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1 THE ORIGINS OF THE DIGITAL VISION

In October 1967, James Merriman, the Post Office's senior director for engineering, outlined a vision for a new digital infrastructure for Britain. In a speech titled "Men, Circuits and Systems in Telecommunications," his inaugural address as chairman of the Electronics Division of Britain's Institute of Electrical Engineers, Merriman described a "general-purpose digital network" that would "freely handle all forms of communication," so giving Britain a public digital infrastructure that would provide voice, data, and video services.[1] In this vision, Merriman blurred the line between the machines that composed this infrastructure and the people who ran and used it. He discussed the interplay between "circuits and men," arguing that telecommunications was "not only a dialogue between sender and receiver, it is a dialogue between user and provider. It is not only circuitry; it is man management."[2] Digitalization would produce a "self-healing, self-governing" network that could administer this management. For the Post Office, digitalization was not only about services but also about management, and would unify information and administration. In this vein, Merriman concluded his speech by arguing that "information and control" were "fundamental to any telecommunication system."[3] Merriman's speech announced the Post Office's plans to build a comprehensive, nationally owned digital infrastructure for Britain and showed an expansive vision of what digitalization meant. This chapter traces this vision's origins from an analogue failure and its influences, including cybernetics, managerialism, the British "government machine," and the threat of independent data networks.

Failures and visions drove this intersection of technology and politics. The history of technology has long shown that focusing on success alone makes for Whiggish stories of technological progress and that understanding failure reveals much about the priorities and expectations of those developing and using those technologies.[4] These visions and expectations, marshaling resources and guiding development, are as central to the history of technology as material artifacts themselves.[5] Failures can be fertile soil for both old and new visions, nurturing an old vision's quixotic status or giving room for a new vision to grow. This does not mean that failure is a prerequisite for success, but rather that the perception of failure and its circumstances shapes the ground from which subsequent visions and expectations can grow. This dynamic between failures and visions helps understand not just the technological history of Merriman's vision, but its political history too. Merriman's digital vision also grew from the belief that British government and the Post Office were not technocratic or managerial enough, and it was these failings, alongside the expectations set by cybernetics and new data technologies, that would fuel the Post Office's vision of a universal digital network.

ANALOGUE FAILURE

Through the 1950s and early 1960s, one of the Post Office's main projects was Highgate Wood, an analogue telephone exchange that the Post Office and British government wanted to be the world's first all-electronic operational telephone exchange. The Highgate Wood project officially began in 1956, when the Post Office formed the Joint Electronic Research Committee with its suppliers, Siemens, ATE, Ericsson, GEC, and STC, to coordinate development with industry.[6] Its origins, however, lie with the Post Office's need, following World War II, to upgrade its old, large, and unreliable network of electromechanical Strowger exchanges. Strowger exchanges automatically routed telephone calls using mechanical selector arms that would relay phone calls by connecting to a specific electrical contact in a contact bank. A Post Office engineering delegation thus visited the United States to report on a new version of the Crossbar exchange, an electromechanical alternative to Strowger.[7] Strowger, first patented in the US by Almon Strowger in 1889, had entered service in Britain in 1912 but was no longer up to standard.[8] The delegation reported that Crossbar cost more, used more mechanical relays, and needed more room and power, but concluded that it provided superior service, was more adaptable, and could flexibly serve many locations, from small rural exchanges to metropolitan and trunk exchanges.[9]

These mixed conclusions perhaps suggest the reported conflict between the two lead engineers on the trip, Tommy Flowers and Donovan Barron. Flowers supported moving straight to electronics, while Barron, later engineer-in-chief of the Post Office from 1965 to 1967, advocated Crossbar as an intermediate step.[10] Flowers won, persuading the controller of research, Gordon Radley, that all research and development should focus on an all-electronic exchange. Radley's support, and Flowers's favor for electronics, arose from Flowers's prewar switching research and his wartime creation of Colossus, a digital codebreaking machine developed for use at Bletchley Park, the Government Code and Cypher School. Before the war, Flowers developed an experimental electronic switching device, which the Post Office used minimally from 1939.[11] The war, however, interrupted, and Radley approached Flowers in 1941 to undertake work for Bletchley Park, at which point Radley and Flowers became the first Post Office engineers initiated into British codebreaking at Bletchley Park.[12] Flowers first worked on a special-purpose electromechanical device for Alan Turing's codebreaking team, but after Bletchley Park scrapped that project, Flowers proposed Colossus, an electronic machine to process German messages. Upon completion, Colossus was an immediate success, doubling the codebreakers' output.

Colossus has been touted as the first electronic computer, but it was more influential on Flowers's pursuit of an all-electronic exchange than it was on the first computers. Colossus is better thought of as a digital signals processor and an "exemplary artifact" of the early digital, a period in which diverse experimental digital devices, including the first digital computers, were built in a range of contexts.[13] In Colossus's case, it had a closer relationship to Flowers's work on electronic switching than it did on computing. Flowers's work on Colossus supported his work on Highgate Wood, even though the former was a digital codebreaking machine and the latter an analogue telephone exchange. When Flowers first proposed Colossus, Bletchley Park codebreakers thought it would be too unreliable and that the war would be over before it was ready. Radley, however, allowed Flowers to pursue the project independently at Dollis Hill, the Post Office's research station.[14] This backing continued after the war. In justifying Highgate Wood to Postmaster General Ernest Marples, Radley invoked Dollis Hill's wartime work for Bletchley Park and capitalized on Bletchley Park's computing legacies by telling Marples that "the various projects undertaken by Dollis Hill during the war had led to the idea that electronic techniques could be applied to telephone switching. Somewhat similar techniques have been worked in the development of computers."[15] According to Roy Harris, a member of Flowers's postwar switching team and later one of the chief architects of the Post Office's digital network, Radley always sided with Flowers in electronic exchange development.[16] Radley's support shows how Colossus's later significance lay more in communications than in computing. This support also shows the lasting influence of Britain's "warfare state." Rather than disappearing with the end of World War II, Britain's wartime interests continued to shape state technology projects well into the 1950s and 1960s, with the British welfare state emerging at the end of the 1960s.[17] While Highgate Wood was not a defense project, the Post Office's, and specifically Flowers's, role in wartime codebreaking helped secure political support for Highgate Wood, thus showing the impression that the warfare state left on even the most civilian of projects.

Flowers, however, remained bitter about Colossus's secrecy. Flowers watched on as his Bletchley Park colleagues, the mathematicians Alan Turing and Max Newman, built from the principles of electronic code-breaking to develop computers, while he had "no power or opportunity to use the knowledge effectively. With no administrative or executive powers, I had to convince others, and they would not be convinced. I was one-eyed in the kingdom of the blind."[18] Flowers attributed delays on Highgate Wood to his lack of "prestige, which knowledge of Colossus would amply have provided."[19] Flowers was perhaps disingenuous here, as he had ample support from Radley, the controller of research, and many more factors contributed to Highgate Wood's delays. But Flowers's view that he lacked prestige compared to Turing and Newman had consequences for his relationship with Turing. After the war, Turing worked on a computer project, the Automatic Computing Engine (ACE), for the National Physical Laboratory (NPL), and commissioned Flowers to undertake development work for ACE. ACE would be a stored-program control general-purpose computer used for laboratory calculations, but suffered numerous problems in its development, including Turing's departure from the NPL. Flowers's sluggish attention had delayed ACE, which he had told Turing would be ready by August or September 1946. Flowers neglected ACE and instead focused on updating the oversubscribed postwar telephone network.[20] In effect, Flowers neglected Turing's work on electronic computing for his own work on electronic communications.

From 1947, a small team under Flowers began developing Highgate Wood's basic principles, pulse-amplitude modulation (PAM), which encoded telephone signals as pulsed samples, and time-division multiplexing (TDM), which transmitted signals by rapidly cycling through pulsed samples. Combining these electronic techniques meant that a single telephone circuit could carry multiple signals and that an electronic exchange could route these signals without mechanically moving the circuit.[21] Highgate Wood's development, however, was slow. The Post Office solicited assistance from its suppliers, but the suppliers' concerns about patent exploitation meant that in 1952 they turned down a proposal that had been the outcome of lengthy discussions with the National Research Development Corporation, the Board of Trade, the Ministry of Supply, and the Treasury.[22] Protracted discussions continued until 1956, when Gordon Radley, then director general of the Post Office, told the suppliers that, unless they agreed, the Post Office would choose one of them as its main development and manufacturing partner. The suppliers quickly fell into line, and in May 1956, the Post Office and its suppliers signed the Joint Electronic Research Agreement, which laid out the terms for pooling research, staff, and development tasks. These lengthy negotiations, rather than Flowers's lack of prestige, were likely a greater hindrance to Highgate Wood's development. Flowers and his team had worked mostly undisturbed on electronic switching, and it was only during the 1950s that these delays, caused by manufacturer negotiations, began. Such tensions between collaborative research and competitive procurement were not unique to this period and would continue to shape telecom development into the 1970s and 1980s.

Rather than Flowers's personal prestige, it was national prestige that drove the development of Highgate Wood. In 1957, Ernest Marples, the postmaster general, became concerned about Highgate Wood's delays, which Radley defended as a matter of national interest.[23] Since Flowers and Barron's 1947 visit, Bell Labs had begun developing an all-electronic exchange. In a letter to Marples, Radley pointed to the export prospects for British manufacturing that Highgate Wood offered, reminding Marples of the "resurgence of national competition and nationalistic considerations [which] have tended to restrict the market. . . . The real chance for British manufacturers is to be able to offer electronic equipment that is a stage ahead."[24] National prestige also defined internal concerns about Highgate Wood's troubled development. Two months after Radley's letter to Marples, engineers adjusted

Highgate Wood's power provision estimates. The experimental exchange needed more power, delivered more reliably and stably, raising costs. Lionel Harris, the engineer-in-chief and father of Roy Harris, one of Flowers's team members, raised concerns, and so Donovan Barron, by this point the assistant engineer-in-chief, suggested that they postpone Highgate Wood until a small, economically competitive, practical exchange could be built. Lionel Harris dismissed this idea and "stressed the prestige value of the installation of a complete working system in view of similar projects now being developed abroad."[25] The motivation to beat out foreign competitors such as Bell Labs was clear and urgent.

Highgate Wood's prestige value also fueled additional construction work needed for its growing power requirements. The existing exchange building in north London had to undergo structural alterations, needing an extra room to accommodate more batteries. In turn, this meant that Highgate Wood needed more ventilation through a fan room of at least 1,600 square feet. The existing exchange building had no space for such a room, and so the Post Office requested that the Ministry of Works build an extra floor on the exchange building. In order to justify this, the Post Office explained, "It is a matter of national prestige for us to be the first to introduce such an exchange. . . . It will be of inestimable value to our export trade to be able to be first on the scene with this new development."[26] Despite the engineer-in-chief's earlier acknowledgement that Highgate Wood was an uneconomic experimental exchange, the Post Office still invoked a relationship between research prestige and export prospects.

"Prestige" was a flexible rhetorical device in Highgate Wood's continuing development. This reflects the role that national prestige played in mobilizing British state actors and institutions behind scientific and technological projects in the 1950s. One such example is Jodrell Bank's Mark 1 Telescope, the world's largest steerable radio-telescope dish at the time of its construction.[27] At Jodrell Bank, "prestige" meant different things to different groups. For the Royal Astronomical Society, it meant the standing of British science, while for the Department of Scientific and Industrial Research, it meant a display of British prominence, and for individual astronomers, it was useful as a funding invocation. For Highgate Wood, prestige displayed similar flexibility in coordinating different groups with different goals. For Flowers, prestige meant recognition for his work on Colossus. For the Engineering

Department, prestige meant international recognition. For the postmaster-general and other government departments, prestige meant raising export prospects. Moreover, the ambition that Highgate Wood would be a prestigious world-first is emblematic of contemporaneous British techno-nationalism, which prized scientific and technological world-firsts, such as Comet, the first civilian jet airliner; Bluebird, the speed record-setting land and water vehicles; and Calder Hall, the first commercial nuclear power station.[28]

Highgate Wood's problems, however, delayed the project, which never became a world-first. The exchange entered service in 1962, four years late, two years after Bell Labs' all-electronic exchange, and was an abject failure. Highgate Wood's components failed at a low rate, but the system had several terminal faults.[29] Its connection stores did not always clear pulses after calls, so channels continued to look busy, meaning it would carry less and less traffic. The variety of pulsing frequencies also led to interference. In 1963, the Post Office thus abandoned research on analogue all-electronic exchanges. Economically, the equipment required was too expensive, while technically, it was clear that analogue pulse-amplitude modulation would continue to produce interference and incompatibility between different pulsed frequencies.[30] Flowers reportedly could not endure this decision and so resigned from the Post Office in 1964.[31] Highgate Wood, however, remained open, as the Post Office felt that "Highgate Wood has prestige value. . . . It will be the only electronic exchange really connected to the public system in Britain . . . and has been an important feature of the visits of parties from abroad. Arrangements are in hand for a visit of continental technical journalists in March [1964]."[32] The experimental Highgate Wood, disconnected from the telephone network, thus remained in place as a symbol of British prestige until the Post Office finally removed it in 1965. Highgate Wood lasted this long because both the warfare state and techno-nationalism sustained its development. While wartime relationships secured early support for Highgate Wood, the project's "world-first" goal as an export prospect was typical of Britain's techno-nationalist political economy. More importantly, however, both trends were tied to the shape that the British state took in the two decades following World War II, a shape built on war-forged relationships and international standing amid a fragile empire. After Highgate Wood's failure, the Post Office and the government turned to new combinations of technocracy and managerialism in Britain's telecom infrastructure.

DIGITALIZATION AND CYBERNETICS

Flowers's departure from the Post Office paved the way for new digital approaches. In 1963, amid the failure of Highgate Wood, Flowers received a research report exploring an "integrated" digital telecommunications system, capable of transmitting both voice and data.[33] The report compared this integrated system with a specialized data network and concluded that specialized data networks might be preferable. The following year, Post Office researchers undertook another exploratory study shortly before Flowers resigned, and again, the integrated digital network concept received a muted reception.[34] After Flowers resigned, however, the new deputy engineer-in-chief, James Merriman, promoted that year, set up a "Rationalisation of the Distribution Network Working Party." This working party concluded in January 1966 that an integrated digital network, providing voice, data, and video, was possible.[35] During these trials, telecom engineers identified that more advanced cables could provide up to nine television channels, along with voice and data, although they recommended a lower bandwidth system, which would be cheaper.[36] Merriman, soon appointed senior director of engineering, the renamed engineer-in-chief position, ordered a follow-up study that confirmed this warmer reception by outlining the economic rationale for such a network.[37] After these reports, the Post Office board approved a trial for Washington New Town in 1967 as the first step toward a "single all-purpose cable to each home—an integrated network."[38] The Washington trial proved highly profitable, and further experiments began in Irvine, Craigavon, and Milton Keynes.[39]

Alongside digitizing transmission, engineers made good progress in digitizing telephone switching. After Highgate Wood, the Post Office dropped analogue pulse-amplitude modulation. It kept time-division multiplexing, allying it instead with digital pulse-code modulation, which the British radio engineer Alec Reeves first developed in the 1930s at International Telephone & Telegraph's Paris research center, Les Laboratoires Standard.[40] The Post Office began work on Empress, a prototype digital "tandem" exchange, which connected two local exchanges rather than providing direct connections to telephone subscribers. Empress's development went very smoothly, and in 1968 the Post Office installed Empress near Earl's Court, London, becoming the world's first operational digital telephone exchange.[41] The success of the integrated network and Empress trials, which both featured in Merriman's 1967 speech, vindicated the digital turn taken since Highgate Wood's failure and Flowers's departure. But while these successes help explain why and when Merriman announced the Post Office's vision of a universal digital infrastructure, they do not help explain the shape of this vision. In his speech, Merriman not only announced the digital network, but also that it would be general-purpose, self-healing, self-governing, and that it would unite information, control, and management. This represented a profound shift in thought, reconceiving the telephone network as an information network.

This vision's first influence was information theory and cybernetics, two connected fields studying information and control. In 1948, the Bell Labs mathematician Claude Shannon published "A Mathematical Theory of Communication," and the MIT mathematician Norbert Wiener published his book *Cybernetics*.[42] Both works contained remarkably similar theories of information, construing information as the amount of order or disorder in a selection of messages, although Shannon and Wiener differed a little in their specific definitions.[43] Shannon was inspired by his wartime work on statistics and cryptography, including the encrypted radiophone system SIGSALY, via which Roosevelt and Churchill talked. He thus took a tight, nonsemantic approach, in which information was a formal mathematical expression of the disorder, or unpredictability, of a message. Wiener, on the other hand, had worked on automatic antiaircraft weapon control systems. These control systems, which used radar feedback to track and predict planes' flight paths, served as a model for Wiener's theory of cybernetics. For Wiener, cybernetics was a theory of communication and control that explained the behavior of organisms and machines in terms of information inputs and outputs, just as the anti-aircraft predictors behaved based on information inputs and outputs from radar tracking. For Wiener, information theory was a corollary of cybernetics, used to analyze the information feedback loops in these systems, and so he took a semantic and pragmatic approach to information, looking at its meanings and effects on recipients. Wiener's novel science of cybernetics captured the public and scholarly imagination in the 1950s and 1960s, particularly in how it blurred the lines between machines and organisms and in Wiener's predictions of a "second industrial revolution," soon reframed as an "information revolution."[44] Meanwhile, information theory also became popular, leading to an "information bandwagon" in academia, where fields from communications to psychology became "informational."[45]

Post Office engineers paid close attention to Wiener and Shannon's ideas. In 1951, Roy Harris, from Flowers's Highgate Wood team, and D. L. Overheu, another Post Office engineer, attended lectures at Imperial College, London, to learn about information theory from Colin Cherry and Dennis Gabor. Along with Donald MacKay at King's College London, Cherry and Gabor made up the English School of information theory.[46] Harris and Overheu reported on information theory to Flowers and subsequently lectured on information theory to Post Office engineers around the country. At the end of their lectures, they thanked Colin Cherry for his correspondence on "information theory and cybernetics."[47] Harris and Overheu mainly addressed Shannon's "communication theory," but they also referenced Wiener's *Cybernetics* and his expansive definition of information, explaining how information theory could integrate subjects as diverse as digital computing and neurobiology by treating all forms of communications as the same.[48] They also used information theory to show how digital pulse-code modulation was less error-prone and delivered higher bandwidth than analogue pulse-amplitude modulation, foreshadowing its failure at Highgate Wood.

These reports expanded beyond Shannon's communication theory to reflect on the communications, biological, and industrial applications of information theory and cybernetics and on an impending "second industrial revolution," again quoting *Cybernetics*. Harris and Overheu pointed out how the versatility of information theory meant that it could assess the efficiency of transmission systems, switching systems, and even control organizations. They extended this further to consider cybernetic analogies between machines and organisms:

> Such machines are self-controlling and are given only a general instruction. Self-guiding projectiles, anti-aircraft predictors, etc., are examples of such machines. The human body is full of such mechanisms which control our temperature, balance, heart rate, etc., and there is evidence that conditioned reflexes operate in a similar way with a memory incorporated in the mechanism. Similarly the faculty of learning must depend considerably on past experience and must use some form of feedback.[49]

In this quote, Harris and Overheu advertised their cybernetic knowledge by referencing two classic examples of cybernetics, Wiener's antiaircraft predictors and the British cybernetician W. Ross Ashby's "homeostat," a device that modeled learning in the human brain by representing environmental adaptation through electrical feedback.[50] Harris and Overheu concluded by reflecting on Wiener's prediction of a "Second Industrial Revolution" from *Cybernetics* to hypothesize that this revolution could mean that "human beings, used as sources of judgement, may also be replaced by machines."[51]

These were expansive understandings of information theory that borrowed heavily from Wiener and cybernetics. By the end of the 1950s, three different definitions of information theory had emerged. The narrowest, associated with Shannon, referred purely to his communication theory. The second was a broader collation of Shannon and Wiener's work on analyzing communication problems. Finally, the third, which was particularly associated with the Imperial College information theory symposia and the journal *Information and Control*, was a synonym for cybernetics.[52] Post Office engineers followed this third definition, which was shown again in September 1952, when Post Office engineers attended another information theory symposium at Imperial.[53] They were joined by the English School and information theorists from the US, such as Stanford Goldman, Robert Fano and Yehoshua Bar-Hillel. One Post Office engineer, D. L. Richards, presented a paper on the effects of the physical properties of a circuit on telephone users' behavior, applying Wiener's pragmatic definition of information theory, viewing the communication system as composed of human and electrical components. A report on the symposium, delivered to Merriman, concluded that few papers at the symposium had "direct application to bread-and-butter communications practice," but suggested that information theory's main benefits may be "a fertilizing and catalytic action on the ideas of designers and development engineers, plus an understanding of ultimate possibilities that will act as a goal."[54]

By 1967, when Merriman was appointed senior director of engineering, cybernetics and information theory had indeed had a catalytic effect on engineers' goals for Britain's telecommunications infrastructure. The idea that the telephone network was an information network that could carry voice, video, and data was rooted in the homogenizing discourse of information theory. This was more than just rhetoric, as Harris and Overheu used information theory to demonstrate that digital transmission, the basis for this new network, was more efficient than analogue methods.[55] The natural extension of these insights was that the Post Office could use a digital telephone network for much more than telephony. Cybernetics too had a significant influence. Merriman built his vision of a "self-healing, self-governing" system on a cybernetic discourse that blurred organisms and machines, as did his two fundamental principles of "information and control," perhaps referencing *Information and Control*, the world's leading cybernetics journal. Merriman's vision of electronic computer control, wherein computers would receive information about traffic flow, determine the optimal route for calls, and control switching centers, leading to an autonomous, self-managing system, cybernetically blended organic and mechanical. This echoed Harris and Overheu's reports, which predicted that the "mechanised thinking of electronic brains together with self-stabilising servomechanisms" would allow machines "as sources of judgement" to manage industrial systems automatically.[56]

This quote also foreshadowed Merriman's seamless shifting between mechanical and managerial control, in which communications was "not only circuitry; it is man management."[57] Merriman explained to his audience that the Post Office's "greatest problem" was the "deployment, use, and, in one sense, control, of manpower."[58] Merriman outlined how the Post Office had increased productivity by harnessing "technological opportunity" and "scientific man-management" to found a new Management Services Department, which had undertaken studies on work measurement, queuing theory, and statistical control.[59] He used a diagram to demonstrate how the Post Office had conceived its works service organization as inputs and outputs of information (figure 1.1). He also outlined how the Post Office used computer-aided management techniques, such as Monte Carlo simulations, to improve engineers' workflows. These examples further suggest cybernetics' and information theory's influences, especially the works service organization as an informational feedback loop, which echoes Harris and Overheu's suggestion that information theory could assess organizational efficiency. But while cybernetics and information theory might explain some of these influences, they do not paint a complete picture or explain why Merriman emphasized administration and bureaucracy. The explanation for this lies with a British governmental tradition of bureaucratic mechanization, which was the second influence on the Post Office's digital vision.

THE GOVERNMENT MACHINE

Merriman had undertaken a similar approach to organization and management on secondment to the Treasury's Organisation and Methods department from 1956 to 1960, where he served as head of office machines.[60] Here,

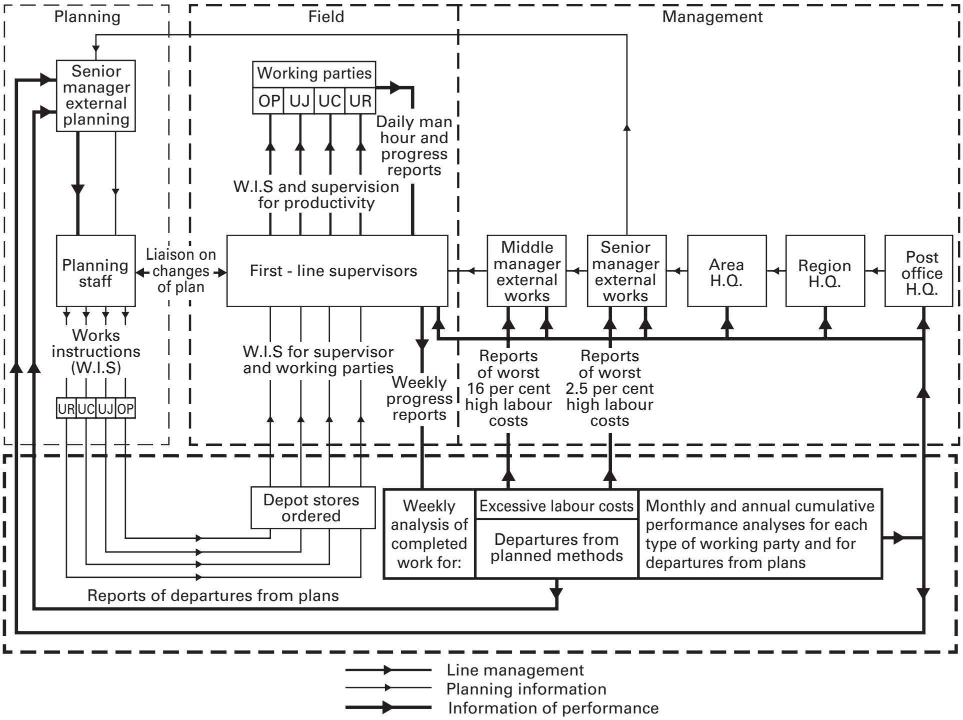

FIGURE 1.1
The Post Office works service organization as inputs and outputs of information. Source: Merriman, J. H. H. "Men, Circuits and Systems in Telecommunications." *Post Office Electrical Engineers' Journal* 60, no. 4 (1968): 241–251. Reproduced with permission from the Institute of Telecommunications Professionals.

Merriman was at the heart of Britain's "government machine," a tradition of discreet yet wide-ranging clerical mechanization that had run through British government since the nineteenth century.[61] In this tradition of "discreet modernism," expert mechanizers such as Merriman ran programs that mechanized and computerized clerical work, while carefully obscuring and setting apart this work from the executive work done by senior "generalist" civil servants. This discretion avoided the problematic notion that government work was wholly automatable.[62] Treasury Organisation and Methods (O&M), which had mechanized Civil Service payroll and statistics production, and computerized the Ministry of Pensions and National Insurance office, was this tradition's most important center. As head of office machines at O&M,

Merriman ran, in his own words, "a year of indoctrination and implementation" during 1959, in which he taught skeptical executive civil servants to see the Civil Service as a modern machine.[63] For example, Merriman used computer simulation "war games," in which executive civil servants competed in management simulations against academics and managers from Rolls Royce, British Rail, and Shell. He also staged "playlets" of bureaucratic work to demonstrate to these executives how the work of the government machine was routine and automatable. Merriman's success came from the line that he drew between specialist, mechanizable, clerical work and generalist executive work. Merriman cast machines as capable replacements for clerical work, and computers as managerial aids for executives' control over state bureaucracy.

Treasury O&M maintained strong ties with Post Office engineering, and so the "government machine" became a model for the Post Office's vision for Britain's digital infrastructure.[64] Cybernetics and information theory help explain the change from an ordinary telephone network to a self-healing, self-governing information network, but they do not explain Merriman's emphasis on personnel and bureaucracy. His background in Treasury O&M, however, does. Merriman had spent several years of his career mechanizing bureaucracy and seeing organizations as machines. Treasury O&M was as much a theory of administration and bureaucracy as it was a program of mechanization, a distinctive British administrative science that, given its prominence in the large-scale bureaucracy of government, was comparable to the management sciences of early twentieth-century America.[65] This explains why, for Merriman, any digital vision of Britain's telecom infrastructure had to combine administration with communication. Digitalization's universalizing tendency, in which everything becomes informational, and the government machine's compatibility with cybernetics and information theory, helped this mix.

Information theory, showing administration as informational flows, and cybernetics' vision of self-governing control systems, meshed well with the government machine as a science of bureaucracy and administration. At the 1958 Mechanization of Thought Processes cybernetics conference at Britain's National Physical Laboratory, one of the founding conferences for the new field of artificial intelligence, Merriman had presented a paper, "To What Extent Can Administration Be Mechanized?"[66] For Merriman, combining the government machine with cybernetic models of information and control was a natural basis for the Post Office's plans for a digital communications infrastructure, which explains why, in closing his paper, he asserted that, in this new digital infrastructure, "both men and systems become self-optimizing." This might not have been the first time that Britain's "government machine" influenced models of technology, as the British model of government bureaucracy quite possibly inspired Alan Turing's theoretical "universal machine," which in turn influenced the design of the modern stored-program computer.[67]

Merriman's emphasis on this infrastructure as a "general-purpose" network, however, was potentially transgressive. Governmental expert mechanizers had always been careful to delineate between specialist clerical work, which was mechanizable, and executive generalist work, which they avoided casting as mechanizable. This had roots in the longer history of the "government machine" metaphor for the Civil Service, which gained traction in the nineteenth century as a way to impart trustworthiness and mechanical objectivity to the new staff—women and lower-class men—drawn into the expanding Civil Service.[68] Casting women and lower-class clerks as mechanical components excused them from the upper echelons' expectations of gentlemanly secrecy and honor, while still affirming their reliability. Yet Merriman had no issue describing a "general-purpose" network that would automate management, and he directly opposed this vision against "special-purpose" networks. Merriman described the "considerable concern, and rightly so, at the possibility of a series of special-purpose networks evolving independently," which he contrasted with the "general-purpose digital network," which would have "versatility and open-endedness built in to permit becoming a better system in the future."[69] His emphasis on how this general-purpose network would computerize management appears taboo compared to the sacrosanct autonomy of the executive generalist civil servant. The explanation for Merriman's stance, however, lies with these "special-purpose" networks. The third influence on this vision was packet-switched data networks, which threatened the Post Office's monopoly.

COMPETITION AND CORPORATIZATION

From around 1960, data communication systems began to appear, particularly in the US. The US Air Force developed a system, the Semi-Automatic Ground Environment, or SAGE, that linked data from radar sites to warn of Soviet attacks on US airspace and began early operation in 1959. SAGE, in turn, influenced American Airlines' SABRE, or Semi-Automated Business Research Environment, which debuted in 1960 and was developed by IBM to book airline tickets automatically. Both systems worked over telephone lines and were thus the first "online" networks, proving the potential of networked data communications.[70] In the early 1960s, a new technique for data communications, packet switching, appeared. Paul Baran, a Polish American engineer at RAND, the American defense think tank, and Donald Davies, a Welsh mathematician at Britain's National Physical Laboratory (NPL), each independently developed packet switching in the early 1960s.[71] Packet switching divides a data message into small chunks, or "packets," which take separate, independent routes to the message's destination, where they are reassembled into the original message.

This differs from circuit switching, used by traditional telephone networks, which opens a continuous circuit along one route between sender and receiver, allowing the back-and-forth transmission of messages, as in a telephone conversation. Using packet switching, a destination can receive multiple messages from different senders simultaneously, whereas with circuit switching, the recipient can receive messages from only one sender at a time, occupying the line for the duration of that message. Packet switching was thus ideal for situations where multiple users needed to connect to the same computer simultaneously, a process called "time-sharing," whereas circuit switching was essential for voice calls. Baran and Davies's defense and scientific contexts shaped their work on packet switching. Hardening the American military communications network against nuclear strikes motivated Baran's research, while Davies developed packet switching to widen remote access to the NPL's scientific computing facilities. Time-sharing quickly commercialized, and the late 1960s was a boom period for the time-sharing industry. The two biggest companies in the industry, General Electric and Tymshare, built time-sharing computer networks that connected cities across the US. By 1972, Tymshare's network connected more than forty US cities and was expanding internationally.[72] This all brought increasing pressure within the UK for the Post Office to expand data services, and from 1967, a new group, the Real Time Club, began lobbying the British government to support packet switching and time-sharing.[73]

Merriman and the Post Office, however, were not so receptive, particularly to the Real Time Club, which complained about the Post Office's aversion to packet switching. In 1965, Davies sent a proposal to the Post Office to develop a national packet-switched data service jointly but received muted feedback.[74] While Merriman did not refer to packet switching explicitly in his 1966 presentation, he clearly stated that specialist data networks threatened the Post Office's goal of an integrated digital communications network based on Britain's existing circuit-switched telephone infrastructure. This attitude was even clearer several years later, in 1971, when Merriman warned the Post Office board that closed packet-switched data networks would infringe the Post Office's monopoly and obstruct its goal of a universal integrated network.[75] The Post Office has been called "ossified" for apparently missing packet switching's potential, and various histories of the internet have blamed the Post Office for Britain's lethargy in developing packet switching.[76] None of these histories, however, consider the alternatives that the Post Office might have had in mind. This was a time of diverse visions for data communications. In 1961, John McCarthy, the US computer scientist and AI pioneer, suggested that computing might become organized as a utility, like telephony, and Paul Baran lent credence to the computer utility proposal six years later, directly referencing the British Post Office's vision of a national data infrastructure.[77] As Merriman's speech shows, this vision extended beyond data to also include telephony, video calling, and television to the entire nation. There was doubtless a defensive, monopolizing quality to this vision, but from the Post Office's perspective, repurposing the national telephone network into a national information network was prudent and ambitious.

The Post Office's ambition, and its reorganization around a singular technological vision, stemmed from the fourth and final influence on the Post Office, which was its shift from a Civil Service department to a nationalized corporation. This shift began with the Post Office's financial troubles and a growing managerialist and technocratic spirit within British government. In 1957, Britain's balance-of-payments crisis and the government's stop-go economic policy cut public-sector investment, reducing the telephone business's ability to finance investment. As a result, the 1959 Conservative manifesto pledged to formally separate the Post Office's finances from the Treasury after a trial separation began in 1955. After the Conservatives' reelection, the 1961 Post Office Act revived a surplus trading fund for the Post Office, allowing the organization to balance its books. Various events and critiques throughout the 1960s highlighted that this act had neither loosened external controls as much as promised nor had the telephone business improved much.

Successive Treasury capital restrictions in 1962 and 1963 limited the Post Office's borrowing, and so the 1961 act was more a "modest milestone" in the Post Office's quest for freedom from the Treasury.[78] In 1963, the National Economic Development Council, founded by the Conservatives a year earlier to reverse Britain's poor economic performance, attempted to rectify this by announcing a near £900 million five-year spending plan for the telephone service.[79] In 1966, however, Labour prime minister Harold Wilson's "July measures," taken to avoid devaluing the pound, cut government spending, reducing the telephone business's investment program by £11.5 million.[80] The sluggish demand for telephone service during these restrictions motivated further critiques of the telephone business. The Brookings Institution, an influential US think tank, sharply criticized the 1961 act in its 1968 report, *Britain's Economic Prospects*, arguing that the act had unintentionally lowered telephone service demand by enabling the Post Office to raise tariffs, while various newspaper editorials demanded greater freedom and a more commercial attitude for the Post Office.[81]

Britain's rising public expenditure fueled technocratic managerialism in British government. Managerial modernization was in vogue in the UK in the late 1950s and early 1960s, emulating trends from the US. In 1956, William Whyte's *The Organization Man* highlighted and critiqued the growing numbers of US corporate managers, and management consultants such as McKinsey imported managerial thinking to the UK.[82] The government's 1961 Plowden Report on public expenditure, for example, made managerial sophistication its key target, and this report has since established a reputation for triggering a managerial revolution in British government.[83] This reputation is perhaps overstated. Computerized systems for management and expenditure planning were in place in the Treasury several years before the report, as the report both noted and praised. Only six years later, another review, the Fulton Committee, also recommended greater managerialism to solve rising public expenditure.[84] While the Plowden Report may have been neither especially novel nor successful, it nevertheless connected the time's managerial spirit with the public expenditure concerns that ailed the Post Office.

Technocratic managerialism had taken hold within the Post Office since the late 1950s as a way of negotiating these expenditure restrictions. The Post Office imported "accountable management" and "management-by-objectives" from the private sector and introduced computers as managerial tools.[85] In 1957, the Post Office opened its first computer center, the London Electronic Agency for Pay and Statistics, or LEAPS, with the promise that "the drudgery and, by modern standards, inefficiency of many dull, repetitive clerical routes will be swept away by the 'electronic office.'"[86] In 1965, a second London computer center followed in Charles House, Kensington, computerizing the preparation of customer statements and bills, which *Post Office Magazine* heralded with the headline "The Post Office Enters the Computer Age."[87] Highlighting this, the Charles House Computer Centre featured in a Post Office publicity poster series titled "Progress" (figure 1.2).[88] This computerized managerialism further reinforced the tradition of Civil Service bureaucratic mechanization within the Post Office. It also shows that the "white heat" of technocracy usually associated with Harold Wilson's first Labour government, elected in 1964, has a much longer history.[89]

Nevertheless, the Labour Party's election victory in 1964 was central to the Post Office's corporatization and its vision for a universal digital infrastructure. The new prime minister, Harold Wilson, appointed Tony Benn, a young modernizer, as postmaster general.[90] Benn's priorities were the "break," reforming the Post Office into a nationalized corporation, and the "split," dividing posts and telecoms into separate businesses. In March 1965, Benn argued to Wilson that Post Office reform was "a necessary act of modernisation," permitting the telephone business to become more entrepreneurial, dynamic, and effective in collaborating with the private sector.[91] The Post Office's struggles and Benn's appointment triggered several reports and committees, including two Joint Working Parties of Post Office, Treasury, and Cabinet officials; an National Economic Development Council subcommittee; an inquiry by the Select Committee for the Nationalised Industries; and a review of the Post Office by McKinsey, the US management consultants.

The first Joint Working Party, chaired by the Treasury, was ostensibly investigatory, making no recommendations, but its investigation still surfaced friction between the Post Office and Treasury. One Treasury official compared the Post Office's attitudes to that of "a Colonial nationalist movement anxious to get rid of the shackles of imperialist rule!"[92] The working party's final report arrived in July 1965 and was inconclusive, but perhaps unsurprisingly, given the Treasury's chairmanship, drew attention to the disadvantages of corporatization, suggesting that the Post Office was already akin to a nationalized industry.[93] James Callaghan, the chancellor of the Exchequer, was more explicit, expressing to Wilson his "doubt whether there

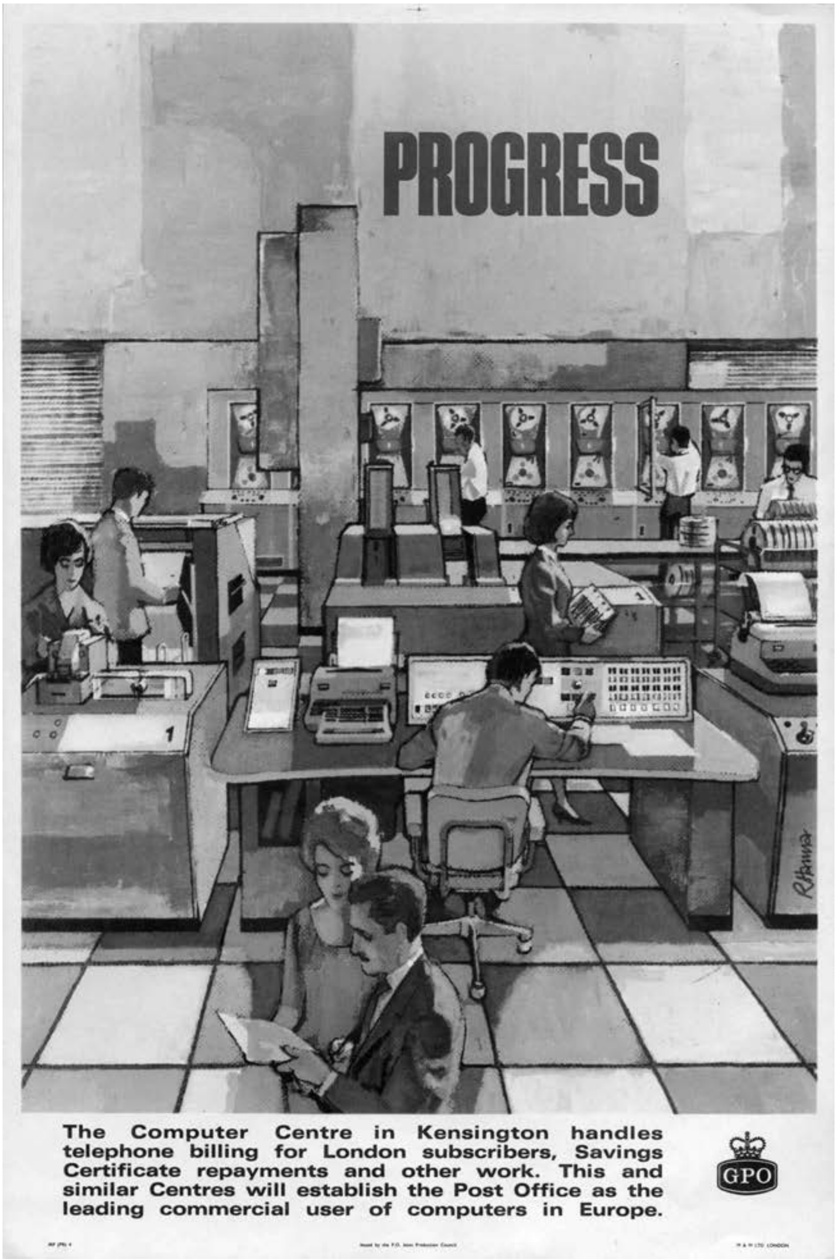

FIGURE 1.2
“Progress”: the Kensington Computer Centre, 1965. Source: TCB 420/IRP (PR) 4, BT Archives. Courtesy of BT Group Archives.

is much profit in pursuing the matter just now."[94] Benn, however, countered with a historical treatise of the Post Office's struggles under Treasury control, which he presented to Wilson as "a hundred years of argument for reform."[95] The prime minister thus agreed to a second committee reviewing the structure of the Post Office, effectively siding with Benn on the break. The task of this second Joint Working Party was to frame the nature of reorganization, and it concluded that the critical question was the "split"—whether the Post Office should become one or two separate corporations.[96]

A National Economic Development Council subcommittee of cabinet ministers also considered the split. The committee studied Benn's arguments and the working parties' reports and, by February 1966, concluded that the Post Office should become a nationalized industry and public corporation, with one board supervising both the postal and telephone businesses, which should be separated at the executive level so that each could function independently.[97] The March 1966 general election, along with Benn's appointment as minister of technology, replaced by Edward Short as postmaster general in June 1966, delayed a public announcement. This delay effectively halted Benn's ambitions for the full separation of the postal and telephone businesses, and Short soon announced corporatization on August 3, 1966, leaving the question of internal structure for later.[98]

Two further reviews into the Post Office's internal organization show the role of technology and managerialism in its subsequent corporate structure. The first review, by the Select Committee on Nationalised Industries, began after Short's announcement and noted in February 1967, in its final report, that the Select Committee's conclusions would guide the Post Office's future organization. The committee offered several possible corporate structures for the Post Office. First, a federal structure with semiautonomous regional boards, comparable to gas and electricity in Britain and the Regional Bell Operating Companies of the US Bell System. Second, a semi-split, in which a coordinating board oversaw separate, largely autonomous executives for posts and telecoms. Third, and favored by the committee, re-creating the Post Office as a corporation, maintaining central support services.[99] The committee argued that telecommunications' imaginative, managerial technocracy would inspire technical thinking in the postal business.[100] The Select Committee considered the postal service's loss of the Post Office research station at Dollis Hill in north London, which mainly undertook telecommunications research (discussed further in chapter 5), as "the greatest drawback" of separating the postal and telephone services.[101]

While the Select Committee's report influenced the Post Office's eventual corporate structure, the McKinsey report was more influential on the Post Office's digital vision. Ronald German, the Post Office's director-general, had hired McKinsey in 1965 to review the postal business, but Benn quickly embraced McKinsey as a potential ally in the fight for the split.[102] McKinsey's appointment further indicates this period's managerialist spirit. McKinsey's reputation grew so quickly in Britain during the 1960s that, by 1969, a journalist for the *Times* could write, "Ask anyone to name a management consultant and chances are, if he is British, that the answer will be 'McKinsey.'"[103] McKinsey recommended increasing the independence of the telephone and postal businesses and enhancing the telephone business's control over engineering and research by abolishing the shared Engineering Department and moving research to telecommunications' control.[104] McKinsey also concluded that telecom development needed more "technologically complete" plans, over a thirty-year timescale. This recommendation soon manifested in the plan for a universal digital integrated network, the most expansive and comprehensive plan for British telecommunications formulated since World War II. This recommendation also led to the Post Office creating a long-range planning department to sustain that vision into the 1980s (discussed in chapter 2), as well as specific reports, committees, and projects to apply that vision to telecom switching and transmission (discussed in chapters 3 and 4).

The Post Office's corporatization, and the associated recommendations for more holistic and managerial technological plans, thus shaped the vision for a universal digital infrastructure for the UK. Not all these recommendations were followed to the letter, however. While the government approved the break, as proposed by the second Joint Working Party and National Economic Development Council subcommittee, it rejected the split or semi-split, as had been advocated by Benn and McKinsey, after the Select Committee argued that central functions, like research, strengthened the case for keeping the postal and telephone businesses together.[105] The Post Office board thus followed McKinsey's recommendations in other ways, appointing separate managing directors for the postal and telephone businesses; abolishing the Engineering Department and position of engineer-in-chief, so that Merriman instead became senior director for engineering; and moving research to the telephone business. The Post Office established separate headquarters for the postal and telecom businesses, while a central headquarters housed support functions. By October 1, 1969, when the Post Office Corporation was formally vested, this new corporation had thus devoted nearly all research, planning, and engineering resources to telecommunications to support the vision for a universal digital infrastructure.

CONCLUSION

The digital vision emerged from the analogue failure of Highgate Wood, which showed the lingering influence of the warfare state on the Post Office. The Post Office's wartime work at Bletchley Park had lent gravitas to Highgate Wood and had forged the personal relationship between Tommy Flowers, Highgate Wood's chief designer, and Gordon Radley, controller of research and later director-general, that sustained the project. Moreover, the development of Highgate Wood shows how a nationalist political economy affected the Post Office at the end of the 1950s and in the early 1960s. Its focus on Highgate Wood came from the government's ambition to promote Britain on the world stage and secure export prospects for British electronics. The failure of Highgate Wood thus meant change on several fronts. The Post Office prioritized national prestige and export prospects less, which meant focusing less on a singular exportable product and more on a systematic future for Britain's telecom infrastructure. Finally, personnel changed, as Tommy Flowers and his Bletchley Park legacy departed, and two new engineers—Roy Harris, Flowers's deputy, and James Merriman, first as deputy engineer-in-chief and then as senior director of engineering—came to the fore.

Harris and Merriman's past experiences had already sown the seeds of this new vision. Harris was one of the Post Office engineers most interested in cybernetics and information theory, attending the influential London Symposia on Information Theory and lecturing Post Office engineers around the country on cybernetics. Meanwhile, as the Treasury's head of office machines, Merriman had become one of the most influential mechanizers in Britain's "government machine." Together, cybernetics, information theory, and the government machine composed the intellectual foundation for this vision. Drawing on cybernetics and information theory meant seeing the telephone network as an information network that could use feedback loops and decentralized machine control to become self-healing and self-governing. Furthermore, cybernetics set the expectation for a forthcoming information revolution, which was particularly influential on the Post Office's practices (as detailed in several of the following chapters). The government machine lent to this framework an ambition to include both bureaucracy and communications, using feedback loops and machine control to manage labor.

Alongside these ideas, two other pragmatic influences shaped this vision. Packet switching brought the threat of independent data networks, incentivizing an integrated digital vision that extended the Post Office's monopoly from telephony and telegraphy to data and video services. The Post Office's corporatization brought managerial and structural changes. Both governmental reviews, such as the 1961 Plowden Report, and key politicians, such as Tony Benn, saw technocratic, corporate managerialism as the solution to the financial and organizational failures of both government and the Post Office. This ethos created a hospitable environment for a vision that was as much about administration as it was about information. This ethos also fueled reviews into the Post Office, leading to its corporatization and greater independence. The McKinsey review, advising that the Post Office develop long-term, technologically complete plans and reorganize engineering and research to devote more support to telecommunications, appears particularly influential. These reviews all meant that, by 1966, Merriman had articulated this long-term, holistic vision, and the government had announced the impending corporatization of the Post Office. By 1969, the Post Office had become an independent nationalized corporation and reorganized its internal technical resources to support this vision.

Thus, by the end of the 1960s, an ambitious vision was in place to launch a national digital infrastructure. This vision, of an automated infrastructure, responsive to perceived threats and crises, such as competition, was more than just a technological vision. It also had an explicit view on labor relations, seeing digitalization as more "man management" than circuitry. The move to embed computer control throughout communications and bureaucracy in this infrastructure would have troubling implications for both staff and customers. Personal networks, especially those that connected Post Office engineering and Treasury O&M, supported this vision, and the Post Office's corporatization meant that material and managerial structures were already in place to implement this vision. Corporatization was key. This vision was also the product of the Post Office gaining more independence from government oversight. In doing so, the Post Office became more like a private corporation, no longer led by an elected official in the postmaster general, but instead by a chairmen and managing directors. Furthermore, this vision was the product of a monopolizing mentality, in which all communications came under the natural purview of the Post Office and consequently the Post Office needed to commercialize digitalization before specialist, private-sector competitors. This mentality even eclipsed packet switching, which had come not from the private sector but from the National Physical Laboratory, another state institution. Merriman's 1966 speech thus bore the traces of the many influences on this vision, showing its depth and origins. The next three chapters, in turn, show the breadth of this vision and its effects, demonstrating why this vision mattered to the digitalization and privatization of British telecommunications.

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Market and Monopoly in British Telecommunications

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