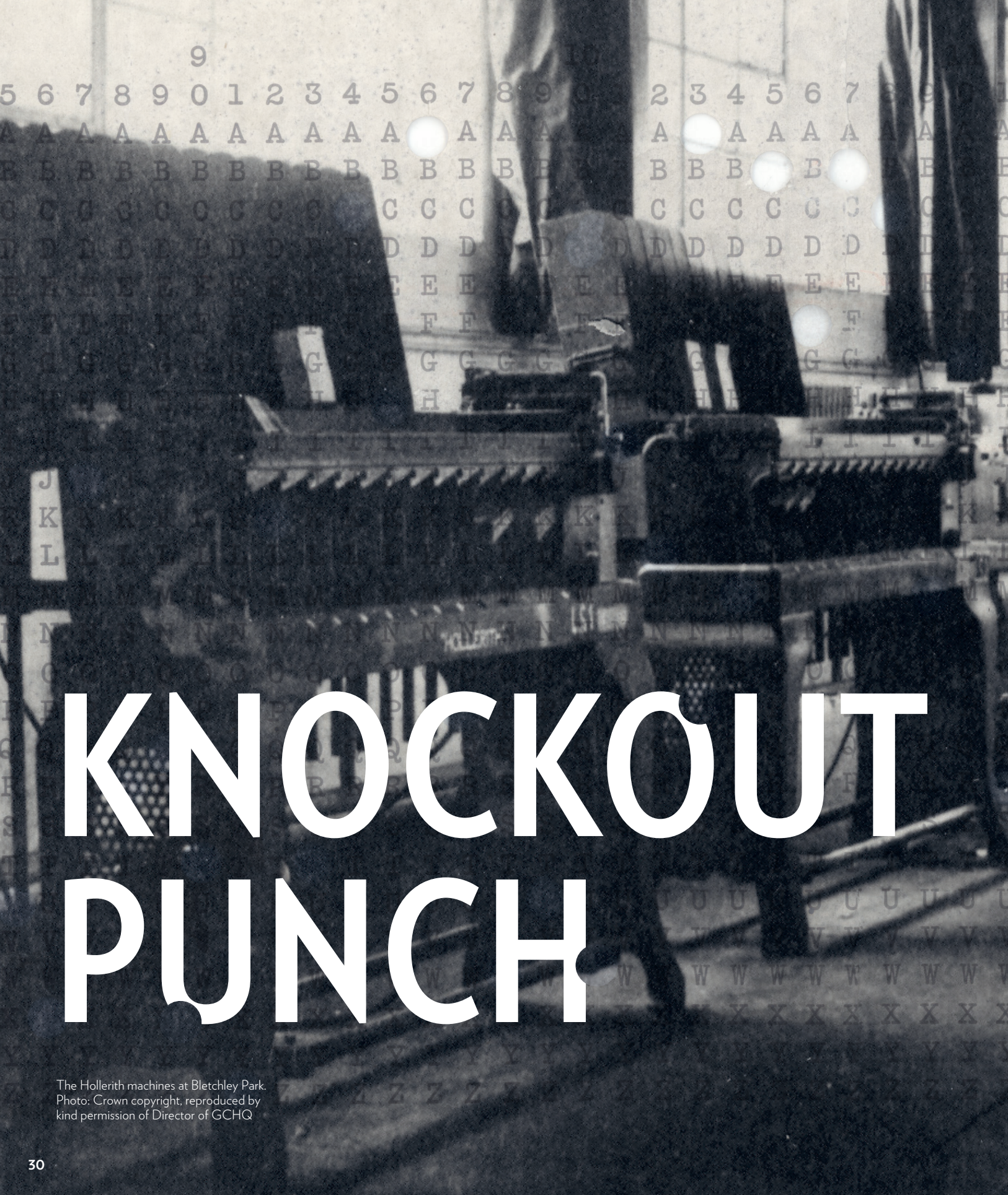
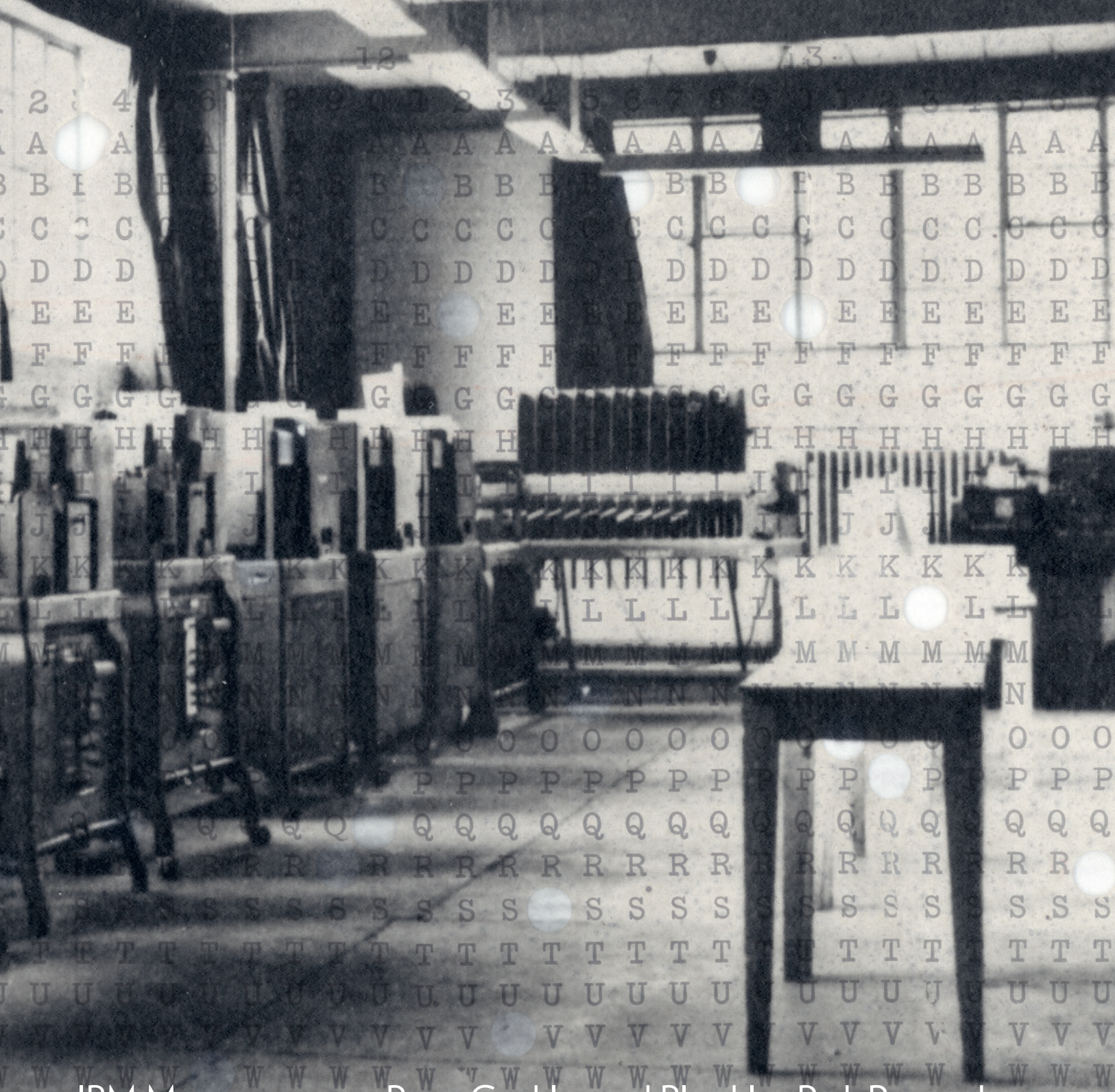


KNOCKOUT PUNCH

The Hollerith machines at Bletchley Park. Photo: Crown copyright, reproduced by kind permission of Director of GCHQ

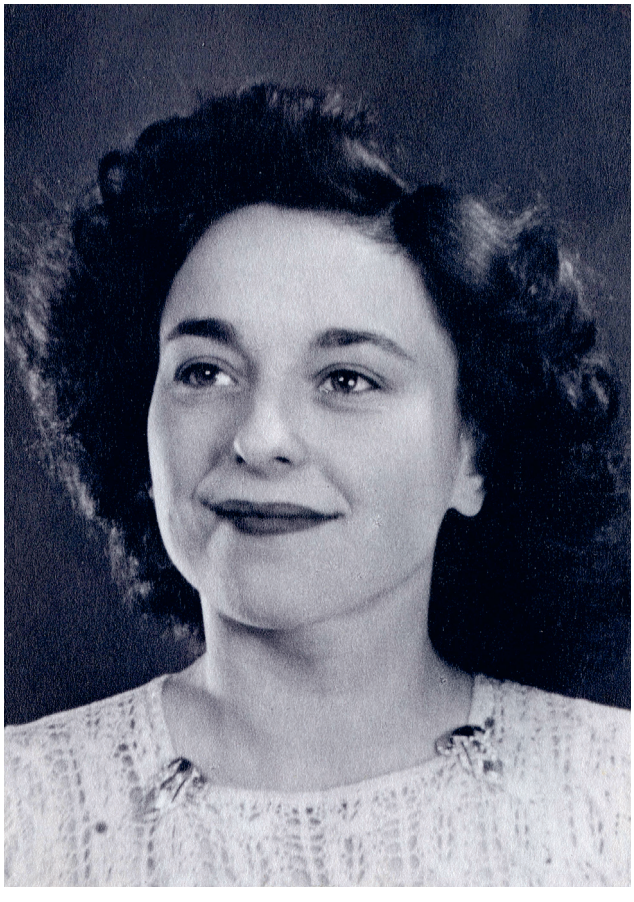


IBM Museum curator Peter Coghlan and Bletchley Park Research Officer Dr Thomas Cheetham reveal how punch-card technology that dated back to the Victorian period became vital to Britain's codebreaking machine

Every day of World War Two, mountains of data arrived at Bletchley Park in the form of intercepted enemy messages. It took thousands of people – from mathematicians and linguists to machine operators, librarians and engineers – to process and analyse it all. This story is revealed in Bletchley Park's newest exhibition, *The Intelligence Factory*.

Facing such massive volumes of data, the Codebreakers quickly realised that the task would be impossible without a way of automating some of the analysis. Bletchley Park is renowned worldwide as the place where the science of cryptography achieved new heights of innovation and mathematical genius. Thanks to films and books celebrating Alan Turing's work, the image of the Turing-Welchman Bombe machine is embedded in the public imagination.

But there is a lesser-known story of codebreaking at Bletchley Park – which relied on a much older, less glamorous technology. It is the story of the Hollerith machines, a predecessor of today's computers, crammed into Hut 7 and later Block C – the modern Visitor Centre – and attended



Cards were processed through the sorter, the reproducer, the verifier, the collator and finally the huge tabulating machine

by nearly 300 operators and technicians. These so-called "Old Iron" machines used punch-card technology that, though mundane and noisy, operated around the clock, providing the scale and speed needed to decode enemy ciphers before the information was rendered out of date.

The story begins in the early 1800s, with the Jacquard loom. French merchant Joseph Marie Jacquard developed a technique to automate textile design. Complex repeating patterns could be painted onto squared paper, and then transferred onto cards, with holes punched where there was no pattern. By feeding the cards into a loom whose thread hooks responded to the presence of the holes, the patterns could be woven at incredible speed.

The Jacquard loom became the inspiration for Charles Babbage's Analytical Engine design in 1837. Babbage proposed a machine that could receive instructions from punch cards to automate mathematical calculations – now widely recognised as the first true computer. At the time, fellow mathematician Ada Lovelace noted: "The Analytical Engine weaves algebraic patterns, just as the Jacquard loom weaves flowers and leaves."

Towards the end of the 1800s, US statistician and engineer Herman Hollerith adapted the Jacquard punch card methodology to record data. Using his newly designed electromechanical equipment, Hollerith demonstrated how data could be "written", read, sorted and tabulated to gather statistical information efficiently, accurately and at speed. He put the technology to use working for the US Census Bureau in 1890. Previously, it took eight years to collect and analyse data from the once-a-decade census. Hollerith's tabulator cut the turnaround time to fewer than six years. It was an astounding leap in data processing, which was quickly noted by governments and industries around the world.

Above: An advert for the IBM 405 Tabulator. Photo: IBM Museum
Left: Joan Joslin, one of the women who punched the cards. Photo: Bletchley Park Trust

By 1911 the punch card equipment manufactured by Hollerith's Tabulating Machine Company (TMC) was being used for censuses in Europe and Russia. In 1924, TMC – now a part of the Computing, Tabulating and Recording Company – adopted its current more-famous name: International Business Machines, or IBM. Fast forward to 1939, and Hollerith-designed punch card systems had been adopted and adapted by manufacturers, retailers, accountancy firms, universities and government departments for every conceivable data management task. The licence to manufacture IBM machines in the UK was held by the British Tabulating Machine Company (BTM), a business that would become intimately involved with the Bletchley Park operation.

The use of punch-card technology in codebreaking had begun to be explored during WW1, before the existence of machine ciphers such as Enigma. During the interwar years, GC&CS lacked the funds to rent the expensive Hollerith machines, but some experiments were organised before WW2, meaning that their potential for processing intercept data was well-understood. BTM set up a small Hollerith operation to support Bletchley Park only a month after war broke out, and the relationship was undoubtedly a factor in the decision a short time later to give the company the contract to manufacture the more famous Bombes. The team was led by Britain's leading expert in the field, Frederick Freeborn, who was accompanied by some of the brightest young talent at BTM's disposal, such as the Whelan brothers, Ronald and Norman, who acted as his deputies. As the task grew, these men were joined by women, many recruited locally, who handled the monotonous work of punching thousands of cards per day and feeding them to the correct machines in the right order.

Women punching cards in the Hollerith section at Bletchley Park. Photo: Crown copyright, reproduced by kind permission of Director of GCHQ

I felt we were on the "ground floor" of the computer age

Messages transmitted by radio could be intercepted relatively easily, but making sense of them, at least from a mathematical point of view, would be a huge challenge. To make this a reality, Bletchley Park had to use every tool at its disposal. Most intercepted messages were manually analysed and collated; this required an army of people sharing every scrap of information and gathering the results into meaningful patterns for further analysis along the chain. But hard work and diligence could only go so far and, wherever resources would allow, processes were mechanised and automated.

As Joan Joslin recalled: "In the punch room you would use the punch machine to record the messages on the cards. Then the pile of cards would go to the machine room and be processed through the numerous machines in there – the sorter, the reproducer, the verifier, the collator and finally the huge tabulating machine. The sorter was 6ft long and sorted the punch cards, reading the little holes to put them in order." According to Doris Marshall, even though she was never told the purpose of her work, "it was never dull – the thing that I suffered from the most was exhaustion".

The Tabulating Section (known as the "Freebornery") occupied an unusual position. Whereas the teams who manned the Bombes and the Colossus computers were created to do very specific jobs, the flexibility of punch-card technology meant the Hollerith Section was in high demand. With never more than perhaps 50 machines, Freeborn assisted almost all of the codebreaking sections at the Park at one time or another. Section heads would draw up plans for a particular data-management task and then pitch them to Freeborn. This put him in a position of unusual influence, solely able to pick and choose what jobs his team undertook, and therefore what codes and ciphers might be broken.

On the other hand, Freeborn often received plans that made good cryptanalytic sense but failed to make the most efficient use of the scarce machines. From 1943 Freeborn was authorised to ask Chief Cryptanalyst John Tiltman to

Work at Bletchley Park sparked innovations, from card reading mechanisms to specialised punch hole counters

assess any task before agreeing to undertake it. Blackboards were erected in Block C to keep staff aware of the urgency of the various jobs happening simultaneously. The way sets of data moved back and forth between the codebreaking sections and the Freebornery – sometimes two or three times a day during particularly complex tasks – is a demonstration of the easy cooperation that made Bletchley Park work so well.

There were always one-off jobs to fit in, but certain consistently valuable tasks became ongoing concerns. The most important of these was the work to support the Banburismus process, which was central to Hut 8's breaking of German naval Enigma. The Hollerith staff called this job "tetra" because their task was to find repeated four-character strings – tetragrams – in the day's intercepted cipher text.

Where two messages exhibited the same tetragram, this statistically unlikely relationship could indicate they were enciphered at similar positions of the machine, a relationship that Hut 8 could reliably exploit to reduce the number of tests they had to run using the Bombe machines, but only if they could spot the repeats among the roughly 80,000 characters of message text handled every day – something no human eye could hope to achieve.

According to Hugh Alexander, the head of Hut 8 and its outstanding cryptanalyst, the "tetra" process was "the foundation of our work and the speedy and efficient service we received played a major part in our success".

The increasing complexity of the tasks at hand meant the operations were never going to be "business as usual" for the Hollerith equipment, and the need to adapt the standard punch card technology became clear very quickly. For certain tasks in Block C, the supervisors drew chalk lines on the floor to show the operators the path the cards were to take between the different machines; in so doing, they "programmed" the entire building to perform a particular job.

Work at Bletchley Park sparked a multitude of innovations, from the addition of new card reading mechanisms to specialised punch hole counters – even asking operators to invert the punch card feeds so they could capture data that could only be read if cards were processed upside down. The limitations of the available devices prompted the engineers at Bletchley Park to request access to an IBM 405 Tabulator, which they knew was in storage at BTM's Letchworth factory. The 405 added a number of features; most vitally, it could print results containing letters as well as numbers. It proved so successful, the Codebreakers ordered a large number of the new machines from IBM's plant in the US. Ronald Whelan recalled that the crates contained an unexpected bonus: boxes of tinned food were hidden among the machines, many of the staff's first introduction to Spam.

Hollerith equipment continued to play a vital role at Bletchley Park until the end of the war, and after; some of the BTM staff were subsequently inducted into GCHQ. Unlike the Bombe and Colossus, which fell into security-enforced obscurity for decades after the war, data processing using punch cards was still widespread into the 1980s. The punched card was one of the primary methods for entering programme data into the early computers that were the distant cousins of Colossus and, for IBM, was the basis for the growth and development of the global IT corporation we see today. The 001 Hollerith Card Punch and the IBM Model 80-card sorter – both dating from the 1940s – are now on loan to Bletchley Park's exhibition *The Intelligence Factory* from IBM's Museum of Computing History in Hursley, Hampshire.

The gulf in scale between that decade and now is vast: it is estimated that the Hollerith Section, using an average of two million punched cards per week, processed at most around 32GB of data during the war, an amount that would easily fit several times over onto a modern smartphone. When the Freebornery is viewed as a data-processing system – which combine mechanical and organic parts – it is easy to see how the innovative ways in which the Hollerith technology was manipulated at Bletchley Park contributed enormously to developments in digital technology, information management and data analysis. As Joan Joslin notes, "I felt we really were on the 'ground floor' of the computer age."

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IBM UK Trust supports the Cyber Security strand of Bletchley Park's award-winning Learning Programme. In 2019, the Learning Programme reached more than 35,000 students through facilitated on-site workshops at Bletchley Park.

The IBM Model 80-card sorter on loan at *The Intelligence Factory* exhibition.
Photo: Bletchley Park Trust/Andrew Lee