the following year. Known as the 4554, it had a fast paper throw of 75 inches per second and a paper stacker which operated at the same speed.

The 4554 had a barrel speed of 1350 lpm and was fitted with a second, higher speed clutch, which engaged after four lines of paper movement. The printer reverted to the lower speed clutch four lines from the end of throw. Paper formatting was controlled by punched paper tape.

	Anelex Series 5	ICT 666	EEC 4554
OEM mechanism cost (£)	4700	3780	3565
Maintenance time (hrs)	154	248	154
Scheduled parts replacement costs (£)	1879	4800	827
Total cost	6579	8580	4392

Figure 1

English Electric printer development involved a continuous programme of learning and improving, particularly in the area of printing dynamics. Great attention was paid to metallurgical aspects of design, looking for the optimum choice of materials and protective finishes by a process of exhaustive life testing. The result was printing components with long life times, which reduced the total cost of ownership, as shown in Figure 1.

This compares the cost of ownership of high speed printer mechanisms at the time of the introduction of the System 4. The figures are arrived at from product specifications and quotations, and are based on an assumption of 20,000 hours switched on with 50% usage (the typical workload of a printer used on two shifts per day, six days per week over four years).

ICL line printers

In 1968 the Ministry of Technology inspired ICT and EEC to merge, forming ICL. ICL's North (Kidsgrove) and South (Stevenage) peripheral development groups were reorganised: Kidsgrove was dedicated to magnetic peripherals and Stevenage to paper and card peripherals.

Following this reorganisation, ICL continued production of both 1900 series and System 4 printers. The company also continued development of the ICT 667 as a high priority, including the plan to use the miniature front stop hammer module (MFSH) in 666 mechanisms operating at 600 lpm as a cost reduction. The EEC 600 lpm low cost shuttle printer, now tested and proven but aimed at the same market, was scrapped. The subsequent failure of the 667 project meant that ICL would have no low cost printer to offer.

As part of the reorganisation, core English Electric printer staff were relocated to Stevenage. But the ICT printer management already there did not want them, and a very unproductive period followed until two EEC executives, Roman Derc and myself, were appointed to manage new positions, Printer Development and Printer Products respectively.

The first new printer requirement after the formation of ICL was for a train printer for "New Range", later to become the 2900 series. With this product, development work in the areas most critical to printing performance was carried out and proven before the company committed to a printer design.

The Printer Development group studied how to improve the System 4 printing components to achieve higher printing rates without sacrificing print quality. This was essential, because the objective was to incorporate the enhanced components in a train printer. The print quality of a train printer will always be inferior to that of a drum device for a given hammer speed and mass, because the characters are not rigidly fixed on all axes and so there have to be greater misalignment tolerances.

So the ICL team needed to make significant improvements to the print actuator, hammer and paper feed, as well as designing a print cartridge. Testing showed that the energy loss occurred in impacting a loosely mounted print slug (with 0.002" front to back clearance) was up to 60%. So relative to a drum printer, the actuator needed to impart a higher energy to drive a lighter hammer.

The development team increased the System 4 printer actuator energy level output from 3mJ to 9mJ with the same input level. They achieved it using a CAD program for optimising magnetic parameters and driving circuits, and by improving the geometry.

Air gaps were now greater than on the System 4 drum printers. Shields were not needed since the mean operating conditions were in the unsaturated state and would reduce efficiency.

Calculation and testing optimised the hammer mass around 0.75 gms. The hammer was made in a lightweight, high strength aluminium alloy. Two prototypes were built and performance tested: settling times were close to 8 msec, as the CAD software had predicted.

ICL further developed the actuator driver circuit. A capacitor was charged via a resistor to a voltage preset by a potentiometer, and was then discharged into the actuator coil via a diode when a thyristor was triggered to conduct. To minimise the physical size of the capacitor for packaging, a high voltage (80v) was used.

For paper movement, the System 4 friction clutch response was improved by laminating the main parts of the clutch magnetic circuit.

After all these developments were complete, the Printer Development team modified an existing System 4 printer to take a train cartridge, and configured it with the newly developed hammers, actuators, drivers and clutches. This was used as a testbed to optimise printing performance.

ICL director 'Echo' Organ was given a demonstration of this modified System 4 printer by the printer development and product managers. After receiving a guarantee from us that we could deliver a production train printer product within one year, having passed all the product assurance tests, he gave us the go ahead. The schedule just met the marketing requirements, and we did in fact deliver the new printer on time.

The new product, called the TP1500, was exhibited at the Hanover Fair in April 1972. It had prime position on the ICL stand, and attracted great interest as the fastest current train printer worldwide. It was released on 1900 series mainframes in 1972-73, and was the standard line printer on the 2900 series when that came along in 1974.

A 2000 lpm version of the TP1500 was used from 1974 in an ICL bureau continually printing high quality manuals — 2000 lpm was about the limit for train printing.

But even while the TP1500 was being developed, the writing was on the wall for future ICL printer designs. In 1971 management under the leadership of Geoff Cross decided to abandon peripheral design and manufacture in the UK, and to purchase requirements instead from OEM suppliers in the USA, especially Control Data.

In early 1975 the printer development and product teams were given 90 days notice of redundancy. We met the Minister for Industry and our local MP in a House of Commons committee room to discuss this abandonment of UK printer development, but got nowhere, because the civil service advisers to the Minister took the view that ICL could not compete successfully with USA printer manufacturers because it could not achieve their volumes. So later in 1975 peripheral development in Stevenage closed down.

Towards the end of the decade band printers took over from train printers. In the 1980s laser printing was perfected, and page printers became the normal computer output device. However, impact printers are still in use today printing those confidential codes sent through the post.

Editor's note: This article is based on a talk given by the author to the North West Group of the Society on 22 February 2000. Tony Wix was ICL Printer Products Manager from 1968 to 1975.

Letters to the Editor

Dear Nicholas,

It was fascinating to read Conway Berners-Lee's account of his visit to the Indian Statistical Institute. I was there four years earlier to advise the UN on whether the Russian Ural Computer should be supplied!

In 1954 I was at MIT with a Commonwealth Fund Fellowship when I had a call to come to the United Nations Technical Assistance office in New York. They explained that the ISI had requested a computer and other things using money from USSR which they were quite keen to spend. Apparently it would offend the Russians if an American was sent to vet the proposal and my presence in the US made me an obvious choice. Would I go to India to look at the proposals and say whether the equipment should be supplied? Yes please!

Calling in at the UK for Christmas, I went on to Delhi where I was told that the Institute was full of Russians and it would be diplomatic for me to stay in Delhi until they left. No problem! Then on to Calcutta, a town which was still crowded with the aftermath of partition; in the evening any walk outside meant stepping over people. By comparison the ISI was delightful and its hospitality superb.

The equipment comprised a Russian computer, a colour lithographic printing press for the journal and machine tools (punches and presses) for making a hand calculator said to be of Indian origin. It was clear they had plenty of work for the computer and could make good use of the printing press but I wondered about the calculator. They let me have the prototype in my room and I took it apart. The parts were badly made, with poor tolerances and sharp edges that made its operation shaky. Also it could overflow in multiplication and there seemed to be a small missing part for which the inter-working parts were prepared and which should have prevented the overflow.

I returned via a debriefing in Paris and then had an office in the UN building for two weeks in which to make my report, which was in favour of the computer and printing press but not the machine tools. But such was the motivation to spend Russian funds that all of it was approved. Later I visited a Block and Anderson showroom and quickly found the 'Indian' calculator which was a copy of an Italian model. The missing part was just where I expected to find it.

Years later Prof Mahalanobis rang me. They were delighted with the lithographic press but were having some trouble getting the Russian computer working. The machine tools had not been unpacked for some time and were badly corroded in the humid atmosphere.

Much more happened in my visit which involved Indian politics, metrication to replace the thousands of local units of measurement and stays in special government guest houses in Delhi. The whole thing was a great adventure and the bugs I picked up tuned my immune system ready for many more visits to India, which became my favourite overseas country. I went back to the ISI once more but without Mahalanobis it was a shadow of its former days of glory.

With best regards,

Donald W Davies
Sunbury-on-Thames
Middlesex
12 January 2000

Dear Editor,

For those interested in the Imperial College Computing Engines, built in the late forties and early fifties, I have placed a short list of references to ICCE I and II, plus 10 photographs of ICCE II, at:

<www.cee.hw.ac.uk/~greg/icce/index.html>

Best wishes,

Greg Michaelson
<greg@cee.hw.ac.uk>
8 December 1999

Editorial contact details

Readers wishing to contact the Editor may do so by fax to 020 8715 0484 or by e-mail to <NEnticknap@compuserve.com>.

Forthcoming Events

Every Tuesday at 1200 and 1400 Demonstrations of the replica Small-Scale Experimental Machine at Manchester Museum of Science and Industry

14-15 October 2000, and fortnightly thereafter Guided tours and exhibition at Bletchley Park, price £3.00, or £2.00 for concessions

Exhibition of wartime code-breaking equipment and procedures, including the replica Colossus, plus 90 minute tours of the wartime buildings

24 October 2000 North West Group meeting on "The Use of the Ferranti Mark I* in Aircraft Design"

Speakers R Lane, H Malbon, P Morton

28 November 2000 North West Group meeting "Do Fish See in Colour?" (a talk on electronic publishing)

Speaker D Griffiths

23 January 2001 North West Group meeting on "Early Design Automation"

Speakers G Adshead and C Lindsey

20 February 2001 North West Group meeting on "Weather Forecasting"

Speaker F Bushby

The North West Group meetings will take place in the Conference room at the Manchester Museum of Science and Industry, Liverpool Road, Manchester, starting at 1730; tea is served from 1700.

Queries about London meetings should be addressed to George Davis on 020 8681 7784, and about Manchester meetings to William Gunn on 01663 764997 or at <bengunn@compuserve.com>.

Committee of the Society (members)

Dr Martin Campbell-Kelly, Department of Computer Science, University of Warwick, Coventry CV4 7AL. Tel: 01203 523196. Email: mck@dcs.warwick.ac.uk
Professor Sandy Douglas CBE FBCS, 12A The Parade, Ashley Road, New Milton, Hampshire BH25 5BS.
Dr Dave Holdsworth MBCS CEng, University Computing Service, University of Leeds, Leeds LS2 9JT. Tel: 0113 233 5402. Email: D.Holdsworth@leeds.ac.uk
Dr Roger Johnson FBCS, 9 Stanhope Way, Riverhead, Sevenoaks, Kent TN13 2DZ. Tel: 020 7631 6709. Email: r.johnson@bcs.org.uk
Eric Jukes, 153 Kenilworth Crescent, Enfield, Middlesex EN1 3RG. Tel: 020 8366 6162.
Graham Morris FBCS, 43 Pewley Hill, Guildford GU1 3SW. Tel: 01483 566933.
Professor Simon Lavington FBCS FIEE CEng, Department of Computer Science, University of Essex, Colchester CO4 3SQ. Tel: 01206 872677. Email: lavis@essex.ac.uk
Brian Oakley CBE FBCS, 120 Reigate Road, Ewell, Epsom, Surrey KT17 3BX. Tel: 020 8393 4096. Email: brian.oakley@ukonline.co.uk
John Southall FBCS, 8 Nursery Gardens, Purley-on-Thames, Reading RG8 8AS. Tel: 0118 984 2259. Email: jsouthall@bcs.org.uk

Resurrection is the bulletin of the Computer Conservation Society and is distributed free to members. Additional copies are £3.00 each, or £10.00 for a subscription covering four issues.

Editor – Nicholas Enticknap
Typesetting – Nicholas Enticknap
Typesetting design – Adrian Johnstone
Cover design – Tony Sale
Printed by the British Computer Society

Committee of the Society (Officers)

Chairman **Ernest Morris FBCS**, 16 Copperkins Lane, Amersham, Bucks HP6 5QF. Tel: 01494 727600. Email: Ernest.Morris@btinternet.com
Vice-Chairman **Tony Sale FBCS**, 15 Northampton Road, Bromham, Beds MK43 8QB. Tel: 01234 822788. Email: t.sale@qufaro.demon.co.uk
Secretary **Hamish Carmichael FBCS**, 63 Collingwood Avenue, Tolworth, Surbiton, Surrey KT5 9PU. Tel: 020 8337 3176. Email: hamishc@globalnet.co.uk
Treasurer **Dan Hayton**, 31 The High Street, Farnborough Village, Orpington, Kent BR6 7BQ. Tel: 01689 852186. Email: Daniel@newcomen.demon.co.uk
Science Museum representative **Doron Swade CEng MBCS**, Assistant Director, The Science Museum, Exhibition Road, London SW7 2DD. Tel: 020 7938 8106. Email: d.swade@nmsi.ac.uk

Chairman, Elliott 803 Working Party **John Sinclair**, 9 Plummers Lane, Haynes, Bedford MK45 3PL. Tel: 01234 381 403.
Email: john.eurocom@dial.pipex.com
Chairman, Elliott 401 Working Party **Chris Burton CEng FIEE FBCS**, Wern Ddu Fach, Llansilin, Oswestry, Shropshire SY10 9BN. Tel: 01691 791274.
Email: chris@envex.demon.co.uk
Chairman, Pegasus Working Party **Len Hewitt MBCS**, 5 Birch Grove, Kingswood, Surrey KT20 6QU. Tel: 01737 832355. Email: leonard.hewitt@virgin.net.
Chairman, DEC Working Party **Dr Adrian Johnstone CEng MIEE MBCS**, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX. Tel: 01784 443425. Email: adrian@dcs.rhbnc.ac.uk
Chairman, S100 bus Working Party **Robin Shirley**, 41 Guildford Park Avenue, Guildford, Surrey GU2 5NL. Tel: 01483 565220. Email: r.shirley@surrey.ac.uk
Chairman, Turing Bombe Project **John Harper CEng MIEE MBCS**, 7 Cedar Avenue, Ickleford, Hitchin, Herts SG5 3XU. Tel: 01462 451970.
Email: bombe@jharper.demon.co.uk
Chairman, North West Group **Professor Frank Sumner FBCS**, Department of Computer Science, University of Manchester, M13 9PL. Tel: 0161 275 6196.

Meetings Secretary **George Davis CEng FBCS**, 4 Digby Place, Croydon CR0 5QR. Tel: 020 8681 7784. Email: georgedavis@bcs.org.uk
Editor, Resurrection **Nicholas Enticknap**, 4 Thornton Court, Grand Drive, Raynes Park SW20 9HJ. Tel: 020 8540 5952. Fax: 020 8715 0484.
Email: NEnticknap@compuserve.com
Archivist **Harold Gearing FBCS**, 14 Craft Way, Steeple Morden, Royston, Herts SG8 0PF. Tel: 01763 852567.