Part 1

1. Prelude to Change: Data Communications, 1949-1968

Overview

Some of the most iconic moments of the 1960s involved the blending of technology and ideas in new ways. Whether it was Neil Armstrong's walk on the surface of the moon, or Jimi Hendrix's burning guitar in Monterey, the foundations of an astonishing era of technology change were being forged. And as with all iconic moments, hundreds of people and decades of effort went into the changes that crystallized in public perceptions as a history-altering spectacle.

The 1960s were likewise a pivotal decade for the data communications industry, even if there was little public fanfare to accompany the key developments. Throughout this book we describe *market-structures*—dynamic relationships between markets and populations of firms that pursue similar product opportunities. During the 1960s, the market-structure for data communications slowly began to emerge, in spite of the dominance of two giant firms AT&T and IBM. The principal obstacle to the emergence of the data communications market-structure was AT&T's contesting the attachment of any devices, not of its own, as well as the interconnection of other networks, to 'its' telephone network. But as we will see in this chapter, the FCC reversed its long-standing support of AT&T in 1968, and allowed independent companies to sell equipment that connected to the public telephone network. The FCC's decisions transformed telecommunications—clearing a path for a rush of new businesses forming around new technologies and the growing adoption of business computing.

But before we get to the fateful events of 1968, and the extraordinary events of the next two decades that are the main subject of this book, we need to begin with a brief review of some of the important decisions and events that occurred between the end of World War II and 1968. We have organized this history into four sections: the federal government and its interactions with AT&T; the emergence of the dominant computing firm IBM; technological innovation; and entrepreneurial individuals who contributed to the emergence of the data communications market-structure.

AT&T, The Regulated Monopoly

Alexander Graham Bell invented telephony in 1876, and created the American Telephone & Telegraph Company in 1885. After a phase of competition with other telephone companies, AT&T became the most powerful telephone company in the United States. Its status as a regulated monopoly was established with the Kingsbury Commitment of 1913, a truce between AT&T and the Department of Justice. As a consequence, AT&T became the largest corporation in America by 1949, with revenue of $2.893 Billion and net income of $233 Million.[1] Enjoying the privileges of a monopoly, however, also invited the constant scrutiny of state and federal regulatory agencies.

[1] $2.893 billion in 1949 is equivalent to $31.6 billion in 2020.

When Harry S. Truman won the presidential election in 1948, he moved quickly to create an Administration with people who believed as he did, in the aggressive use of antitrust to save the economy for competition. Monopolies were the enemy. And AT&T, the biggest of them all, had escaped the leveling cleaver of antitrust. Or so they believed. Holmes Baldridge, who became the new chief of the Antitrust Division's General Litigation Section, had for years harbored frustrations that AT&T had not been punished after an investigation during the 1930s—an investigation of which he had served as chief counsel.[2]

Hush-a-Phone

Baldridge had fresh justification handed to him on December 22, 1948, when the Hush-A-Phone Corporation (HAPC) filed a complaint with the FCC against AT&T. The complaint charged that AT&T's Foreign Attachment Tariff Restrictions prohibited telephone subscribers from using the Hush-A-Phone, a product that had been available since 1929. It was simply a plastic cup that fit over the telephone microphone to increase the privacy of telephone conversations and reduce extraneous noise. As innocent as it would seem, AT&T and the Bell operating companies interpreted the Foreign Attachment Tariff Restrictions as a very clear prohibition against any type of physical attachment to any AT&T equipment or facility, period—including a plastic cover on a telephone book in a public phone kiosk. AT&T's formidable legal department argued, quite forcefully, that federal regulations were on their side. In place since 1911, the Tariff read:

> Equipment, apparatus and lines furnished by the Telephone Company shall be carefully used and no equipment, apparatus or lines not furnished by the Telephone Company shall be attached to, or used in connection therewith, unless specifically authorized in this tariff.[3]

Inspired by the growing number of complaints, on January 14, 1949, the Justice Department filed a civil antitrust suit against AT&T and its manufacturing subsidiary, Western Electric (WE). The Justice Department charged that the two companies had established a monopoly in the manufacture, distribution, and sale of telephone equipment. It asked the court to force WE to sell its 50 percent interest in Bell Labs to AT&T; divest AT&T of WE and split WE into three separate companies; require AT&T to bid all purchases competitively; and to license its patents to all applicants. Baldridge was not deterred by the conclusion from a recent investigation by California regulators that WE prices were 45 percent below an average of Independent manufacturers' prices.[4] Under Baldridge, the Justice Department had clarity of purpose: AT&T was a monopoly. It needed to be broken up.

To defend itself, AT&T relied on a decades-old strategy: any chips in its technical foundation would undermine its exceptional technological service for the American public. Mike Slomin, who served as an FCC staff attorney in the 1970s, summarized AT&T's strategy in a 1988

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[2] "Baldridge later made it clear, at congressional hearings long after he left the government and after the case ended with a consent decree, that the complaint had been largely his personal project." Fred W. Henck and Bernard Strassburg, *A Slippery Slope: The Long Road to the Breakup of AT&T* (Greenwood Press, 1988), 57.

[3] Jordaphone Corp of America and Mohawk Business Machines v AT&T, Decision, 18 FCC 644 (1954).

[4] Alan Stone and William L. Stone, *Wrong Number - The Breakup of AT&T* (Basic Books, 1989).

interview: "Well, you know, the Hush-A-Phone distorts speech, and any one of 200 million people in this country might be called by, or might call, someone using a Hush-A-Phone. They're going to get a lousy telephone call. That's harm. They're not getting what they paid for."[5] The power in this defense was that it appealed both to the technological complexity of the telephone system, as well as to AT&T's carefully crafted image as a civic-minded monopoly, one that had the unique and sacred responsibility of ensuring quality service for all Americans. The small office caught in the middle of this debate—AT&T on one side, and antitrust regulators on the others—was the FCC's Common Carrier Bureau (CCB or bureau). The CCB eventually responded to its difficult position by acting creatively, and, ultimately, paving the ground for the emergence of a new market-structure.

On February 16, 1951, the FCC released its initial decision and dismissed the Hush-a-Phone complaint in favor of AT&T. Hush-a-Phone petitioned for review, which sent the case into another phase of oral arguments and expert testimonies. As the months passed, AT&T successfully marshaled Department of Defense (DOD) support for their cause. DOD personnel began lobbying for case dismissal. AT&T had become indispensable to the DOD. It had recently taken on management of Sandia National Laboratories (responsible for the U.S. nuclear stockpile). Moreover, in 1952 AT&T responded to the Defense Department's request to help it construct a strategic air defense system. AT&T's role was to design an instrument capable of transmitting digital data over the analog telephone lines, and to design and build a telephone network connecting radar sites in Northern Canada to computers in the States and then onto aircraft and missile sites. This initiative would have lasting consequences for the Data Communication market-structure, as well as for the convergence between communication and computer technologies and market-structures.

The antitrust negotiations between the Justice Department and AT&T that began in the spring of 1953 had now dragged on for over two years. In the fall of 1955, the Justice Department once again solicited FCC advice on the issues of the antitrust suit. The chief of the CCB prepared the first response. The Commissioners thought it too weak in representing FCC powers, and sent it back for redrafting. The job was assigned to CCB staff lawyer Bernard Strassburg—an individual who would go on to play a pivotal role over the next decades. Strassburg's response emphasized the Commission's powers to examine rate bases and to take appropriate actions, pointing out rate reductions that had been negotiated.

Independently, on December 21, 1955, Judge David Bazelon handed down the Court decision on the Hush-A-Phone case. Judge Bazelon reasoned that since the same effect of the Hush-A-Phone plastic cup could be created by cupping one's hands around the microphone, such a tariff was an:

> Unwarranted interference with the telephone subscriber's right reasonably to use his telephone in ways which are privately beneficial without being publicly detrimental. Prescribing what changes should be made in the tariffs to render them "just, fair, and reasonable" and determining what orders may be required to

[5] Mike Slomin, oral history interview by James L. Pelkey, March 10, 1988, Allentown, New Jersey. Computer History Museum, Mountain View, California. Available from https://archive.computerhistory.org/resources/access/text/2017/09/102740208-05-01-acc.pdf.

> prohibit violation of subscribers' rights thereunder are functions entrusted to the Commission.[6]

Henceforth, independent equipment suppliers would be able to sell equipment that attached to the PSTN without requiring AT&T permission beforehand. What mattered was that the conditions of being "privately beneficial without being publicly detrimental" were met. Hush-a-Phone's plastic cups, in the end, were proverbial stones in the hand of David that created the first chips in the foundations of AT&T's monopoly. AT&T responded by changing their tariff restrictions to allow foreign attachments, but only if they did not "endanger telephone employees, property or service." AT&T continued to restrict foreign attachments, thus ensuring that the debate over the boundaries of its monopoly power would continue.

Accordingly, the career staff in the Justice Department continued to keep a close watch on AT&T and other large firms, guided by prevailing economic theories that monopolies would inhibit innovation. Even so, the political winds above them had shifted. The election of Dwight D. Eisenhower as President in 1952 resulted in a more conservative, pro-business philosophy of antitrust enforcement. The Justice Department sought to resolve as many of the 144 active antitrust cases as quickly as possible.

This left a major impact on AT&T and the communications industry, namely when the Justice Department and AT&T announced on January 24, 1956 that an out-of-court settlement of U. S. v. Western Electric had been reached. In some of the key terms of the agreement, AT&T:

1. Did not have to divest Western Electric, although Western Electric could not manufacture equipment other than that used by the Bell System, or the Government.

2. Was enjoined and restrained from engaging in any business other than the furnishing of common carrier communications services,

3. Was required to license Bell patents to any applicant that agreed to pay a reasonable royalty and agreed to make available their patents to Bell.

The significance of these latter two aspects of the Consent Decree—preventing AT&T from competing in the computer industry, and licensing the Bell System's patents—can hardly be overstated. As we will see, the long-term dynamism of the data communications and internetworking market-structures flowed from these restraints on AT&T. But in the near and medium term, AT&T's continued ownership of Western Electric and continued monopolistic control over telephone service generated tremendous profits: from 1949 to 1968, the revenues of AT&T grew from $2.893 Billion to $14.0 Billion, or by 380%.

Again AT&T had foiled the Federal Government's efforts to introduce competition into telecommunications. In essence, no one was willing to risk the uncertainty of what might happen if AT&T were forced to do what it steadfastly resisted; and not without reason, for not only had AT&T created the world's finest telephone system, but as the world's largest corporation any

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[6] *Hush*-A-*Phone* v. United States, 238 F.2d 266 (D.C. Cir. 1956).

negative impact on its hundreds of thousands of employees and shareholders would certainly have political consequences. So the Justice Department did what it could to prevent the monopolist from interfering with other competitive markets, and constrained AT&T, and WE, to common carrier communications.

AT&T had equally fought off the efforts of other companies to connect non-AT&T devices to their network. Granted, their tariffs had to be "just, fair, and reasonable," but who was to say what those words meant other than AT&T; and challenging AT&T's interpretations had proven lengthy, and expensive, with little hope the FCC would rule against AT&T. The tradition of fighting any changes at the periphery of the network, a tradition dating to the 19th century, had again proven successful: AT&T's monopoly remained intact.

So the world of telecommunications, as in AT&T, had walled itself away, steeling itself against change, seemingly harmonious with the pace of the 1950's, but soon to be at odds with the great changes to be introduced by computers. They were already facing the massive investment and challenging task of managing the conversion of their network from analog to digital. One of the reasons Bell Labs was innovating computers was to use them as digital switches. As a result, it made sense for AT&T to get into the computer business, both because they were one of the largest customers of IBM and Digital Equipment Corporation (DEC), and because Bell Labs was already designing and building computers. But the 1956 Consent Decree they had just signed prohibited their entering competitive markets.

Challenges to AT&T: MCI and Carterfone

Another set of business and legal challenges to AT&T came from aspiring competitors who petitioned the FCC to allow access to wireless frequencies for private communications. In 1956 a number of trade associations and manufacturers of microwave equipment lobbied the FCC for more relaxed regulation of the use of radio frequencies for private installations. This prompted the FCC to review its policies for allocating radio frequencies. A few years later, in 1959, the FCC ruled, in what would be known as the "Above 890" decision, that private companies could use radio frequencies above 890 megacycles (microwave frequencies) for use to meet private transmission needs.

In 1963, a company was launched that few at the time had any idea would become a serious competitor to AT&T. The original idea for the business came from a motivated entrepreneur who saw the opportunity in microwave technology to increase the sales of his short-wave radio equipment and service business. John D. "Jack" Goeken along with Donald and Nicholas Phillips, Leonard Barrett ad Kenneth Garthe founded Microwave Communications, Inc. (MCI) on October 3, 1963. Goeken's vision was to offer shipping companies in the Midwest affordable microwave communication lines, between truckers along Route 66 between Chicago and St. Louis, and between barges on the Illinois Waterway. Customers would share the same line so that their rates would be far less than was offered by the telephone company. Goeken planned to connect two-way radios with microwave relay stations—in short, a service for mobile business communications. Goeken filed an application for a license to the FCC in December 1963. In addition to the always pressing need to raise money, Goeken and the other founders knew they needed legal help. In January they hired Haley, Bader and Potts. Attorney Michael Bader, having recently fought a successful case against AT&T over a television microwave relay system in Texas, thought that if MCI were successful, this new area of communications law would be a promising source of business for his firm. Goeken and Bader began the lengthy process of making presentations to FCC commissioners and staff. Eventually a hearing before Herbert Sharfman, the examiner appointed by the FCC, was scheduled for February 1966.[7]

As Bernard Strassburg, who had become chairman of the CCB in November of '63, prepared to make the bureau's recommendations on the MCI application, he wasn't convinced Goeken and his company could deliver on their goal of a private microwave communication service. However, after consulting with two economists, Manley Irwin and William Melody, Strassburg decided that approving the MCI application would be a good way to test the waters of competition in the communications market. Convinced that the growing demands for new communications technologies would add to the market and stimulate additional communication services, he urged the FCC to grant the application. On July 1967, the CCB sent Sharfman their "Proposed Findings of Fact and Proposed Conclusions" recommending approval of the MCI application. Sharfman released the preliminary response in favor of MCI in October of '67.

In the meantime, another wireless entrepreneur had made himself a thorn in AT&T's side and asked the federal government to stop the monopolist from crushing him. Thomas Carter was an easy-going entrepreneur from Texas—a practical man who invented a clever device named the Carterfone. His invention was motivated by the simple desire to solve the communication problem of oil field workers, far from phones, maybe aboard an off-shore oil-rig, trying to reach home.

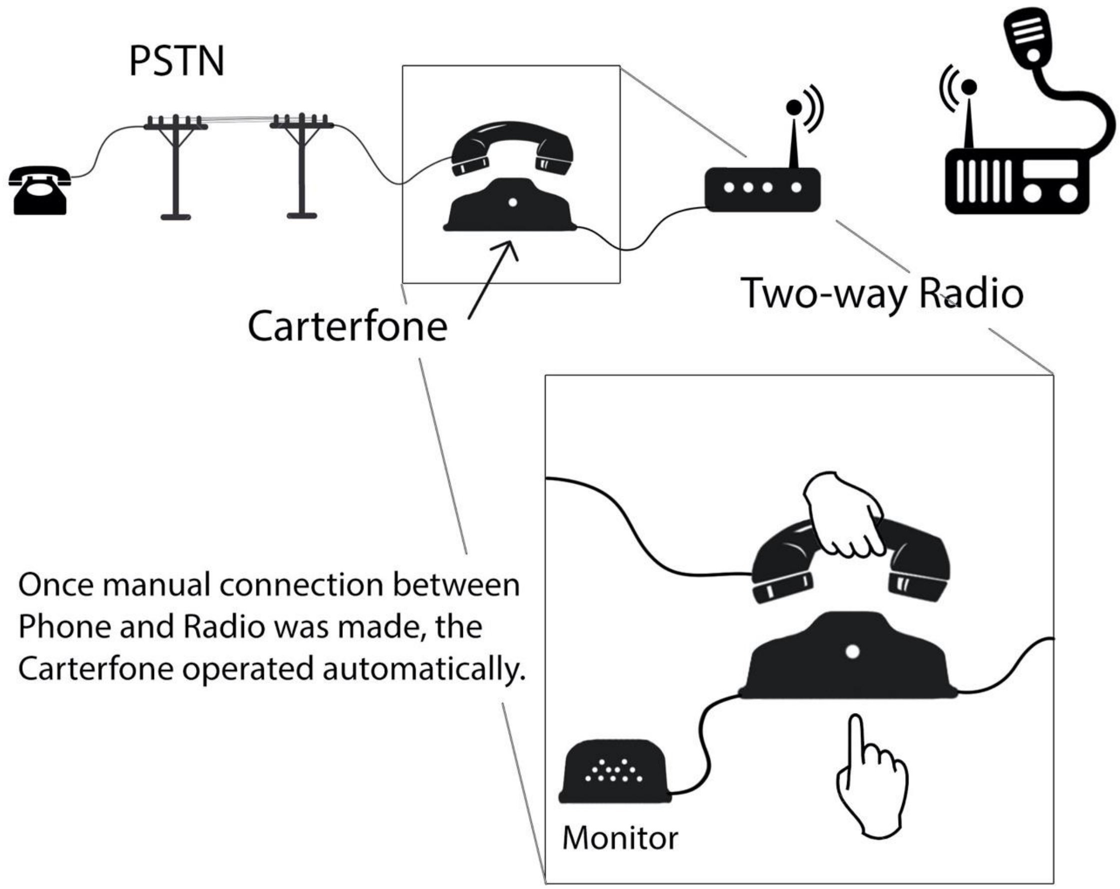
It's important to note that Carter, like MCI's Goeken, was seeking to meet the communication needs of business users. Neither was looking to create a mass-market gadget; and neither was using output from a research lab to create new technologies. Rather, these were practical men who saw opportunities for devices that could solve practical problems that arose in the course of ordinary business.

The Carterfone was a device that connected a two-way radio to the telephone network. (See figures 1.1 and 1.2) It would allow calls between users on a two-way radio and users on the telephone network. Once an operator made the connection between the two callers by placing the phone handset on the acoustic cradle, the Carterfone automatically transmitted the signal from the telephone handset to the radio and then stood by to receive the voice signal from the radio. The operator of the Carterfone could then monitor the call and adjust levels manually if needed.

Figure 1.1

The Carterfone

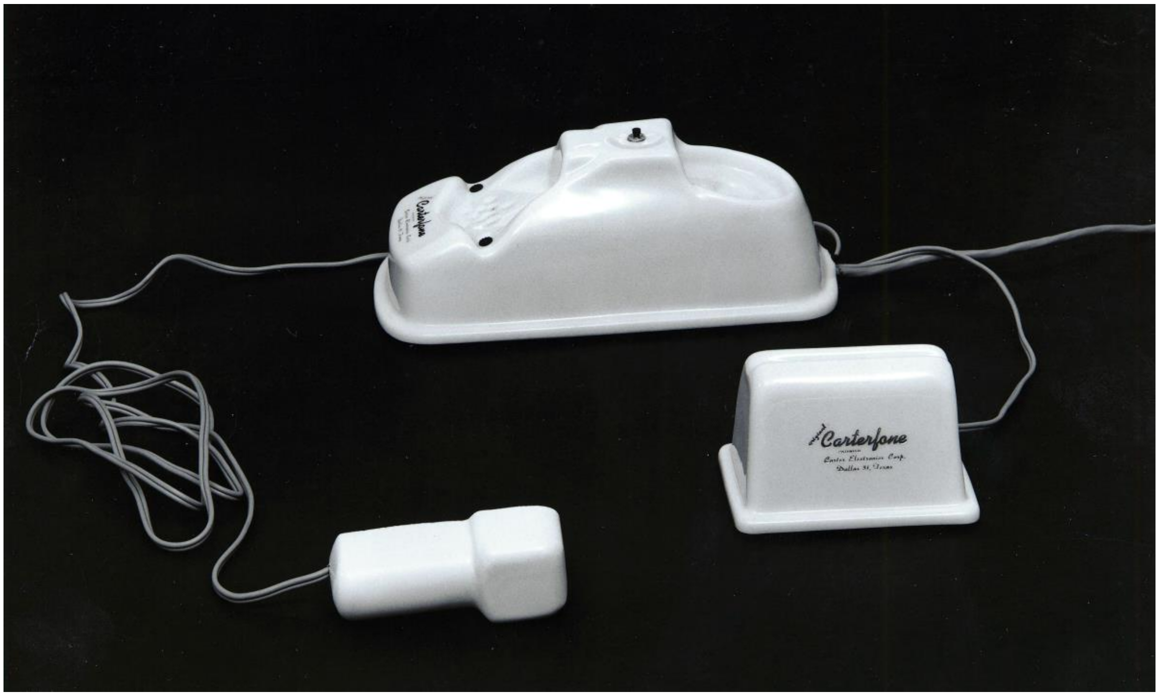
[7] Philip Louis Cantelon, *The History of MCI 1968-1988: The Early Years* (Heritage Press, 1993), 31-47.



Source: Illustration by Loring G. Robbins

Figure 1.2

The Carterfone



Source: Image Courtesy AT&T Archives and History Center.

When Carter first introduced the Carterfone in 1959, he had been surprised to learn the reasons why the telephone company objected to its use: it interfered with their end-to-end service responsibility and could be harmful to telephone service. As a result, it violated the tariffs banning foreign attachments to the telephone network. Carter was not so easily discouraged, and sold Carterfones anyway—approximately 3,500 units in the United States and overseas by 1966. But threats that the telephone company would terminate customers' telephone service posed a real obstacle to sales, so in 1966, Carter brought an antitrust suit against the Bell System and the General Telephone Company of the Southwest. The United States District Court, Northern District of Texas, referred Carter's case to the FCC under the doctrine of primary jurisdiction to resolve questions of whether the tariff permitting telephone companies to suspend, or terminate, service if non-AT&T devices were connected to telephone company facilities was valid. The key issue was one of "foreign attachments."

Once at the FCC, the Carterfone case was referred to the CCB, the same office that had dealt with the Hush-A-Phone controversy in the 1950s. The CCB scheduled hearings to collect information for both cases—MCI and Carterfone—for 1967. At the same time, bureau staff members were mobilizing to have an unprecedented public discussion about the future of communication services in the United States, with an eye toward anticipating technological changes that could alter long-established regulations and market-structures.

Strassburg, who had written the Bureau's opinion for the Hush-a-Phone matter, was beginning to speak publicly about the profound technological, political, and economic challenges that he saw on the horizon. In 1965 Strassburg assembled a task force to examine data communications, and spoke regularly—and publicly—with industry professionals on subjects such as market entry, information privacy, and the coming convergence of computers and common carrier communications. He remarked in a 1966 speech: "Few products of modern technology have as much potential for social, economic and cultural benefit as does the multiple access computer."[8]

The far-reaching consequences that he discerned prompted him to view the FCC's role, and his bureau's role, in a broader way than one might expect from a career government lawyer steeped in the philosophy of supporting the monopolistic AT&T. On October 20, 1966, he gave a speech to an audience of computer and data processing professionals in which he articulated his understanding of the responsibilities and roles of the FCC:

> The Commission is obliged by the policies and the objectives of the Communications Act to ensure that the nation's communication network is responsive to the requirements of an advancing technology. The Commission has the obligation, the authority, and the means to reappraise and refashion any established policies in order to promote the public interest through an effective realization of the social and economic benefits of current technology.[9]

In early 1967, Haakon Ingolf (H. I.) Romnes, who had previously been President of Western Electric, became AT&T's new Chairman and Chief Executive Officer. Romnes did not fully subscribe to AT&T's long-standing policy opposing foreign attachments. Shortly after taking office, he expressed the opinion that Bell's responsibility for the network could be maintained if there were "suitable interfaces or buffer devices to keep the attached equipment from affecting other users of the network."[10]

The MCI hearings began in February and lasted nine weeks. The Carterfone hearings were scheduled next, for April. Fred Henck, Editor of the respected trade publication *Telecommunications Reports*, would comment later that it was hard to find someone to report on these two insignificant cases, referred to around the office as the "cats and dogs."[11] Strassburg, on the other hand, began to see the Carterfone hearings as a way to revisit the foreign attachments tariff, which, as he was increasingly learning, was a real impediment to the use of the telephone system for data processing and to innovation of communication devices. He reflected on this period in a 1988 interview:

> We used the Carterfone issue and the Carterfone proceeding as a vehicle for revisiting the policy, which was basically a Bell System policy, which had been embraced by the FCC and the regulatory commissions for many generations,

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[8] Bernard Strassburg, "The Marriage of Computers and Communications—Some Regulatory Implications," *Jurimetrics Journal* 9, no. 1 (1968): 12-18.
[9] Strassburg, "The Marriage of Computers and Communications."
[10] Peter Temin and Louis Galambos, *The Fall of the Bell System: A Study in Prices and Politics* (Cambridge University Press, 1987), 44.
[11] "At *Telecommunications Reports*, we reflected the view of our news sources that neither case was very important. Our main problem was finding someone on our small staff with enough time to cover what we considered rather insignificant hearings. Along with a few other minor cases going on at the time, the Carterfone and MCI hearings were referred to generically in the office as "cats and dogs." Henck and Strassburg, *A Slippery Slope*, 102.

> against customers, willy-nilly, interconnecting anything they chose to the telephone network, no matter how innocuous it might be unless the item was specifically authorized by the telephone company's tariffs. Well, the telephone company wasn't likely to tariff anything of consequence, so as a result, anytime anybody wanted to promote a piece of equipment and to have it work with the telephone network, they either had to sell it to the Bell System, if they could convince Western Electric and Bell that they had something sellable, or if they couldn't succeed in that channel, then attacking the tariff insofar as the claim was unlawful -- and that the Commission should order it amended in order to accommodate their device. But that was a very cumbersome process to go through; the administrative hearing and the time and the cost involved that, to a small entrepreneur with a piece of equipment -- it discouraged people. It discouraged the market from developing, and that's why, I think, the United States was so far behind other countries, because, in terms of customer-premise equipment, simply because there was no entrepreneurship, the entrepreneurship was blunted and discouraged by this institutionalized practice of saying: ‘You can't connect with us.’ In other words, everything that went on had to go on within the Bell System, Bell Laboratories. That was where innovation began and ended.[12]

When it came time to argue the Carterfone case before the Hearing Examiner, Chester F. Naumowicz, Jr., the CCB took the position that the tariff provisions limiting use of customer-provided equipment be canceled. It should be replaced, instead, by a clear and affirmative statement that “customer-provided equipment, apparatus, circuits, or devices may be attached or connected to the telephones furnished by the telephone company… for any purpose that is privately beneficial to the customer and not publicly detrimental.”[13] In other words, the CCB was not arguing that users could substitute customer-provided equipment for that provided by the telephone company—only that it should be permissible to connect or attach devices to telephones furnished by the telephone company.[14]

The Carterfone hearings took but seven days. Maybe sensing a fundamental change in progress, Romnes assembled a high-level Tariff Review Committee to conceive alternative interconnection tariffs that would protect the network. The facts that AT&T permitted

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[12] Bernard Strassburg, oral history interview by James L. Pelkey, May 3, 1988, Washington, DC. Computer History Museum, Mountain View, California. Available from https://archive.computerhistory.org/resources/access/t[illegible]2015/11/102738016-05-01-acc.pdf.

[13] Henck and Strassburg, *A Slippery Slope*, 104-105.

[14] "We were also being very cautious in how far we thought the tariffs ought to be amended and how far we ought to go. We didn't view the issues in Carterfone as having to do with any replacements or substitutions for the equipment provided by the telephone company. It was how the telephone service provided by the telephone company, including the instrument, the terminal, should interface with other equipment and under what circumstances it should permit connection to other equipment which it didn't provide. We were not talking about eliminating or abandoning this whole concept of end to end responsibility by the telephone company. We were talking about what can be done at each end by the customer with the service that he buys from the telephone company." Strassburg interview, Computer History Museum.

connection of foreign attachments by the military and government, as well as equipment of TV networks, all suggested there had to be a solution other than total prohibition.

In August 1967, Examiner Naumowicz issued his initial decision. Ignoring the argument for a broad policy change, he ruled narrowly that harm from use of the Carterfone had not been proven. Left unsettled were the overarching questions about how AT&T could defend the boundaries of its monopoly, and how the FCC and courts would define that monopoly in the face of technological change and entrepreneurial incursions.

IBM

Now to the story of the emergence of the computer industry, the features that made it so attractive to AT&T, and the potential that made it so concerning to Bernard Strassburg in his new role as chief of the bureau.

At the end of WWII, when AT&T dominated telecommunications as a regulated monopoly, IBM was a large corporation that dominated the office equipment market. It did not even enter the computer market until 1952. Yet within a few decades, IBM was ascendant—the largest computer firm within an oligopoly of a few firms. How that happened is critical to our history.[15]

IBM was already a substantial and successful company before the idea of selling computers ever crossed the minds of any IBM executives, in particular, Thomas Watson Jr. the son of the president and CEO. In 1949, the revenues of IBM were $183 Million, every dollar of which came from the office equipment market, which had been their primary source of revenue ever since their inception--none came from computers.

The initial genius and entrepreneur of IBM was Herman Hollerith who was the inventor of punch card tabulation machines in the mid 1880s. In 1911, he sold his company, Tabulating Machine Company, to Charles Flint, who merged it with two other firms he had recently acquired to form the Computing-Tabulating-Recording Corporation (C-T-R), the recognized starting point of IBM, although it was not until 1924 that they changed the name to International Business Machines. Thomas J. Watson Sr., was hired as the general manager in 1914 after a successful career with the National Cash Register Company (NCR), and became president of IBM in 1915. By the 1950s, IBM's major competitors were: Remington Rand, NCR and Burroughs. When IBM chose to invest in expansion during the Depression, whereas the other three elected to retrench, IBM became the leading firm. In 1950, IBM controlled 90% of the punch card market.

When the Korean War broke out in 1950, Watson Sr. offered IBM's help. So IBM undertook a study to determine how it could best aid in the war effort. James Birkenstock, manager of the IBM Future Demands department, and mathematician Cuthbert Hurd recommended IBM build a "general-purpose scientific" computer. Code named the Defense Calculator, it became the most

[15] See generally James W. Cortada, *IBM: The Rise and Fall and Reinvention of a Global Icon* (MIT Press, 2019).

expensive investment in the company's then history.[16] Watson Jr. remembers the subsequent confusion: "Our engineers and production mangers weren't sure how to proceed."[17]

1952 proved to be a very busy year for IBM. On January 21, the Justice Department filed an antitrust lawsuit against IBM alleging they had acted illegally to preserve their 90% share of the highly visible punch card business. (As with AT&T in the communications industry, the government wanted to restructure the leading firm in the office equipment industry. These would not be the last antitrust suits the Justice Department would file against AT&T and IBM.) Watson Sr. added fighting the lawsuit to running the company, while Watson Jr. focused on his passion—getting IBM into the computer business. On April 29, Watson, Jr., announced at the annual meeting that IBM was building "the most advanced, most flexible high-speed computer in the world." [18] The new machine was introduced a year later on April 21, 1953 as the IBM 701 Electronic Data Processing Machine.

IBM was not the first company to sell an electronic digital computer; that distinction belongs to the Eckert-Mauchly Computer Corporation, and Engineering Research Associates (ERA). It took little time for IBM to assert market dominance in the computer market behind the skillful leadership of Thomas Watson, Jr., who became president in 1952. Watson Jr. remembers his father believing: "the electronic computer would have no impact on the way IBM did business, because to him punch-card machines and giant computers belonged in totally separate realms."[19] Once IBM entered the commercial computer business with its IBM 701 in 1953 and their scientific computer the IBM 650 two years later, they lost no time in making sizeable capital and research investments to accompany their extensive organizational capabilities. Despite his father's cautionary advice, his son had seen a very different future for the company.

Understanding IBM's deficiencies in computing, Watson Jr. made it a priority to win the contract being let by MIT and the Air Force to develop a computer for the the SAGE (Semi-Automatic Ground Environment) air defense system. Jay Forrester, the MIT engineer responsible for procurement, held serious discussions with Remington Rand, RCA, Raytheon, Sylvania, and IBM. In October 1952, he selected IBM to be the subcontractor assisting MIT's Lincoln Laboratories to finalize the SAGE computer design. For IBM, SAGE represented the opportunity to learn state-of-the-art computer technologies from the most advanced computer development laboratory in the world. But while IBM learned, staff at Lincoln Labs felt burdened. Norman Taylor, one of Forrester's most trusted managers, remembered: "IBM seemed awful stupid to us. They were still designing circuits like radio and TV circuits."[20]

The SAGE project was a prime example of a massive government sponsored project with an explicit goal to innovate existing and new technologies. The scale of the project itself required a level of organizational complexity that few if any firms had ever considered. SAGE impacted the fortunes of IBM and other firms involved almost immediately. The technology trajectory of

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[16] Thomas J. Watson and Peter Petre, *Father, Son & Co: My Life at IBM and Beyond* (Bantam Books, 1991), 216-217.
[17] Watson and Petre, *Father, Son & Co*, 259.
[18] "A Notable First: IBM 701," https://www.ibm.com/ibm/history/exhibits/701/701_intro.html.
[19] Watson and Petre, *Father, Son & Co.*, 200.
[20] Glenn Rifkin and George Harrar, *The Ultimate Entrepreneur* (Contemporary Books 1988), 22-23.

computers had accelerated significantly. SAGE innovations such as core memory, real-time response to multiple users, keyboard terminals, computer-to-computer communications, printed circuit board construction, and diagnostic and maintenance systems became standard features in all future computers. At the time, it catapulted IBM from a "stodgy company" (as Watson Jr. characterized it) to a technological leader.

Watson Jr.'s first significant act after taking over the reins from his father was to sign a consent decree ending the 1952 antitrust lawsuit. In the 1956 decree, IBM agreed, among other restrictions, to separate itself from its Service Bureau Corporation. The restrictions placed on the punch card business were not severe and with each passing year would prove insignificant, for punch cards were becoming less and less important to the company as a whole.

By the mid '50s, IBM management fully understood the benefits of designing and building advanced computers for the government—the company could generate invaluable goodwill, while maintaining access to cutting-edge knowledge it could apply in its next generation of computer designs. After IBM lost a bid in 1955 to build a super-fast computer for the University of California Radiation Laboratory, they sold a more aggressive design, to become known as STRETCH, to Los Alamos National Laboratory, as well as to the Atomic Energy Commission (AEC) and the National Security Agency (NSA).

The STRETCH computer was sold commercially as the IBM 7030, announced in April 1961, and like the earlier 7070 introduced in '59, used transistors instead of vacuum tubes. Early transistor computers also included the IBM 7090, a mainframe designed for large-scale scientific and data calculations. An early application of the 7090 was for the massive airline reservation system for American Airlines (AA). The name of the project—as well as much of the underlying technology—was drawn from the SAGE project, and titled Sabre for "Semi-Automatic Business Research Environment."

The inspiration for Sabre came from a fortuitous airplane conversation in 1953 between senior IBM sales representative, R. Blaire Smith and C. R. Smith, then president of AA. The two connected the concept of the SAGE network with the need for an automated flight reservation system in which flight reservations could be created and recorded and the data made available to agents in any location. Before the two organizations began discussions on how to implement the project, president C. R. Smith of AA was quoted as saying: "You'd better make those black boxes do the job, because I could buy five or six Boeing 707's for the same capital expenditure."[21] In 1959, IBM and AA signed a development agreement that eventually led to a $30 Million project.

IBM failed to foresee the massive amount of software development involved in implementing the Sabre system and consequently the project experienced many cost and schedule overruns. Initially, IBM terminals were located in travel agencies and connected by telephone lines using modems to IBM computers in AA's headquarters. When it was finally operational in 1964, Sabre revolutionized the airline reservation industry and was quickly duplicated by other airlines.

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[21] James L. McKenney, Waves of Change: Business Evolution Through Information Technology (Harvard Business School Press, 1994), 111.

In October 1959, IBM announced the 1401, targeted for small business customers. After deliveries began in 1960, more 1401s would be installed than any other computer at that time – by the mid 1960s more than 10,000 had been installed.[22] Business customers were clearly embracing the use of computers, and IBM was successfully positioned to benefit the most from this trend.

At the same time, IBM faced a major challenge in maintaining order across its two computer divisions: the General Products Division (GPD), which sold lower priced computers, and the Data Systems Division (DSD), which sold general purpose scientific and business computers. These divisions were making and selling a variety of different computer models, effectively competing against each other. But the main issue was the massive cost in software development for each project. Of the main transistorized models in production in 1960, none ran compatible operating systems. In the early 1960s, senior executives sought a drastic simplification of IBM's products, reducing its several product lines to one computer architecture that could meet the full spectrum of customer requirements, all using the same peripherals and software.

In January 1961, Frederick P. Brooks, Jr., lead designer for a recently cancelled 8000 series of business computers, was assigned to head development of a new line of compatible products that could serve all the requirements of IBM customers. As product manager, Brooks oversaw the massive hardware and software development effort involved in developing this revolutionary new "computer architecture", a term he first coined. The new system would be called the System/360. Gene Amdahl, who had previously worked on the 704,709 and Stretch computers, was engineering manager and chief architect.

The production of the System/360 was a massive gamble, but based on the difficulties in developing software to operate the new family of processors, as well as previous experiences with Sabre, it is worth noting that the efforts IBM undertook to develop advanced understanding in software development foreshadowed the future importance of software in computer history. The challenges, delays and huge time and cost demands on IBM resources were no more evident to anyone but Brooks. In his chronicles of the project, "The Mythical Man-Month," he coined what became known as 'Brooks' Law,' which states that "adding manpower to a late software project makes it later."[23]

On April 7, 1964, Thomas Watson Jr. and the management of IBM made the most important product announcement in their company's history. IBM would begin shipping six models of the revolutionary new System/360 in April 1965. In the first thirty days IBM sold an unbelievable 1,000 System/360's. At a cost to IBM of an estimated $5 billion, the System/360, the innovative new series of mainframe computers sent IBM's competitors scrambling for survival.

By investing in large-scale production, distribution channels, and management structures, IBM had secured first-mover advantages and created a dominant design for the mainframe computer industry. The scale and scope of attention IBM was able to bring to an average sale would dwarf

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[22] Pugh, *Building IBM*, 266.
[23] Pugh, *Building IBM*, 295.

whatever any competitor could do. As evidence of IBM's dominant market-structure position, IBM was shipping "over 1,000 model 360 systems a month" by 1969.[24]

The competition could do little at first other than wage a war of words. They argued that IBM could never deliver, it was too expensive, and it was not even state-of-the-art -- it didn't use integrated circuits, for example. But all were forced to develop new product lines to stay competitive. One way competitors tried to differentiate their products from System/360 was time-sharing -- largely because IBM did not support time-sharing in the announced System/360s.

The explosion in growth of computer service bureaus seemed to validate the notion that computers were analogous to utility service in electricity or water.[25] Service bureaus sold computer time and services to other companies as independent organizations or operations of computer manufacturers.[26] Existing since the earliest days of commercial computing, it was not until time-sharing that service bureaus could support real-time access to many users at the same time. By 1966, an estimated 800 service bureaus generated $650 million in revenues – thought to be growing at 40% per year.[27] IBM, even though restricted as to how they could compete in the service bureau business by their 1956 Consent Decree with the Justice Department, ran two nationwide service bureaus.[28]

By the end of the 1960s, IBM dominated the mainframe industry, thanks to Watson Jr's entrepreneurialism, technologies fueled by defense funding, the flexible and modular architecture

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[24] "Since it entered the computer business 15 years ago, IBM's volume has increased 17 times (to $5.3 billion last year [1967]) and its net income has gone up 20 times (to $651.5-million). Last year, IBM zoomed past Texaco and U.S. Steel to become the nation's eighth largest industrial company when it added $1.1-billion in revenues. That is like creating another Coca-Cola or another Celanese in just one year. In Wall Street's assessment, IBM is now the most valuable corporation around. Early this week, IBM's common shares were worth $41.5-billion. The common shares of AT&T, with assets eight times larger, were worth $26.3-billion. The stock market appraises IBM stock as worth at least as much as the combined shares of 21 of the 30 companies that go to make up the Dow-Jones industrial average." "Where IBM looks for new growth," *Business Week* (June 15, 1968), 88.

[25] Manley R. Irwin, "The Computer Utility: Competition or Regulation?" *The Yale Law Journal* 76, no. 7 (1967): 1299-320; Robert M. Fano, "The Computer Utility and the Community," *IEEE, Int'l Conv Record,* Part 12, (1967), 30-34; Paul Baran, "The Future Computer Utility," *The Public Interest* (Summer 1967): 75-87.

[26]John L. Roy, "The Changing Role of the Service Bureau," *Datamation* (March 1970), 52.

[27] Gilbert Burck, "The Computer Industry's Great Expectations," *Fortune* (August 1968), 142

[28] Irwin noted: "These new developments in technology and services raise the question, once again, of the status of IBM's consent decree. Does time sharing merely permit IBM to sell computer time over telephone lines, or is IBM processing customer data for a fee? What is legitimate activity for IBM as a manufacturer and IBM as a service bureau? The answers to these questions are not clear, but as if to hedge its short term anti-trust bet, both the Service Bureau Corporation and IBM, the parent corporation, have recently introduced nationwide systems of time-shared computer centers. In the long run, however, IBM many find it necessary to convince the Justice Department that new technology has invalidated major premises of its 1956 judgment." Irwin, "The Computer Utility: Competition or Regulation," *Yale Law Journal*: 1299.

the 360 line of computers, and an expert sales and marketing operation. But the increasing demand for timesharing soon would create opportunities for competitors.

New Technologies for Computing

The shifting fortunes of the two dominant firms in the converging fields of communications and computing, AT&T and IBM, depended upon several factors, including the changing regulatory environment, and the decisions of key executives to risk pursuing new opportunities. At the same time, the story of data communications in the decades between World War II and the late 1960s is in large part the story of technological innovation. During this period, new developments in computer technology, and the resulting decrease in the cost of computing, changed the landscape of possibilities for a growing number of institutional and commercial customers and the existing companies and many entrepreneurial startups that served them.

Transistors

The transistor was the first of three technological discontinuities to radically alter the computer market-structure, the other two being the integrated circuit and the microprocessor. Transistors became an alternative to vacuum tubes, which were large, costly, unreliable and consumed large amounts of energy. Although functionally equivalent to vacuum tubes, transistors had profound technological differences from vacuum tubes: where tubes worked by electrons flowing through voltage gradient, transistors channeled electrons through semiconductor materials.

During World War II, the US government significantly increased funding of semiconductor research at Bell Laboratories, universities and industrial companies, and created the MIT Radiation Laboratory to coordinate the research. These investments bore fruit on December 23, 1947, when the first transistor was demonstrated at Bell Labs. Walter H. Brattain and John Bardeen demonstrated a crude, but working, amplifying transistor made from germanium and wires. Their demonstration motivated William B. Shockley to work out the seminal principle of a solid-state transistor over the following five weeks, which was announced publicly in early 1948. AT&T subsequently sought to disseminate knowledge of transistors widely through seminars and licensing agreements. Managers at AT&T and Bell Labs understood that they would not be able to keep the technology to themselves. Had they kept the transistor proprietary, then the subsequent growth in the semiconductor, and all related industries, would certainly have been very different.[29]

By 1952, Western Electric (and a few other firms) manufactured approximately 90,000 point-contact transistors, which were sold primarily to the military. Data from 1955 to 1960 clearly shows the importance of government purchases (see table 1.3). Two important sources of demand were the early commitment of the Air Force to use semiconductors in the Minuteman Missile in 1958, and the growth of IBM. IBM was the largest customer of every semiconductor company, due to their transition to transistorized computers such as STRETCH in the mid-1950s.

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[29] On Bell Labs, see generally John Gertner, *The Idea Factory: Bell Labs and the Great Age of American Innovation* (Penguin, 2013).

Table 1.3

Government Purchases of Semiconductor Devices 1955-1960

	Total Semiconductor Shipments ($ millions)	Shipments to Federal Government ($ millions)	Government Share of Total Shipments (percent)
1955	40	15	38
1956	90	32	36
1957	151	54	36
1958	210	81	39
1959	396	180	45
1960	542	258	48

Source: Richard R. Nelson, *Government and Technical Progress: A Cross-Industry Analysis* (Pergamon Press, 1982), 60.

One of the first transistor computers, the Burroughs Atlas Mod 1-J1 Guidance Computer built for the Air Force, was operational in September 1957. IBM announced its 7070 transistorized computer in September 1958; RCA, the 501, in December 1958. The first available commercial transistor computer was the General Electric 210, delivered in June 1959.

The transistor, as a technological discontinuity, as the economist Joseph Schumpeter might describe it, would strike "not at the margins of the profits and the outputs of the existing firms, but at their foundations and their very lives."[30] Transistors made computers more reliable, faster, smaller, and consume less power and generate less heat. Once firms started making computers with transistors, they never again used vacuum tubes.

Integrated Circuits

Transistors represented a major improvement over vacuum tubes, but were not without problems of their own. Transistors came packaged as one transistor per each small "pot." The pots were much smaller than vacuum tubes, hence more devices could be squeezed into the same space. But as the desired complexity of device interconnections kept growing, wiring all these small devices became an interconnection nightmare, and very costly. From the years 1952-1959, firms and governments around the world searched for an answer to the problem of interconnections. Two companies—Texas Instruments (TI) and Fairchild Semiconductor—played the most significant roles in solving this problem.

[30] Joseph A. Schumpeter, *Capitalism, Socialism and Democracy* (Harper & Brothers, 1942), 84.

In 1958, TI made the propitious decision to hire Jack Kilby. Within two months, he conceived of the solution to the problem of interconnecting large numbers of transistors and other components. Kilby's idea would come to be known as the “Monolithic Idea,” where a single "monolithic" block of semiconductor material would contain all components and interconnections. Kilby hand-fabricated a monolithic, “integrated” circuit in September 1958, and TI filed for a patent in February 1959. But Kilby was not alone: another team of scientists, also with roots at Bell Labs, was likewise achieving impressive results with silicon.

In early 1956, William Shockley left Bell Labs to start Shockley Transistor Laboratories in Palo Alto, California—located in the future Silicon Valley. Shockley recruited people who would become legends in the history of semiconductors, including Robert Noyce, Gordon Moore and Jean Hoerni, to join his firm. But Shockley was no executive. Eight of his recruits were terribly dissatisfied, and made it known they would prefer a new home. Instead of moving to an established firm, the ‘traitorous eight’ raised venture capital and founded Fairchild Semiconductor Corporation in early 1957. Noyce is considered the father of the integrated circuit because he not only conceived of the Monolithic Idea, as had Kilby, but also its means of manufacture - the planar process. Fairchild's patent was filed in July 1959. The problem of interconnecting transistors had been solved. Ever since, the path of innovation has been to make device and interconnection features smaller, and the resultant integrated circuit, or chip, bigger.

The integrated circuit was not an overnight success for one simple reason: they cost too much to make. Development of the integrated circuit soon received a boost in May 1961, when President John F. Kennedy challenged the imagination of the American public to put a man on the moon. To do so would require the use of integrated circuits. Through 1964, purchases of integrated circuits for the Apollo Guidance Computer, used in the Apollo spacecraft modules, and the Air Force Minuteman guidance computer drove the market for integrated circuits. (See table 1.3.) Once again, government support proved essential to market lift-off.

Table 1.4

Government Purchase of Integrated Circuits, 1962 - 1968

	Total Integrated Circuit Shipments ($ millions)	Shipments to Federal Government ($ millions)	Government Share of Total Shipments (percent)
1962	4	4	100%
1963	16	15	94
1964	41	35	85
1965	79	57	72
1966	148	78	53
1967	228	98	43
1968	312	115	37

Source: Richard R. Nelson, *Government and Technical Progress: A Cross-Industry Analysis,* 63.

Even though the government had committed two critical programs to integrated circuits, into 1963 there remained sharp debate as to whether integrated circuits were the ultimate solution. But by then the costs of manufacturing integrated circuits were in steep decline, due to the volume purchases by the government, and any doubt as to their reliability was dispelled.

A new computer start-up, Scientific Data Systems, founded in 1961 by Max Palevsky, was the first to introduce a computer using integrated circuits. The SDS 92 shipped in 1964; IBM did not ship a computer using integrated circuits until 1969.

Modems

The SAGE system described above was the source of several landmark innovations in the history of computing, including advancements in memory; novel input/output devices such as cathode ray terminals (CRTs) and light pens; and a systems approach to the coordination of thousands of engineers, programmers and managers. But for the purposes of our focus on data communications, the innovations that supported its data communication capabilities stand out above the rest—specifically, the invention of the modem.

By 1955, SAGE consisted of two Q7 computers residing at each of 23 direction centers across the United States. These direction centers were in turn connected to radar sites across northern Canada and to the airfields and missile sites in the US. AT&T was contracted to design and build the telephone line network as well as the instrument to convert the digital signals to analog for transmission and then back to digital for the computers. AT&T Bell Labs worked with the Cambridge Research Laboratory of the Air Force to create the radar data processing and transmission equipment for the SAGE system. The first modems emerged from this collaboration. These modems transmitted data from remote radar sites in Canada to IBM 790 computers in the United States. A paper, "Transmission of Digital Information over Telephone Circuits," describing this first modem implementation was published in the *Bell System Technical Journal* in 1955. The name modem comes from its function: *mod*ulating, or suppressing, information onto a telephone line, and then *dem*odulating, or recovering, the modulated information from the line. The design objective is to accurately transmit as many 0's and 1's as possible in a fixed period of time. Since each 0 or 1 is a bit, the convention is to rate modems by how many bits per second (bps) they transmit. The faster the modem, the more challenging it is to innovate.

By the time the SAGE system was completed, AT&T built and installed well over two hundred SAGE modems. In addition, AT&T then redesigned the modem and began selling commercial modems in 1958, beginning with the Bell Data Set 101 that transmitted at the “blazing” speed of 110 bps. This formally marked the beginning of the Data Communication market-structure (See figure 1.5).

Figure 1.5

Bell 101 Modem – 1958

Source: Image Courtesy AT&T Archives and History Center.

Mainframes and Modems

The Mainframe era of computing refers to the 1950s, when IBM and its competitors produced systems like the IBM 700/7000 series that suited the highly centralized corporations of the day.[31] The mainframe era has clear roots in the technologies and architecture of SAGE. The mainframe architecture featured one big computer, the Host computer that sat in a raised-floor, air-conditioned, often high-security room. Terminals, printers, and other peripherals were directly wired to the Host computer in essentially a star configuration. The host, or "Big Blue" was thought the "boss" and all other devices were "slaves."[32] This centralized architecture was perpetuated by IBM, and gave a great deal of power to their corporate clients, the Data Processing (DP) or Management Information System (MIS) departments.

At first all the slave devices were local, but following the success of the IBM System/360, corporations wanted to locate terminals and printers at remote locations. To do so required sending the bits over the analog circuits of the telephone network. That drove the need for modems of higher speeds (bps). Modems and multiplexers - products that enable more than one computer device to share a telephone circuit - were the products of the first wave of computer communications: data communications. Modems and multiplexers were highly co-evolving technologies, yet only a handful of firms mastered both.

Time-sharing

Time-sharing as an idea first surfaced in the late 1950s. Frustrated with the time consuming method of batch processing, where jobs were created on punch cards and delivered to a computer operator who would run the job later, scientists and computer programmers sought ways to interact directly with the computer. In 1959, Christopher Strachey, a British mathematician, gave the first public paper on time-sharing at a UNESCO congress; and, working independently, Professor John McCarthy distributed an internal memo about time-sharing at MIT. Under the leadership of Professor F.J. Corbato, time-sharing was first demonstrated at the MIT Computational Center in November 1961.

Time-sharing might have lingered there were it not for the visionary leadership of Dr. J.C.R. Licklider and his license to invest government funds. In October 1962, Dr. Licklider became the first director of the newly created Information Processing Techniques Office (IPTO) of the Advanced Research Projects Agency (ARPA). His charge was to invest in advancing information technologies. Based on his experiences at MIT Lincoln Labs and Bolt, Beranek & Newman (BBN), and his vision of man-machine interactions, too briefly summarized as interactivity, he prioritized funding to time-sharing projects. And if projects didn't exist, he created them. For example, at MIT he helped create Project MAC (for machine-aided cognition or multiple-access computer) under the leadership of Professor Robert M. Fano, and approved $3

[31] The market-structure of First Generation mainframe computers (1950-1959) consisted of only seven companies and 31 computer models. Other companies developed computers, but they did not sell them commercially. Research and development funding came almost entirely from the U. S. Government. Although a commercial computer market existed, it was far from clear what its economic potential might be.

[32] For recent discussions around eliminating the once-conventional "master/slave" terminology, see Elizabeth Landau, "Tech Confronts Its Use of the Labels 'Master' and 'Slave'," *Wired* July 6, 2020, https://www.wired.com/story/tech-confronts-use-labels-master-slave/.

million a year in funding for the project. It would become the most influential effort in time-sharing. In 1967, IPTO funding to over a dozen time-sharing projects, at both universities and research organizations, exceeded an estimated $12 million.

Time-sharing required new software and hardware, as well as the most challenging innovation—an operating system that could support many simultaneous users and create the illusion that each user had exclusive control of the computer. The speed of the computer made this sleight of hand possible: if the computer could switch back and forth between programs fast enough, users perceived that they had both real-time and on-line performance. This experience was simply impossible in operating systems designed to process programs in batch fashion.

The first computer company to embrace time-sharing was General Electric (GE). In May 1964, a GE computer was used in a time-sharing demonstration at Dartmouth College. That summer, GE announced its 600 series computers would all support time-sharing, using software developed at Dartmouth. And that fall, MIT surprised everyone when it announced it would buy a GE computer for use as the main computer for Project MAC. IBM, which had abandoned internal efforts to develop a time-sharing system and did not support time-sharing in its initial releases of System/360, had jeopardized its valuable connection to MIT. Support for time-sharing was added when IBM released the TSS/360 timesharing operating system for the 360 model 67 released in ’67 and later the System/370 announced in 1970.

As time-sharing spread, so did the demand for the required communications hardware, such as modems, multiplexers and communications processors to transmit data between terminals and mainframes.

Minicomputers

The roots of minicomputers can also be found in the SAGE Project. In 1953, Kenneth Olsen, a recent graduate of MIT and one of 400 engineers hired to staff the SAGE Project, was reassigned to work as a liaison to IBM, the firm contracted to manufacture the SAGE computers. When it was time for a new assignment, Olsen went to work for an advanced engineering group at MIT Lincoln Labs led by Wes Clark. Clark had approval to build a transistorized computer, the TX-2. The contrast between the working environments of IBM, where development was slow and subject to heavy bureaucracy, and the lively pace of research and collaboration at Lincoln Labs, made a lasting impression on the young Olsen, who was inspired to recreate the research lab culture in his own business. In early 1957, Olsen left MIT to test his entrepreneurial skills and, together with Harlan Anderson, and supported by venture capital from American Research & Development, they founded Digital Equipment Corporation (DEC) in August 1957. Their first product, the PDP-1, released in 1959, borrowed significantly from the TX-2. In the fall of 1965, DEC introduced the first commercially successful minicomputer: the PDP-8. In 1966, DEC went public with a valuation of $77 million, 770 times its founding valuation. In the few years that followed, venture capital investors eager to discover the next DEC, funded an explosion in the number of minicomputers.

It was not until DEC introduced their PDP-8 that businesses began to use the minicomputer as a smaller version of a mainframe computer. For smaller companies, minicomputers would soon occupy the central role that mainframes occupied. They were the repository of all the accounting and operational data and enabled printing of timely reports. Eventually they performed the same role with manufacturing data, such as inventory levels and purchasing information on vendors and orders outstanding. The next stage was integrating all the manufacturing data and information into what became known as MRP systems (initially Material Requirements Planning and later, as the software became more inclusive and sophisticated, Manufacturing Resource Planning). It took roughly a decade for third party software vendors to emerge and create, sell and support software that even the minicomputer companies had a hard time creating. In the interlude, minicomputer companies found a welcome home focusing on the fast growing data communication market, providing statistical and time division multiplexing functions, acting as communication processors or becoming a building block of private networks.

Minicomputers were also used as timesharing computers. DEC's first computer to support timesharing was the PDP-6, released in 1964. The DEC timesharing operating system TSS/8, which ran on the PDP-8 was released in '68. Later in the mid-1970's, Hewlett-Packard introduced their HP 3000, another popular minicomputer that supported time-sharing.

Venture Capital & Public Capital Markets

The success of an entrepreneurial endeavor often hinges on the availability of capital needed to fund the proposed business idea. Traditional sources of startup funding came from institutional loans and wealthy families, but in the late 1960s, venture capital partnerships were beginning to emerge as an alternative source of risk capital for early stage startups.

The modern venture capital industry is generally considered to have begun with the founding of American Research and Development Corporation (ARD) in 1946 by Georges Doriot, a former dean of the Harvard Business School who many consider the "father of venture capitalism," with Ralph Flanders and Karl Compton (a former president MIT) and other distinguish leaders from the Boston area. ARD is considered the first major venture capital success story with its initial investment of $70,000 into the founding of DEC for 70% of the ownership in 1957. DEC's initial public offering (IPO) in August 1966 was considered a "wild" success story, valuing DEC at $8.25 million[33]. The success of ARD's 'long-tail' investment strategy, in which one or a few high performing outliers in the 'long-tail' of the distribution curve increased fund returns significantly, proved the viability of a well-managed portfolio of early stage equity investments.

Another important influence in the development of the modern venture capital industry came in the form of government policy, when in July 1958, President Dwight D. Eisenhower signed into law the Small Business Investment Act. The act licensed private, Small Business Investment Companies (SBICs), and made available Small Business Administration loans to leverage a company's pool of capital by up to 4 dollars for every one dollar of private investment. More than 500 SBIC licenses were issued by the end of 1961.[34] The majority of SBICs invested in debt financing or real estate, but many invested in private companies, including the growing number

[33] "Digital Equipment Markets Its Shares" *New York Times*, August 19, 1966, 42.
[34] John W. Wilson, *The New Venturers – Inside the High-Stakes World of Venture Capital* (Addison-Wesley, 1985), 21.

of semiconductor manufacturers and other technology startups that were founded in the 1960's. Prominent SBICs that made investments in early technology startups included Continental Capital Corporation, founded in 1959 by Frank Chambers, and Boston Capital Corporation, founded in 1960, the largest SBIC at the time, with an investment pool (including government loans) of about $100 million ($810 million in current dollars).[35] Some notable companies that received SBIC funding included American Microsystems, Inc., Intel, and ROLM. The growth in private investment companies as a result of the SBIC act helped many young investment professionals gain experience and capital, inspiring several to form new venture partnerships. William Draper, III, and "Pitch" Johnson formed their SBIC, Draper and Johnson and went on to build successful venture partnerships Sutter Hill and Asset Management Company.

The 1960's saw the formation of influential venture partnerships such as Greylock Partners, founded in 1965 by former ARD vice president William Elfers, and Venrock Associates, by Laurance Rockefeller in 1969, both prominent East Coast examples, while on the West Coast, Draper, Gaither & Anderson was the first limited partnership, started in 1959. One of the most successful venture capitalists in the early tech industry was Arthur Rock. Rock and Tommy Davis started their limited partnership, Davis & Rock in 1961. Rock's investments in Scientific Data Systems, Fairchild Semiconductor, and later Intel, were among the legendary investments of early Silicon Valley history.

The sustained growth economy of the United States that began in the early 1950's had neither the breadth nor legs to support the policies and actions of the Federal Government during the 1960's. The simultaneous spending on both "guns and butter" -- the Vietnam War and the "Great Society" -- forced the Government to issue excess money. Perceived by a growing number of professional fund managers as a certain prescription for inflation, they sought new ways to increase their investment returns to offset the erosive potential of inflation.[36] Seeking higher returns than could be earned by investing in bonds, the fund managers began investing in stocks, and were amply rewarded on January 10, 1967. On that day, following President Lyndon B. Johnson's State of the Union address, buying stocks for their growth potential turned into a stampede when the third largest volume of shares at that time were traded on the NYSE. A two-year bull market ensued. The most desired stocks were the "glamour" stocks or "Houdini issues:" IBM, Xerox, Polaroid and Kodak.[37] Stock prices traded as high as fifty times next year's projected earnings.

Investor appetite and willingness to pay high prices for technology companies induced private technology companies to go public in order to raise always-needed cash and create desired liquidity for shareholders. Computer leasing companies proved an immediate favorite. By June/July 1967, investor actions resembled a "speculative orgy" according to *Business Week* with the AMEX up 50%. By August it would be up 70%. It seemed as if all a company had to do was embed "tronics" in its name, and it became a "high-flyer." The markets peaked in September 1967, then regained momentum in the spring of 1968, opening another market window for technology companies, especially those that were computer related.[38]

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[35] Tom Nicholas, *VC: An American History* (Harvard University Press, 2019), 136-140.
[36] "The market warms up," *Business Week* (January 21, 1967), 25.
[37] "Pension advisors play it cool," *Business Week* (April 1, 1967), 116.
[38] "Speculative spree alarms AMEX," *Business Week* (July 15, 1967), 36.

The “hot” market for technology stocks induced the transformation of venture capital from largely an activity of wealthy families to one of professionally managed fund partnerships like ARD. Investors, having made money on their private investments that went public, wanted to reinvest their capital gains in other new, private technology companies. The goal was to achieve ten to twenty times their investment in three to five years. A new breed of venture fund managers emerged in response. Unprecedented sums of money began flowing into venture capital. By 1970, the first year for which records were kept, $83 million was invested, up from $10 million (by estimate of the authors) in 1966.

The Early Entrepreneurs of Data Communications

Entrepreneurs have always played valued roles in human societies. Why? Because societies have always confronted problems, and curious individuals enjoy the challenge of solving them. But to be successful, entrepreneurs must have more than curiosity; they must possess the unique combination of vision and leadership. They must envision a new way of doing things and be capable of attracting others to help them achieve that vision. Very few entrepreneurs have all of the resources at their disposal to solve their problems of choice—so the help of others is essential. Beyond the initial idea for a business, the entrepreneur or co-founders needed to build a team, raise the necessary capital to develop the technical product, and build a successful model for generating business revenue.

As important as the vision and leadership of individual entrepreneurs, is the environment in which they act. The massive government investment in technology following WWII resulted in an unprecedented scale of technological innovation and created the building blocks for many of the entrepreneurial innovations of the emerging information economy. When combined with changes in regulatory policy favoring competition and the growth in the availability of venture capital, the time was ripe for those with entrepreneurial aspirations. The pioneers in the early evolution of computer communications paved the way for the flourishing entrepreneurial culture of the late ‘60s, ‘70s, and ‘80s. The work of Thomas Carter, William Shockley, Kenneth Olsen, and many others of this time marked the first wave in the explosion of new products, new methods of production, and the formation of new industries.

Codex

Entrepreneurship does not always begin with a grand vision of the future. Sometimes the motivation can simply be a desire to do what one enjoys most, to escape an unpleasant work environment, or being forced to try something different. Such was the case for Jim Cryer and Arthur Kohlenberg in 1962 when their employer, Melpar Electronics, informed them that they were closing the advanced research laboratory they had been running as director and chief scientist, respectively. Even though offered the option to move to Virginia, both men had little desire to leave the Boston area. They believed that on their own they could win technology development contracts being let by government agencies. So they incorporated a new company, Codex, and joined thousands of other companies swept up in the Federal government's funding of technological innovation that included large defense projects following SAGE, and newer ones like NASA’s Apollo project.

Cryer and Kohlenberg knew just such an opportunity: the Air Force wanted better error-correcting codes for digital transmission over telephone lines. They also knew Robert Gallager, then a young professor at MIT, and his graduate student, Jim Massey, had developed new error-correcting techniques, thought a sure bet to secure a development contract. Their instincts were right. Soon they had a contract to develop exotic error-correcting codes for the Air Force's Ballistic Missile Early Warning System (BMEWS), the successor to SAGE. Error-correcting codes were needed to restore the lost data. Better codes required more of the total capacity of the communication lines, or bandwidth, leaving less bandwidth for radar data. More powerful codes also required faster modems.

Even before taking possession of their first AT&T modems in the 1950's, the Air Force wanted faster ones. The need for speed came from wanting to create and maintain a worldwide command and control system for air defense. Brigadier General H. R. Johnson, Director of Point-to-Point Planning for Headquarters Airways and Air Force Communications Systems (AFCS), USAF, from 1950 to 1955, remembers a senior member of his technical staff, Bill Pugh, calculating: "a suitable goal would be 10,000 bits per second in a voice band" for modems. That goal was then set forth in 1956 in: "the proposed General Operational Requirement that AFCS sent to the Air Force, which subsequently became the research document for the Air Force Communications System."[39] Yet a decade later, reliable modems operating at that speed remained an elusive goal.

Such was the background in 1966, when Cryer and Kohlenberg began taking seriously the idea of Codex developing a leased-line modem to sell to the Air Force. That they knew the Air Force yearned for higher speed modems for their air defense system made the opportunity seem a sure bet. But there was a problem: up to that point, Cryer and Kohlenberg had little experience, or for that matter any real interest, in selling products. Their competence lay in solving difficult technical problems, not in managing what they imagined as the boring business of stamping out the same products, day-in, day-out. The very prospect demeaned Codex's proud corporate ethos of: "if not technically challenging, it was not worth doing."[40] Even so, Cryer and Kohlenberg worried about Codex's dependence on the feast-or-famine nature of government contracts; when sales could be $1 million one year and nothing the next. Selling a product, such as modems, did have prospective advantages.

In discussing the subject with MIT's Gallagher, Cryer and Kohlenberg learned a high-speed 9600 bits per second (bps) modem—four times faster than the fastest commercial modem then available from AT&T—was possible. Wanting to know how, they pressed him further. Gallagher then told them about Jerry Holsinger, a 1965 MIT PhD graduate whose thesis had been on high-speed data transmission over telephone lines. He last heard Holsinger had left MIT Lincoln Labs and was employed by a small R&D shop on the West Coast named Defense Research Company (DRC). Intrigued, Cryer and Kohlenberg convinced themselves that a 9600 bps modem would

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[39] Harold Richard Johnson, oral history interview by James L. Pelkey, May 3, 1988, Cupertino, California. Computer History Museum, Mountain View, California. Available from https://archive.computerhistory.org/resources/access/text/2016/04/102738128-05-01-acc.pdf.

[40] Art Carr, interview by James L. Pelkey, April 6, 1988, Newton, Massachusetts. Computer History Museum, Mountain View, California. Available from https://archive.computerhistory.org/resources/access/text/2015/10/102737982-05-01-acc.pdf.

give Codex the competitive edge and hopefully the financial security they needed to be successful while upholding their proud tradition of solving hard problems.

On meeting Holsinger in early 1967, Cryer and Kohlenberg discovered he had already formed a company, Teldata, and was soliciting investment from venture capitalists or anyone else who had money. Holsinger claimed he had a working prototype of a 9600 bps modem, one developed at Defense Research Corporation with funding from the National Security Agency (NSA). He confided his original design had not worked on normal telephone lines, but he had perfected the design, and had a working breadboard prototype. All he needed to do was convert his modem to printed circuit boards to have the world's first 9600 bps modem.

Holsinger thought of himself as an entrepreneur, not an employee working for a salary or as a research scientist, but he was having trouble convincing others that they should invest their money with him – not surprisingly given he lacked business experience and was only two years out of graduate school. Holsinger remembers how green he was: "If somebody like me were coming to me now, I would probably tell them the same thing. Go belly up to somebody." It didn't take long for him to realize: "it wasn't really what I wanted to do. I thought that I wanted to run a business, but it wasn't in the cards at that point, so I ultimately got together with Codex and they bought out the rights of the people on the West Coast, and they effectively got me and a production-prototype modem design in that process."[41]

Cryer and Kohlenberg persuaded Holsinger they were serious about building a modem business and, lacking an alternative, Holsinger agreed to sell Teldata to Codex in May 1967. Codex acquired 82.36% of Teldata's shares for $94,000. Securing the technology for its first product accomplished, Codex engineers turned to the task of developing the actual product. As often is the case with cutting edge technologies, the process was fraught with challenges and setbacks.

Milgo

Codex embarked on its journey into modems by way of acquisition. Many other defense contractors and electronics companies, like Rixon Electronics, Collins Radio and Stelma, began selling modems, like AT&T had, by using technology they developed for the government. The first independent company to really challenge AT&T, Milgo Electronics Corporation (Milgo), hired a talented individual, Sang Whang, and funded the project internally.

Monroe Miller and Lloyd Gordon, the 'Mil' and 'Go' of the name 'Milgo,' had served the defense agencies and NASA ever since founding their company in 1956. They, like Cryer and Kohlenberg, learned that NASA and military agencies wanted faster modems. In 1965, they hired Sang Whang out of Brooklyn Polytechnic Institute to develop a line of modems to sell to the Kennedy Space Center for down range instrumentation. In 1967, Milgo introduced its commercial 2400 bps modem, the 4400/24PB. Edward Bleckner, head of Milgo's efforts to enter the modem business, hired an executive search firm to find a seasoned sales/marketing executive with modem experience. They luckily caught up with Matt Kinney on the telephone as he was

[41] Jerry L. Holsinger, oral history interview by James L. Pelkey, April 6, 1988, Westborough, Massachusetts. Computer History Museum, Mountain View, California. Available from https://archive.computerhistory.org/resources/access/text/2016/04/102738129-05-01-acc.pdf.

stranded by a snowstorm at LaGuardia airport. He remembers: "They asked me if I'd like to come and talk to them about a job, and I said, 'Where are you?' They said, 'Miami, FL.' The answer: 'You bet your sweet life!'"[42]

In joining Milgo in January 1968, Kinney brought to Milgo needed experience in selling commercial data communication products and an understanding that significant changes might soon propel the demand for data communications; that is, if Tom Carter won his case against AT&T. Kinney remembers: "Tom Carter is one of my oldest and dearest friends. Hell, I knew in '66 that if Carter prevailed, which seemed highly unlikely at the time, that the industry would take off."[43]

Carter's chances depended entirely on the willingness of federal regulators to re-examine the fundamental assumptions upholding AT&T's monopoly.

Bernard Strassburg

In entrepreneurship, it is not only the case that the motivation needs be economic or defined by the starting of a company. Accordingly, our usage of the term comes from our recognition that entrepreneurs exist in all elements of society. To restate what we said in the Introduction, we follow Joseph Schumpeter's definition of entrepreneurship: "The typical entrepreneur is more self-centered than other types, because he relies less than they do on tradition and connection and because his characteristic task—theoretically as well as historically—consists precisely in breaking up old, and creating new, tradition." The last entrepreneur we will mention here is not an entrepreneur from the business sector, but one from the government regulatory sector who, nevertheless, acted with similar foresight and vision in relation to the emerging technologies of computer communications. The emergence of the new market-structure of data communications was fueled by technological innovation as well as acts of entrepreneurship from multiple individuals across multiple sectors. In an area that was heavily regulated, *policy* entrepreneurship was complementary to the efforts of entrepreneurs in companies such as Codex and Milgo—and, arguably, every bit as creative and significant.

Before 1965, Bernard Strassburg, Chairman of the Common Carrier Bureau of the FCC, viewed the relationship between AT&T and the FCC as collaborative: "It was truly a symbiotic relationship. The regulated monopoly operated in what was considered to be the public interest and, in turn, was shielded against incursions by rivals and competitors, including the possibility of government ownership."[44]

By late 1966, however, Strassburg had radically rethought his view as he began to understand the importance of computers. Upon learning about developments in data communications in 1965, he recalled that he "assembled a task force, a small group of staff members to sort of take an overview of the various dimensions of data communications; what the problems seemed to be, if

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[42] Matt Kinney, oral history interview by James L. Pelkey, March 9, 198, Sunrise, Florida. Computer History Museum, Mountain View, California. Available from https://archive.computerhistory.org/resources/access/text/2017/10/102738573-05-01-acc.pdf.

[43] Kinney interview, Computer History Museum.

[44] Henck and Strassburg, *A Slippery Slope*, xi.

any, and what we should do about them."[45] Knowing he had to educate the Commissioners to the needs of computers, he also contacted the Institute of Electrical Engineers (IEEE) to give a series of lectures to the Commissioners. One of the lecturers was Paul Baran, who Strassburg knew, and as future chapters will make clear, was a dominant figure in the history of computer communications.

Strassburg's revised understanding of emerging computer technology was due in large measure to the research of economist Manley Irwin, who consulted with the FCC in 1966 and who was assigned to draft a speech Strassburg was scheduled to make at American University on the subject of computers. Irwin's paper outlined the developing trend: computer technology required a method of sharing data over large distances, and the method in use at the time was via telephone lines and modems. In addition, AT&T employed an increasing amount of computer technology in their own operations, both for processing internal data and for switching in their telephone networks.

What Irwin saw was the coming convergence of the computer and communications industries. Strassburg realized the importance of Irwin's ideas and recognized that he would do well to get out in front of the potential for conflict between the two evolving industries.

Strassburg realized computer users would want to interconnect terminals and computers over the telephone network in ways certain to be resisted by AT&T. In a speech to an audience of computer professionals on October 20, 1966, he declared, "Few products of modern technology have as much potential for social, economic, and cultural benefit as does the multiple access computer."[46] One obstacle to this potential was economic – the problem of market entry: Who would be allowed to sell what products and services? Did AT&T have the right to monopolize products and services others wanted to sell? Strassburg was about to test the waters to see how serious the problem of convergence was. He remembers: "I decided that we ought to formalize this thing. We sensed enough ferment out there to say: 'Well, look we're going to encounter some problems here, and let's get on top of them sooner, rather than later, and for once let a regulatory agency be out in front, rather than trying to shovel up the mess that's left behind."[47]

Consequently, Strassburg and Irwin led the FCC in initiating a formal proceeding on November 9, 1966, when the FCC, announced the Common Carrier Bureau (CCB) would hold a public inquiry titled: "Notice of Inquiry, In the Matter of Regulatory and Policy Problems Presented by the Interdependence of Computer and Communications Services and Facilities (Docket F.C.C. No. 16979)."[48] The Notice of Inquiry, also written by Irwin, read: "We are confronted with determining under what circumstances data processing, computer information, and message switching services, or any particular combination thereof--whether engaged in by

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[45] Strassburg interview, Computer History Museum.

[46] Strassburg, "The Marriage of Computers and Communications."

[47] Strassburg interview, Computer History Museum.

[48] Strassburg remembered: "I decided that we ought to formalize this thing. We sensed enough ferment out there, or enough concern, to say: 'Well, look we're going to encounter some problems here, and let's get on top of them sooner, rather than later, and for once let a regulatory agency be out in front, rather than trying to shovel up the mess that's left behind." Strassburg interview, Computer History Museum.

established common carriers or other entities--are or should be subject to the provisions of the Communications Act."[49]

In anticipating the challenges brought on by the emerging field of data communications, Strassburg had acted, in fact, as an early entrepreneur of the same industry. His vision of the coming demand for new technologies and innovative ways of using existing technologies helped open areas of opportunity for many others.

Emergence of the Data Communications Market-Structure

The technologies and early products of data communications were well developed by the late 1960's and had formed the beginnings of a viable market, mainly to government agencies and institutions that leased private access to AT&T's telecommunications network. The entrepreneurs of the leading companies in the field, Codex and Milgo, both made the important decision to expand beyond their reliance on government contracts and to focus on developing and selling new products to commercial customers. The timing was important, for having the foresight to see the coming of deregulation, their early moves in developing commercial products and establishing sales and distribution put them ahead of the pack when the rush to start companies began at the close of the decade.

In Perspective

There were multiple forces of dynamism in American communications and computing in the decades after World War II. Massive federal investments drove advancements in the technological underpinnings of electronics and computing. Individuals working in a number of different settings—established corporations like IBM and new companies like Codex and Milgo, and researchers at MIT and other universities—seized the moment to create new opportunities. Even in an industry that appeared to be stable, the telephone industry monopoly, the incumbent monopolist was under increased attack, forced to defend itself from antitrust officials, FCC regulators, and entrepreneurs who aspired to be AT&T's competitors.

1968 was shaping up to be a very busy and potentially transforming year for the FCC and CCB. While FCC Examiner Naumowicz had issued his initial decision in August of '67 that the Carterfone did not pose a threat in connecting to the telephone system, the debate continued over the wider implications of allowing users permission to interface with AT&T's network. On the matter of MCI, after Scharfman's initial response in favor of approving MCI's license, the FCC, at the time operating with 6 commissioners after the retirement of commissioner Loevinger, was split along party lines with the 3 Democrats in favor and the 3 Republicans against. Their final decision would not be made until after the politically auspicious appointment of commissioner Rex Lee by President Johnson, which was made in late '68, before the election of Richard Nixon. By the end of '67, Strassburg and the CCB had received responses to the Notice of Inquiry and, as we shall see in the following chapter, it was to be the tip of an iceberg heralding an unforeseen demand for communications technology.

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[49] Computer I, Docket No. 16979, NOI 7 FCC 2d 19 (1967).

In addition to the key events at the regulatory level, private firms like Codex and Milgo were poised to take advantage of a rush of new interest and investment in technology, giving rise to many garage tinkering startups as well as well-funded ones like Intel.