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HISTORICAL NARRATIVE

VOLUME 1 OF 3

HISTORICAL NARRATIVE STATEMENT
OF RICHARD B. MANCKE, FRANKLIN M. FISHER
AND JAMES W. McKIE

Introduction

The pages which follow represent our attempt to place the record of this case into an historical perspective. We believe the question whether IBM today possesses or at any time has possessed monopoly power in any relevant market can only be assessed by reviewing the history of the EDP industry from its birth to the present and in so far as the evidence permits into the future as well. We therefore have prepared for the Court our analysis of the major events in the life of the computer industry over the past 30 years, as reflected in the record of this case. We do not suggest that we have summarized for the Court in this historical narrative every fact or opinion which appears in the record of this case. We have attempted, however, to set forth those events which appear to us to be the most significant in understanding the development of the industry, the position of IBM within the industry and the reasons for the great success which IBM has had with its computer products and services.

In order to avoid duplication and to expedite the massive job of culling through the more than 100,000 pages of trial transcript and the many thousands of exhibits and depositions which in their totality dwarf even the massive amount of transcript available, we have divided the task among the three of us. Dr. Mancke prepared the initial section of our historical analysis covering generally the period from the beginning of the industry to the early 1960s. Drs. Fisher and McKie then reviewed and discussed his draft and concurred in the final product. In like manner, Drs. Fisher and McKie prepared the second and third portions, respectively, of our historical analysis covering generally the period from the development of IBM's System/360 in 1961 through the end of the 1960s and then the 1970s.

In preparing our historical narrative, we were provided with assistance by IBM personnel assigned to work on the litigation and by counsel for IBM in this case. Those people obtained from the record (and other sources) material when we requested it, checked our citations against the sources we utilized, put the citations into a consistent format and proofread and provided necessary editing, administrative and clerical assistance.

The historical narrative here presented represents the product of our collaboration. We believe it accurately and fairly reflects the history of the computer industry and IBM's participation in it as reflected by the record and our understanding of the record. Accordingly, we present it to the Court as a part of our testimony.

I. THE BEGINNINGS OF THE EDP BUSINESS: THE 1940s

1. Evolving EDP Technology. Early research and development of computer technology was sponsored in substantial part by various branches of the military and related intelligence agencies who had extensive computational and data processing requirements. During World War II and continuing thereafter, the United States government was a driving force in the EDP field, calling upon organizations to build ever more advanced computer products. (DX 280; DX 3420A; DX 10283, pp. 6-7; DX 7528, Mahoney, pp. 58-59; Plaintiff's Admissions, Set IV, ¶¶ 23.0, 48.0, 53.0, 204.0, 221.0.)

Thus, the first large electronic digital computer,* the ENIAC, was developed during World War II by a team of scientists/engineers, led by J. Presper Eckert and John W. Mauchly, at the University of Pennsylvania's Moore School of Engineering under contract with the United States Army.

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* Digital computers are distinguished from analog computers in that "[a] digital computer operates on discrete quantities and essentially counts", whereas "[a]n analog computer operates in analogy with some physical phenomenon". (Fernbach, Tr. 437.) That is, an analog computer "solves problems by translating physical conditions such as flow, temperature, pressure, angular position, or voltage into related mechanical or electrical quantities and uses mechanical or electrical equivalent circuits as an analog for the physical phenomenon being investigated. In general it is a computer which uses an analog for each variable and produces analogs as output. Thus, an analog computer measures continuously whereas a digital computer counts discretely." (DX 5202, p. 263; see also Beard, Tr. 10195; JX 1, pp. 8, 39; DX 4992, pp. 6-7; DX 5126, pp.7-8.)

(Fernbach, Tr. 438-40; Eckert, Tr. 730-32; PX 1, p. 2; DX 5476, p. 26; DX 5423, Smagorinsky, pp. 8-9; DX 7532, Parten, p. 11; Plaintiff's Admissions, Set II, ¶ 800.0.) ENIAC was designed to be used in calculating trajectories for field artillery and bombing tables for the U.S. Army Ballistics Research Laboratory at the Aberdeen Proving Ground. It "was developed specifically for the purpose of generating firing tables. That was the original purpose because, prior to that time . . . they had a large number of mathematicians who had to sit in rooms with desk calculators, numerically integrating trajectories, and the basic reason for developing the digital computer in the first place was to speed up the process of numerical integration." (DX 7532, Parten, pp. 11-12.)*

The ENIAC was a physically enormous machine (measuring 100 feet long, 10 feet high and 3 feet wide, and containing about 18,000 vacuum tubes) and was described as "one of the most complicated devices in the world". (Eckert, Tr. 729, 771; Plaintiff's Admissions, Set II, ¶ 800.2.) Indeed, it was so complicated that Dr. Enrico Fermi reportedly

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* ENIAC was also used to perform calculations for the Atomic Energy Commission at Los Alamos and to develop and test models for "short-range [weather] prediction for the Terrestrial Atmosphere". (DX 5423, Smagorinsky, pp. 8-9; see Eckert, Tr. 744-45; Metropolis, Tr. 1133-34; Plaintiff's Admissions, Set II, ¶¶ 557.4, 800.6.)

"doubted if the machine would run for more than five minutes at a time". (Eckert, Tr. 771.) In fact, when the ENIAC became operational in 1946, it broke down only about once a day. (Eckert, Tr. 770.)

The ENIAC differed from prior computational machines in that prior machines had all been electromechanical--that is, they performed arithmetical calculations by using electricity to close mechanical relays. (Fernbach, Tr. 438.) ENIAC's use of vacuum tubes rather than electromechanical relays allowed it to be faster than its electromechanical predecessors by "at least a factor of a hundred and . . . probably 500". (Eckert, Tr. 758; see Fernbach, Tr. 439.) With the ENIAC, it was possible to perform a wide range of previously impracticable or impossible calculations. (Plaintiff's Admissions, Set II, ¶ 800.13.)

The ENIAC had to be programmed by setting switches--and whenever the program needed to be changed, the switches, numbering in the thousands, all had to be reset by hand. (Eckert, Tr. 778; Metropolis, Tr. 1141-44; DX 5423, Smagorinsky, pp. 8-9; Plaintiff's Admissions, Set II, ¶¶ 557.5, 800.7-.11.) This limitation was removed by the next major step forward in computing--the development of electronic <u>stored</u> <u>program</u> digital computers. (Eckert, Tr. 776-80; H. Brown, Tr. 82962; Plaintiff's Admissions, Set II, ¶ 802.4.)

In 1944, while the ENIAC was still under construction, a group of people located at the Moore School, including Dr. Herman Goldstine, J. Presper Eckert, Dr. John Mauchly, Dr. Arthur W. Burks, Adele Goldstine, and, after August 1944, Dr. John von Neumann, began to meet regularly to develop the conceptual design of an internally modifiable stored program digital computer that became known as the EDVAC. (Eckert, Tr. 780-81; PX 5657, p. 2; Plaintiff's Admissions, Set II, ¶ 802.0-.1.) The "stored program" concept was based on the realization that computer instructions could be represented as numbers and could be stored in memory with other numbers, provided there was a way to identify them as instructions. (Plaintiff's Admissions, Set II, ¶ 802.4.) The concept of "internal program modification" recognized that instructions stored in memory could be handled and modified arithmetically in the same way as other numbers stored in memory.* (Plaintiff's Admissions, Set II, ¶ 802.5; see Hughes,

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* A stored program is a series of instructions to the computer telling it what to do, and usually depends on either the results previously achieved or the conditions existing at the time the computations are made. (Plaintiff's Admissions, Set II, ¶ 782.9.) In computers based on the "stored program" concept, instructions are stored within the machine in the same form as data. They are capable of being stored anywhere in the system, recalled from anywhere with the same ease, or modified to the extent of the capability of the system. This capability of "computing" or processing parts of the control program results in a far more flexible system than had been known before. (Hughes, Tr. 33881, 33886-87.)

Tr. 33881; Hurd, Tr. 86405; Knaplund, Tr. 90461; DX 8988, pp. 2-3 (Tr. 88281).)

The EDVAC's stored program concept was developed in detail in a series of papers written by, among others, von Neumann and Goldstine. (Hurd, Tr. 86327-28; DX 44, p. 5; Plaintiff's Admissions, Set II, ¶ 802.2-.3.) These papers were widely circulated after World War II and were the subject of extensive and intense discussion among a "very close fraternity of people" in universities, industry, and government, working on designing and developing computers. (DX 13526, Forrest, p. 66.) These persons communicated actively with each other about new circuits, new devices and new computing machines by circulating technical papers and attending symposia. (Hurd, Tr. 86327-28, 88206; DX 5423, Smagorinsky, pp. 11-13; DX 13526, Forrest, p. 67.) In 1948 the Association for Computing Machinery was formed and quickly became the "premier technical society associated with computing". The ACM provided an organization (and an associated publication) in which "the scholarly and pioneering work of computing could be laid down and distributed into the society at large". (Perlis, Tr. 1853.)

In the late 1940s, following the initial scientific/technical discussion of the EDVAC stored program concept, many universities, government-related laboratories, and private firms began to design and develop stored program computers, frequently with government funding. A list--which does not purport to be all-inclusive--of 21 nonprofit organizations designing and developing prototype stored program digital computers in this time frame is set forth in the footnote below.* Among the private firms engaged in designing and developing prototype electronic digital stored program computers in the late 1940s (often in connection with military projects) were American Telephone and Telegraph, Raytheon, Eckert-Mauchly Corporation, and Engineering Research Associates. (Eckert, Tr. 773, 782; R. Bloch, Tr. 7566-70; Hurd, Tr. 87662; DX 280.) The activities of these firms in the late 1940s are discussed in some detail below and in the company profiles which form a part of this testimony.

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* The University of Amsterdam; the University of California at Berkeley (CALDIC); the University of California at Los Angeles (as operating agency) (SWAC); Cambridge University (EDSAC); the University of Frankfurt; Harvard University (Mark III); the University of Illinois (ORDVAC, ILLIAC); the Institute for Advanced Study at Princeton (IAS Computer); the University of Manchester; the University of Michigan (MIDAC); Massachusetts Institute of Technology (Whirlwind); the University of Pennsylvania (EDVAC); the University of Rome; the University of Vienna; a university in Sweden; the Federal High School in Zurich; the Los Alamos Scientific Laboratory (MANIAC); Patrick Air Force Base (FLAC); the RAND Corporation (JOHNIAC); the National Bureau of Standards (SEAC); and the Naval Research Laboratory. (E.g., Hurd, Tr. 86324-26; see also DX 5423, Smagorinsky, pp. 11-13; Plaintiff's Admissions. Set II, ¶¶ 558.0-.6; Plaintiff's Admissions, Set IV, ¶¶ 48, 121.)

2. <u>Potential Early Entrants Into EDP.</u> By the early 1950s, the knowledge and resources necessary to build primitive computer systems were widely held and, therefore, many firms were well positioned to develop and supply computer systems. The most likely participants possessed one or more of the following attributes:

(a) expertise in the relevant electronic and electromechanical technology necessary to build computers (e.g., vacuum tubes, relays and transistors);

(b) experience in obtaining federal research and development contracts (typically from either the military or intelligence agencies) to design and build one-of-a-kind data processing and/or control systems; and

(c) expertise at selling products to the rather small number of sophisticated organizations thought likely ever to purchase a computer system.

Examples of firms possessing these attributes included:

(a) Bendix, Boeing, Douglas, Hughes, North American Aviation, Northrop, Raytheon, and Sperry who were high technology defense contractors with expertise in designing and building sophisticated electronic control systems and were consumers of large amounts of computational power;

(b) General Electric, Westinghouse, RCA, and

Philco who were large manufacturers of electrical equipment and had a broad base in the relevant technologies, in addition to being potentially large data processing customers;

(c) American Telephone and Telegraph, International Telephone and Telegraph, and General Telephone and Electronics who had experience in manufacturing and consuming communications switching equipment; and

(d) Burroughs, Friden, IBM, Monroe, National Cash Register, Remington Rand, Royal, and Underwood who produced calculators and/or business machines such as typewriters, unit record equipment, and accounting machines.

AT&T, because of its early involvement in computing techniques, its huge size, Bell Labs' research capabilities, and Western Electric's experience as a defense contractor and large-scale producer of electronic and electromechanical products, was perhaps the best situated of all these companies.

In addition to the established firms listed above, there were a few recently formed, typically much smaller firms developing computer systems in the late 1940s and/or early 1950s, often for the U.S. government. These included Eckert-Mauchly, Engineering Research Associates, Consolidated Engineering Corporation, Electronic Computer Corporation, and Computer Research Corporation (a spin-off from Northrop

Aircraft Corporation). (Eckert, Tr. 805-08; Norris, Tr. 5599; Oelman, Tr. 6120-21; Hangen, Tr. 6262; McCollister, Tr. 10995-96; Withington, Tr. 55983; Hurd, Tr. 88028; DX 280, p. 1; DX 12694.)

Finally, besides firms of the sort listed above, nonprofit, government-funded think tanks (such as the RAND Corporation) and the research affiliates of major universities (such as Massachusetts Institute of Technology's Lincoln Laboratory) secured substantial federal funding from the military and intelligence agencies to build prototype computer systems. (Crago, Tr. 85961-62, 86008-09; Hurd, Tr. 86324-26, 88089-90, 88156, 88213-15.) In the formative years of the EDP business, when, as we describe later, nearly everyone believed that the size of the total market was severely limited, these nonprofit organizations posed substantial potential competition to their profit-making counterparts.

In sum, many firms were well-positioned to develop and supply computer systems and, typically with government funding, several had actually been developing computer products.

3. <u>Sources of Uncertainty About the Commercial Possibilities of EDP.</u> Though the computer's potential for performing large and complex calculations was widely recognized by 1950, and though many companies had the knowledge and resources necessary to build computers, great uncertainty as to both the size of the potential market and the feasibility and costs of producing computer systems caused potential entrants to be reluctant about actually investing substantial scientific, technical, production, marketing, managerial, and financial resources to become commercial suppliers of computer systems (as opposed to building prototype or one-of-a-kind computers under contract for the government). The belief that there might not be a significant market for computer systems, which is described in more detail in the following sections, was deduced from the following premises:

(a) Only a few customers--primarily the military, Weather Bureau, intelligence agencies, defense contractors (especially airplane manufacturers), the Atomic Energy Commission and its subcontractors, and the Bureau of the Census--were thought to have computational needs of sufficient magnitude and complexity to fully utilize a computer system as well as be able to afford such a system.

(b) Many of these potential customers, as well as several major universities and nonprofit scientific laboratories, were designing and building their own computer systems.

(c) The first computer systems were physically enormous, difficult to program, required complex circuitry that, with the prevailing vacuum tube technology, was prone to frequent failure, and were many times more expensive than the most expensive electromechanical unit record equipment, business and accounting machines then on the market.

(d) Few people had sufficient training to be able to use a computer system. Most people skilled in computer programming, utilization and maintenance were those already employed by organizations that were developing computers. Thus, to market their equipment on a commercial basis, the manufacturers themselves would have to provide users with most of the programming, education and support needed to operate the system.

(e) Moreover, since the basic computer technology was in the process of being developed, and engineering and production feasibility had not been demonstrated, it was impossible to predict either costs or product performance and reliability with any degree of accuracy.

Hence, though many large firms were well-positioned to develop and supply computer systems and though several had actually been developing computer products, it is not surprising that most hesitated about becoming commercial suppliers of computer systems. Remington Rand and IBM would be the first two established firms to accept the risks and begin to make investments of the magnitude necessary to become commercial suppliers of computer systems.

II. FIRST ATTEMPTS TO COMMERCIALIZE COMPUTER SYSTEMS: THE EARLY 1950s

4. Remington Rand's Entry. In 1950 Remington Rand was primarily a manufacturer of unit record equipment, typewriters, office supplies, filing cabinets and file accessories. (DX 7584, Mauchly, p. 37.) Beginning in 1950, however, it quickly obtained the leading position in the nascent computer field by acquiring two of the most advanced firms specializing in the design and manufacture of computer systems: the Philadelphia-based Eckert-Mauchly Computer Corporation (acquired in 1950) and the Minneapolis/St. Paul-based Engineering Research Associates (acquired in 1952). (Eckert, Tr. 715, 717, 719, 783, 960-61; Norris, Tr. 5599-601, 5693; Withington, Tr. 55980; PX 1, p. 2; DX 7597, p. 2; DX 13526, Forrest, p. 44.)

(a) Eckert-Mauchly. Shortly after World War II (and the completion of their government-funded work on ENIAC), J. Presper Eckert and John Mauchly left the University of Pennsylvania's Moore School of Engineering and established the Electronic Control Company with a view toward becoming commercial suppliers of computer systems. (Eckert, Tr. 715, 772; PX 1, p. 2.) The name Electronic Control was originally chosen because Eckert and Mauchly thought the easiest way to get into the business of building commercial computing devices was "to build a very small machine that could be used in a chemical plant or power station . . . to control some simple problems they had there." Eckert and Mauchly soon concluded, however, that the applications they had intended the Electronic Control Company to perform were far beyond their capability. They then established a new company, the Eckert-Mauchly Computer Corporation. After doing preliminary design work on what later became the UNIVAC (discussed below), Eckert-Mauchly contracted with Northrop Aviation (which in turn had a contract with the U.S. government) to build a one-of-a-kind computer called the BINAC ("Binary Automatic Computer") to be used for missile navigation. Eckert described the BINAC as "sort of an experimental venture" and, in fact, Northrop solved this navigational problem with gyroscopes.* (Eckert, Tr. 772-74, 781-82; PX 1, p. 2.)

Eckert-Mauchly then made computer history by contracting in 1948 with the Bureau of Standards to build a large scale, fully automatic, general purpose computer system called the UNIVAC ("Universal Automatic Computer"), which was based on the ENIAC development, for the United

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* The BINAC did originate "two new ideas to the computing art--namely, the principle of internal self-checking and the employment of serial logic". (PX 1, p. 2.)

States Census Bureau to process data collected in the 1950 Census. (Eckert, Tr. 782-84, 790, 867; DX 280, p. 2; Plaintiff's Admissions, Set II, ¶ 804.1.) The UNIVAC was the first electronic stored program computer system available commercially, i.e., it was intended to be a standard machine rather than one-of-a-kind and was available for sale to anyone desiring to acquire it. (Fernbach, Tr. 460; Perlis, Tr. 1854, 1875; Withington, Tr. 55980; J. Jones, Tr. 78716; DX 69, p. 5; Plaintiff's Admissions, Set II, ¶ 804.0.) The first UNIVACs were beginning to be manufactured at the time of Eckert-Mauchly's acquisition by Remington Rand. The first delivery was in 1951, to the Census Bureau, at a purchase price of approximately $1 million. (J. Jones, Tr. 78741; PX 1, p. 2; PX 127, p. 70; DX 280, p. 2; Plaintiff's Admissions, Set II, ¶ 804.1.)

Professor Perlis described the UNIVAC (subsequently called the UNIVAC I) as a "creative masterpiece", (Perlis, Tr. 1874-75; PX 299) because it demonstrated what he described as the "extraordinarily important recognition" that "the computer which had been born to carry out ballistics calculations for the Army [i.e., the ENIAC] was adaptable [and] economically useful in the commercial fabric of the nation". (Perlis, Tr. 1855.) According to Eckert, the UNIVAC I was good at scientific computing and was used by the AEC at the Lawrence Livermore Laboratory for seven or eight years.

(Eckert, Tr. 790; see also Fernbach, Tr. 464-65; J. Jones, Tr. 78720-29; PX 272.) Eckert also testified that the UNIVAC was good at (and, indeed, had been designed "primarily" for) processing "problems of the type the Census Bureau had, where you were mostly processing long chains of data or batches of data such as would be found in various government enterprises or . . . found in businesses like insurance . . . things we ordinarily think of as commercial data processing problems today." (Eckert, Tr. 716, 790; see J. Jones, Tr. 78720-29; DX 280, p. 2.) According to Eckert:

> "[W]hat we attempted to build in the first UNIVAC was a machine which within the limitations of cost and speed and memory size could be used universally, that is to say, could be used for scientific problems or could be used for statistical problems such as the Bureau of Census had, or could be used for business problems, such as a company or insurance company might have." (Tr. 867.)

Remington Rand and Eckert-Mauchly initially planned to build six UNIVAC I's. (J. Jones, Tr. 78704; see DX 7584, Mauchly, pp. 24-25.) Mauchly testified that he recalled a forecast for on "the order of 12 of these systems, arrived at ostensibly [by] the cost of the system, and the number of companies in the U.S. who could afford to buy a system at that cost." (DX 7584, Mauchly, p. 38.)

The handful of customers who installed UNIVACs between 1951 and 1953 were all government or government-related organizations. (DX 7584, Mauchly, p. 32.)* Indeed, according to Mauchly, in 1951-53 it was "a gamble . . . whether any UNIVAC system would be sold to a commercial customer". (DX 7597, p. 4.) The first installation of a UNIVAC with a private customer explicitly for non-government related applications occurred in 1954 at General Electric's Louisville "appliance park". (DX 7584, Mauchly, p. 32; DX 9070, Ream, p. 33.) Following the GE installation, demand picked up, and approximately 40 UNIVAC I's were eventually installed. (Eckert, Tr. 783-84; DX 7584, Mauchly, pp. 205-07.)

It does not diminish Eckert and Mauchly's contribution to stress that the UNIVAC I was a primitive computer.** It required rather extensive maintenance; initially it could only be programmed in machine language; and while "it was staggering in speed relative to what we knew at that time, . . . it was, indeed, a very slow machine". (J. Jones, Tr. 78719-20, 79342.)

(b) <u>Engineering Research Associates (ERA).</u> ERA was formed in 1946 by a group of ex-naval officers, includ-

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* The first five UNIVACs were delivered to the Bureau of the Census, the Air Force, the Army, the Navy and AEC's Lawrence Livermore Laboratory. (J. Jones, Tr. 78810; DX 7584, Mauchly, pp. 31-32; see also DX 5043, p. 3.)

** IBM's first commercially available computer, the 701 (discussed below), was also described as "a very primitive machine". (Hart, Tr. 80226.)

ing William Norris, who did extensive work on communications and computing techniques during World War II.* At the end of the War, agencies of the U.S. government became concerned that the naval communications group might be disbanded. To prevent this they indicated to some of its members that, if they could find sufficient private capital to set up a company to carry on classified EDP work, the government would consider contracting with them in the area of computer research and development. (DX 280, pp. 1-2.) The necessary financing was obtained,** and ERA was established with the objective of serving "Navy requirements for special purpose computing machinery in a highly classified environment" (id.)--these included devices not only for military purposes, but for the purposes of deciphering secret information. (Eckert, Tr. 807-08; Norris, Tr. 5599.)

In 1946 ERA contracted with the Navy to design, develop, and deliver a complete stored program computer system. (DX 13526, Forrest, pp. 55-56.) In fulfilling that contract (known as Task 13), ERA produced a computer system

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* Much of this research was classified. It was directed toward military intelligence rather than more orthodox naval applications. (Norris, Tr. 5598-99; DX 280, p. 1.)

** A substantial portion of ERA's initial capitalization was provided by John Parker of the Northwestern Aeronautical Corporation, which had been a manufacturer of plywood gliders during World War II. (DX 280, p. 2.)

called the ATLAS I. (Id., pp. 75-77; DX 280, p. 2.) The government permitted ERA to seek other customers for ATLAS-type computers. According to Henry Forrest, who marketed ERA's computers from 1948-58, "[t]here never was any attitude by the Government that that which we developed in full or in part through government sponsorship could not be put out commercially." (DX 13526, Forrest, p. 78; see DX 280, p. 2.) The ATLAS I, renamed the 1101, became ERA's first commercially available computer system.*

The 1101 used vacuum tubes and had a rotating magnetic drum for its main memory. (DX 13526, Forrest, pp. 45-46; DX 280, p. 3.) First delivery was in 1951, prior to ERA's acquisition by Remington Rand. (Eckert, Tr. 809; DX 13526, Forrest, p. 55; DX 280, p. 2.) As an offshoot of the 1101, ERA also developed the 1102 computer system, introduced in 1952. (DX 280, p. 2.) According to Forrest, the 1102 had a "general purpose machine at the heart of the complex", but it had "certain special purpose features [contained in what Forrest called the "periphery"**] to allow it to be used in an instrumentation activity". (DX 13526, Forrest, pp. 46-

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* The 1101 was first delivered in December 1950 (DX 280, p. 2; DX 438, p.2), several months before the first UNIVAC I was installed at the Bureau of the Census. The UNIVAC I had been announced, however, prior to the time that the 1101 became commercially available. (See DX 13526, Forrest, p. 65; DX 7567, p. 212.)

** Forrest testified that the "power" of a general purpose

48.)* Approximately three 1101s and three 1102s were sold to customers. (Id., pp. 46, 53-55, 84; DX 280, p. 2; see also Withington, Tr. 57482-83.)

According to Forrest, ERA did not find "a large customer segment" interested in acquiring the 1101:

> "We felt we didn't have the right assemblage of components arranged in the right configuration and this was evident from the customer response, that for those dollars and for the kinds of things the customer wanted, they just weren't going to buy the thing. Technology and machine architecture and organization development was proceeding so fast and so much progress was being made . . . [that] we withdrew [the 1101]." (DX 13526, Forrest, pp. 84-85.)

As early as 1949, ERA began designing a new computer system, the 1103. The 1103 was markedly superior to the 1101 "in terms of organization, what it would do for the customer and on a price performance basis." (Id.) The first 1103 was delivered in 1953, following ERA's acquisition by Remington Rand. (DX 280, p. 2.) Approximately 20 1103s were eventually

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computer was its ability "to construct general programming routines that would work over a class of problems" and would allow one to "alter his programs to perform . . . different functions, or new added tasks." In contrast, the special purpose features he described were not susceptible to change "except with a soldering iron, or a different set of components." (DX 13526, Forrest, pp. 47-48.)

* ERA's 1102 computer system included products obtained by ERA from other companies. For example, one ERA 1102 computer system acquired by the Government at a cost of $574,586 consisted of an ERA 1102 processor, six Teletype punches, one Ferranti paper tape reader, ten Friden Flexowriters and an EAI digital plotter. (Plaintiff's Admissions, Set II, ¶ 146.1-.3.)

delivered for both scientific and business applications.* (Id., p. 3; Withington, Tr. 57481.) Some of the features of the 1103 were derived from the 1101, but the machines were not compatible. (Eckert, Tr. 809; DX 280, pp. 2-3; DX 13526, Forrest, pp. 87-89.)

According to Eckert, Remington Rand's acquisition of ERA in 1952, with its approximately 500 employees (DX 280, p. 3), "represented a substantial increase in the electronic or computer ability for the organization". (Eckert, Tr. 808; see also DX 5423, Smagorinsky, p. 16.) Indeed, ERA had more people involved with computers at the time of the acquisition than did Remington Rand (including Eckert-Mauchly). (Eckert, Tr. 808.)

In a letter describing William Norris' involvement with computers--first at ERA, and then at Remington (Sperry) Rand and CDC--written in 1969 by John Lacey (with blind copies to Norris and several other former ERA/Remington Rand employees then at CDC), it was "estimated that by the end of 1952 ERA had built and delivered more than 80% of the value of electronic computers in existence in the United States

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* By way of example, one customer of the 1103 was the Air Force's Aeronautical Systems Division, which in 1956 replaced the OARAC, a one-of-a-kind computer built by GE, with an 1103. (DX 4993, p. 4.). Forrest recalled "40, or more" initial sales and leases of the 1103 and 1103A combined. The 1103A, an improved version of the 1103, was delivered in 1954. (DX 13526, Forrest, pp. 90-91; see DX 280, p. 4.)

at that time". (DX 280, p. 3.)

(c) <u>The Leadership Position of the Merged Companies.</u> Remington Rand's acquisition of Eckert-Mauchly and ERA, coupled with its own corporate resources, gave it the leadership position in the EDP field. Some examples from the record illustrate this point.

(i) Cuthbert Hurd, Director of Applied Sciences at IBM in the early 1950s, testified that "Remington Rand was the leading company in the EDP industry in the early 1950's" with the acquisition of ERA and Eckert-Mauchly, and with the delivery of the UNIVAC; indeed, "IBM's first computers were popularly referred to as 'IBM's UNIVAC's'".* (Tr. 86423-24.)

(ii) John L. Jones operated one of the first UNIVAC I's when it was installed at the Pentagon in 1952, and wrote (while at the Air Force) what became the first operator's manual for early UNIVAC I users. (J. Jones, Tr. 78716-20.) Jones testified that UNIVAC had an "initial year to two-year lead . . . by having a machine that was available and operational before other machines began to appear". (Tr. 79344.)

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* See also DX 105, a 1969 <u>Business Week</u> article entitled "UNIVAC Comes in from the Cold": "In the beginning, UNIVAC's product lead was so long that their name was better known by the general public than the word computer."

(iii) Richard Bloch, head of Raytheon's computer group through 1955, described UNIVAC, along with "probably" Raytheon, as the "leader" in terms of "scope of competence" in computers in the early 1950s. (Tr. 7570, 7736.)

(iv) Henry Forrest, who had joined ERA in 1948, testified that he stayed on when ERA was acquired by Remington Rand in 1952 because "it was a technically exciting company . . . probably the leader in digital system technology in the country at that time over any other company". (DX 13526, Forrest, pp. 44, 100-01.)

(v) In Dr. Mauchly's view, Remington Rand had an "immense advantage", a "5-year lead", over IBM in 1951. "Of course, at that time we did not know that we had a 5-year lead, but assumed that we had at least a 2 or 3-year lead". (DX 7596, p. 1; DX 7597, p. 3.)

(vi) William Norris, one of the founders of ERA, viewed Remington Rand as facing "emerging competition" from IBM in the early 1950s, but believed that at that time Remington Rand "had a chance to take over the computer market". (Tr. 5722; DX 305, p. 1; see also DX 3979, J. Johnson, pp. 15-16.)

5. <u>IBM's Early EDP Involvement.</u> IBM was built by Thomas J. Watson, Sr. from a manufacturer of punch card products and time recording equipment (such as time clocks) in 1914 to a firm with U.S. revenues of approximately $180 million in 1949. (Hurd, Tr. 86324; DX 8888, p. 5.) In the 1930s IBM entered the typewriter business and began producing its first electric typewriter. (DX 8888, p. 5; see also Hurd, Tr. 86324.)

In the 1930s and 1940s, IBM had also sponsored research in the techniques of electromechanical computation, including the MARK I, a project initiated by Harvard's Howard Aiken, and on which he and IBM personnel worked together between 1937 and 1944. (Eckert, Tr. 760; Metropolis, Tr. 1135, 1204; Hurd, Tr. 86335; Plaintiff's Admissions, Set II, ¶ 798.) In addition, in 1944-47 IBM had developed and built a one-of-a-kind, partially electronic and partially electromechanical, stored program digital computer called the SSEC ("Selective Sequence Electronic Calculator"), which used relays, punched paper tape and electronic registers for storing a program. (Hughes, Tr. 33890-92, 33898, 71948-50; Hurd, Tr. 86335; Plaintiff's Admissions, Set II, ¶ 801.0.)* The SSEC occupied about 1500 square feet at IBM's World Headquarters in New York City and was demonstrated to the public in 1948. (Hughes, Tr. 33889, 33898.) At that time, no other manufacturer had installed and demonstrated

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* IBM's development work on the SSEC began at about the same time as work began on the conceptual design of the EDVAC, described above.

a stored program computer system, and the designers of that computer received a significant patent on the machine, including a claim covering the stored program. (Hughes, Tr. 33892-99, 33912-13.)

In the late 1940s, IBM established its Applied Science group to probe possible business applications of the evolving electronics technology.* IBM's initial interest in electronics, however, was tentative; other than a limited amount of electronic circuitry incorporated in its unit record equipment, little else was done with this new technology. (Hughes, Tr. 33874-76; Hurd, Tr. 86335.)

Events related to the outbreak of the Korean War in 1950 led to IBM's subsequent entry into the manufacture and marketing of electronic digital computer systems. At the War's onset IBM's chairman, Thomas J. Watson, Sr., wrote President Truman offering IBM's services to aid in the war effort. Mr. Watson, Jr., who had rejoined IBM in the late 1940s following his discharge from the armed services and who in 1952 had the title of Executive Vice President, made it clear to IBM's management that the "offer was not limited to IBM's existing products or services and was to be a priority undertaking." (Hurd, Tr. 86338; PX 3330A, p. 17; PX 6054, pp. 23-24.)

During the second half of 1950, James Birkenstock, Special Assistant to Mr. Watson, Jr., and Cuthbert Hurd "visited government

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* The Applied Science Group was headed by Cuthbert Hurd, who was one of IBM's first PhD's when he was hired in 1949. (Hurd, Tr. 86327, 86334.)

contractors and spent many days in the Pentagon, knocking on doors to ask in what fashion IBM's abilities and resources might best be utilized" to aid the war effort. These visits "verified [Hurd's] view that government agencies had problems whose solutions required large amounts of processing and calculations."* He concluded that all these problems could be performed better on the type of "general purpose computer" then being discussed within the scientific and academic communities. (Hurd, Tr. 86339.)

Within IBM, however, there developed substantial internal resistance to the idea of building such a computer. Thomas J. Watson, Sr., and high level executives in Engineering and Sales initially opposed such an effort. They questioned whether there would be a demand for computer systems and feared that funds would be diverted from R&D for IBM's principal products, unit record equipment. (Hurd, Tr. 86333-38; DX 7594, McDowell, pp. 193-94.)

According to W. W. McDowell, who was IBM Director of Engineering at that time (and who retired from IBM in 1968), the dispute as to the wisdom of developing a computer system arose because:

> "The large majority of our people were not knowledgeable in the field of large computers . . . . It required that we train and hire people who did have these kind of abilities.
>
> ". . . .
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> "We had to get that knowhow and this meant that we had to spend considerably more money, for instance, in research and development, and that was not an easy decision to make.

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* Those visits also led to IBM's participation in the design and manufacture of analog computers used in bomb sights for the B-52 bomber. (Wright, Tr. 12789; Hurd, Tr. 86339; PX 5951 (DX 14510) p 5; PX 6049, p. 8.)

"There were not unlimited funds within the IBM Company." (DX 7594, McDowell, pp. 187-88; see id., pp. 195, 211.)

Steven Dunwell, then in IBM's Future Demands Department, described how the development of computer systems technology required different skills than theretofore present at IBM. According to Dunwell, the developers of IBM's unit record equipment were "Edisonian" engineers who solved problems "by trial and error rather than by understanding the underlying physical nature of the problem." (Tr. 85521.) This group foundered when confronted with electronic rather than electromechanical technology.*

Hurd described how "[c]ompared with IBM's punched card equipment, . . . general purpose computers differed in terms of components, method of control, amount of human intervention required, and the problems which could be solved." (Hurd, Tr. 86328.) His description merits lengthy quotation:

> "(a) The components of punched card equipment included brushes which would detect the presence of a hole in a punched card and which then produced an electrical signal, commutators which divided an electrical signal into a number of timing

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* Dunwell testified:

"Between 1949 and 1951 a new group of approximately thirty electrical and electronic engineers was hired. I know of none of those who had past experience in punch card equipment. Of those thirty, approximately eighty percent were hired directly out of college. Included in that group were Gene Amdahl, Charles J. Bashe, Erich Bloch, Werner Buchholz, Robert Crago and Lawrence Kanter. In fact, the engineers from Endicott [N.Y.] were discouraged from transferring to the Poughkeepsie [N.Y.] electronic group for fear that they might dishearten the young electronic engineers". (Tr. 85522; see Hughes, Tr. 33874-75.)

intervals, relays which opened and closed--much like a light switch but which were actuated by magnets, mechanical devices for punching holes in cards and mechanical printers. Relays could be opened and closed a few dozen times a second and were subject to unreliable operation because they were mechanical and because of dust particles, for example. IBM had built a variety of machines using these components, including a key punch, verifier, interpreter, reproducer, gangpunch, collator, tabulator, sorter and calculator.

"(b) These devices were controlled by control panels or "plug boards". . . . Such a control panel might measure three feet by two feet and contain perhaps a thousand holes. Each machine type had a different control panel. It was desirable to memorize the functions of each of these holes. For example, a given hole on the control panel might correspond to Column 1 on a punched card. Using a wire which had two metal ends a connection could be made between the reading of Column 1 of the card and a particular counter within the machine. The wiring and testing of such a control panel might require several months from the time the proposed connections began to be drawn on a picture of the control panel, called a planning sheet, to the time the panel was operational.

"(c) In operation, it was necessary to place the proper control panel in a particular machine, physically pick up a deck of cards, hope that you didn't drop them and destroy their order, insert the deck in the card reader, allow the cards to pass through that machine, wait a few minutes, in many cases go around to the other end of the machine, pick up the deck of cards, . . . possibly make a decision to divide that deck of cards into one or more packs, . . . carry them to another machine for which another control panel had been wired and inserted, put them in the card reader of the second machine, etc. In order to solve a particular problem, it might be necessary to go from one machine to another a dozen or more times. Operators became specialists in a particular machine and therefore might hand the output deck of cards from one machine to another operator. At Los Alamos [where Hurd had been employed] I remember watching in amazement as Ph.D.s moved from machine to machine for hours performing these manual operations on the punched card equipment that was installed there to solve relatively simple calculations. Their presence was necessary because of the decisions that had to be made when work was completed on individual machines. The scientists also looked for errors before proceeding to the next machine.

"(d) In the use of punched card equipment, manual intervention, as with the Los Alamos Ph.D's, was the key and because of manual intervention and because of the mechanical nature of the devices, the results were slow and unreliable. Consequently, there was a sharp limit on the size and kind of applications or tasks that could be performed. Thus, although simple arithmetic operations and sorting and merging were possible, the machine operations were only an elementary assistance to individuals, who were responsible for coordinating the sequence of simple operations in the course of completing the applications. If one of the specialized operators in a particular application was absent, it might not be possible to process the application at all.

"(e) By comparison, general purpose computers relied on electronic technology. This technology utilized vacuum tubes and diodes which . . . were thousands of times faster than the electromechanical components then being used in punched card equipment. Moreover, the electronic technology permitted high speed random access storage on cathode ray tubes and high speed magnetic recording on media such as tapes and drums and high speed communication between various portions of the machine.

"(f) Not only were the components different, but the method of control was also completely different. The concept of a modifiable stored program meant that a completely automatic machine could be built. For example, a general purpose computer, when . . . fed a few instructions, can call for more instructions and for data from input devices, can assign addresses for such instructions and data, can consider a number of sub-programs which have been written independently and assign addresses for each and assemble them into a single program, and can then generate new instructions and new data as the processing proceeds, while at the same time discarding instructions and data which are no longer needed--An Automaton!" (Hurd, Tr. 86328-32;

Dunlop, Tr. 93607-08; DX 7594, McDowell, pp. 190-92, 225-26.)*

McDowell testified that IBM's decision to develop computers

> "wasn't a clear-cut one in the sense many people disagreed with this direction of developing a large scale computer. They felt strongly that we were--we would be foolish to spend the time and the money on that kind of effort as compared to our more--the field in which we were primarily competent, the punched card equipment.
>
> "This feeling was from the highest level . . . on down within the organization.[**]

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*Robert Dunlop, who was a customer engineer for IBM in the early 1950s, testified concerning the differences between electric accounting machines ("key punch, sorters, reproducing punches, multipliers, collators") and one of IBM's first computers, the 702:

> "There are many differences . . . between the IBM 702 and the equipment I had been servicing as a customer engineer, differences such as the use of instructions or programs as compared to a control panel with control panel wires, differences in the cycle times that were contained internally in the machines.
>
> "On the 702 the cycle time was in micro-seconds, where on the EAM the cycle time we dealt with was milliseconds.
>
> "The skill levels that I as an individual working on the IBM 702 or the programmers or the customers were different and required much more understanding of electronics as compared to just electrical mechanical types of devices." (Tr. 93607.)

McDowell testified that computers "required a completely different approach in terms of customers' use than did the punched card equipment", and "different kinds of people." (DX 7594, pp. 190-91.)

** Indeed, Mr. Watson, Sr., once told Hurd that the one SSEC IBM had built "could solve all of the important scientific problems in the world involving calculations." (Hurd, Tr. 86334.)

> "And what I am trying to emphasize by this is that it was a tough decision to make, and required--I have often used the term 'guts'--to say we were going to move ahead with a significant, expensive--expensive in the terms of development--computer of the Defense Calculator type." (DX 7594, McDowell, p. 189.)

There was concern that if IBM made the choice to develop a computer, it might be unable to keep its "bread and butter line", that is, punch card equipment, "modern". (Id., p. 190; see also Hurd, Tr. 86336-38, 86342.)

Another source of uncertainty that troubled many within IBM was the high price customers would have to pay for a computer--"not just the cost of the machine itself, but the cost of reorienting the customers' use of the machine." (DX 7594, McDowell, p. 191.) The opponents argued that only a few organizations would ever be willing to pay that price, and that, therefore, the product would lead to a dead end. (Hurd, Tr. 86336-38, 86342; DX 7594, McDowell, pp. 190-98.)

Dunwell testified that "there was little evidence that more than a few government agencies and aircraft manufacturers would ever consider their computing work important enough to justify the expenditures involved in such a machine." (Tr. 85523.)

Hurd described his conversations with IBMers who opposed developing a computer:

"[T]hey told me that they believed that general purpose computers would not be used in great numbers by IBM's customers and would not contribute significantly to IBM's profitability. They also told me that in their opinion, general purpose computers had nothing whatsoever to do with IBM or IBM's main line of equipment and profitability, IBM's customers or the problems those customers wished to solve. They told me that they could not imagine that enough problems or applications could ever be prepared by IBM's potential customers to keep a computer busy because such machines were to have the capability of performing several thousand operations a second and that, therefore, customers in industry would never spend the money to acquire such a machine. They told me that they believed that magnetic tape could not be used as a reliable input/output or storage device because, unlike punched cards, it could not be checked manually to verify the accuracy of the data it contained." (Tr. 86336-37.)

By mid-year 1950, while the debate within IBM was underway, Eckert-Mauchly, ERA, and Raytheon had announced their intention to build commercially available, general purpose computers, but none had yet been delivered. In addition, none of the one-of-a-kind computers being developed by universities and research organizations, described earlier, were operational on a regular basis. (Hurd, Tr. 86326.) Dunwell testified that there was

"no evidence that a machine of such complexity could be made to work reliably or could be maintained in working condition. . . . No one had ever programmed a machine of that kind except on paper, and even such questions as how to get the machine started taxed our imagination. Every single instruction used by the machine had to be written by hand and an error of a single bit in a program was sufficient to make the entire process inoperative." (Tr. 85522-23.)

Moreover, the construction of such a computer required "the development of high-speed circuitry, a new form of high-speed storage, and major sub-systems such as magnetic drums and magnetic tapes which IBM had not delivered in any machine". (Hurd, Tr. 86343.)

a. <u>The Defense Calculator or IBM 701.</u> After substantial internal debate, Mr. Watson, Jr., who was then 36 years old, and who had developed an interest in electronics as a result of his wartime experience as a pilot and as a result of his 1946 visit to the Moore School from which the ENIAC and EDVAC came, eventually authorized the development of a high-performance computer, initially called the "Defense Calculator," later renamed the IBM 701.* (Hurd, Tr. 86334, 86341-46; DX 7594, McDowell, pp. 200-02.)

The initial paper design for the Defense Calculator called for a machine that would rent for $8,000/month, and 30

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* The name "Defense Calculator" "helped to ease some of the internal IBM opposition to it since it could be viewed as a special project (like the bomb sights, rifles, etc., which IBM had built during World War II) that was not intended to threaten IBM's main product line." (Hurd, Tr. 86346)

letters of intent were received for this proposed product from defense and related agencies and companies. However, after completing the detailed design work IBM realized that although its computer system would be substantially more powerful than that initially proposed, it would also be much more costly than had been anticipated. When IBM raised the Defense Calculator's proposed price to $15,000 per month in approximately March 1951, all but six letters of intent were withdrawn. Nevertheless, IBM's management made the decision to build 19 of these expensive products.* (Hurd, Tr. 86345-46.) The first customer installation was made in spring of 1953 (Hurd, Tr. 87679) and thereafter, IBM began shipping one Defense Calculator, or 701, per month, a production record unmatched in that timeframe by any other company. (Hurd, Tr. 86345-46.) Indeed, the 701 was the first computer to be "manufactured on a multiple, identical, assembly-line basis". (Hurd, Tr. 86360.)

IBM described the 701 in the May 1952 announcement as an "Electronic Data Processing Machine", a term which had

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* After IBM made the decision to build the 701, this became the full-time mission of its Poughkeepsie Laboratory. (Dunwell, Tr. 85524.) At the same time IBM began to tear down the SSEC, which filled three stories at 590 Madison Avenue, and turned that whole staff over to preparation for the 701. (Hurd, Tr. 87699.)

been coined by James Birkenstock.* (Hurd, Tr. 86440.) The IBM 701, like the UNIVAC I, was a stored program, general purpose computer system between 10 and 100 times faster than the ENIAC.

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* The term "electronic data processing" (EDP) has since been used by industry participants to mean the same thing as processing with computers or computer systems. (Dubrowski, Tr. 84288-89, 84456-57; see Hangen, Tr. 6246; Lacey, Tr. 6560-61; Beard, Tr. 8708; McCollister, Tr. 9475-76, 9491-94; Butters, Tr. 43834; Welch, Tr. 74681; O'Neill, Tr. 75709, 75777; J. Jones, Tr. 78709-10; JX 1, p. 44; DX 1256, p. 42; DX 1783, p. 40; DX 3129, p. 53; Plaintiff's Admissions, Set II, ¶ 774.0.) The 1956 Consent Decree in U. S. v. IBM (Civil Action 72-344) defined an electronic data processing system" as:

> "any machine or group of automatically intercommunicating machine units capable of entering, receiving, storing, classifying, computing and/or recording alphabetic and/or numeric accounting and/or statistical data without intermediate use of tabulating cards, which system includes one or more central data processing facilites and one or more storage facilities, and has either
>
> "(1) the ability to receive and retain in the storage facilities at least some of the instructions for the data processing operations required, or
>
> "(2) means, in association with storage, inherently capable of receiving and utilizing the alphabetic and/or numeric representation of either the location or the identifying name or number of data in storage to control access to such data, or
>
> "(3) storage capacity for 1,000 or more alphabetic and/or decimal numeric characters or the equivalent thereof."

It also defined an "electronic data processing machine" as "a machine or device and attachments therefor used primarily in or with an electronic data processing system." (Consent Decree, Jan. 25, 1956, p. 3.)

(Hart, Tr. 80203-04; Hurd, Tr. 86352, 86905, 87679; Plaintiff's Admissions, Set II, ¶ 557.8.) It included a central processing unit (CPU), card reader, card punch, magnetic tape unit, and magnetic drum. (Hart, Tr. 80204; DX 8952.) The 701's basic circuitry was an "8-tube pluggable unit" that "eliminated a lot of wiring on the back panels of the computers, and . . . led to more efficient and lower cost manufacturing techniques and provided for easier maintenance or replacement of failing components in the field". (Case, Tr. 72248; see Crago, Tr. 86175; Hurd, Tr. 86357.) The 701 was the first computer to be packaged "in boxes in such fashion that any box would fit in a standard size elevator and go through a standard size door and fit on a standard size dolly." Thus, it was the first general purpose computer that did not have to be built, or rebuilt, in the customer's computer room. (Hurd, Tr. 86411; see J. Jones, Tr. 78717.)

In certain respects the 701 was initially less capable or flexible than the Univac I. For example the UNIVAC I had the ability in its hardware to handle directly both numeric and alphabetic characters, whereas the 701 hardware did not have "the ability directly to handle alphabetic characters." In 1953, however, after first delivery of the 701, IBM provided utility programs or software "which made the 701 able to handle alphabetic characters by conversion under program control." (Hurd, Tr. 86407.)

On the other hand, the 701 was superior to the UNIVAC I in a number of respects. For example, the IBM 726 tape drive, a peripheral for the 701, used plastic tape and a vacuum column drive. In contrast, the UNIVAC I tape drive used metal tape and mechanical rollers. The introduction of plastic tape enabled the IBM tape drive to be operated more quickly:

> "[It] could be started and stopped with less mechanical energy because it had less inertia, and the vacuum column provided a significant advance over the previous mechanical rollers that had been used on the UNIVAC I." (Case, Tr. 72655. See also Withington, Tr. 56488-89; Hurd, Tr. 86355-56; DX 4740: Evans, Tr. (Telex) 4032.)*

The 726 tape drive also used the NRZI recording method, which improved the reliability of recording information and then checked the information recorded. (Case, Tr. 72660; Hurd, Tr. 86356.) In addition, the 701 used a Williams tube random

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* Today, virtually all tape drives use plastic tape and vacuum columns. (Aweida, Tr. 49061-63; Withington, Tr. 56488-89; Case, Tr. 72652.)

From the beginning, peripheral devices played a significant role in customer procurements. For example, in 1953 the Joint Numerical Weather Prediction Unit (a joint effort between the Weather Bureau, Air Force and Navy) selected an IBM 701 in preference to an ERA 1103 "because [the 701's] input/output devices were more effective in meeting JNWP's operating requirements." (Plaintiff's Admissions, Set II, ¶¶ 559-560.) The JNWP then sold some computer time on its 701 to the Weather Bureau's General Circulation Research Section for "exploratory work" in the circulation of the atmosphere, the dynamics of climate and long-range weather prediction. (Id.)

access main memory with a capacity of 1,024 bits.* (Case, Tr. 72337; E. Bloch, Tr. 91519.) The UNIVAC I's main memory was an acoustic delay line which allowed only serial (or non-random) access. (Hurd, Tr. 86533-36; Fernbach, Tr. 442.) Hurd testified that the 701's introduction of a Williams tube random memory gave it a competitive advantage.** (Tr. 86533-36.)

Although the 701 was initially thought to be oriented more toward performing "scientific" applications for defense contractors involving complex numerical calculations (as evidenced by the initial lack of a direct capability to handle alphabetic characters), it was also used to perform business applications (e.g., accounting). (Hart, Tr. 80205-06 (GM); Hurd, Tr. 86352-54; DX 9070, Ream, pp. 20, 30-31 (Lockheed)⁄.) Indeed, Withington estimated that some users of the 701 employed that machine for business applications as much as 50% of the time. (Tr. 56885, 56893-94.) Hurd recalled several applications IBM personnel wrote for 701 customers:

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* The Williams tube was invented prior to that time by F.C. Williams at Manchester University in England. (Hurd, Tr. 86354; see also Fernbach, Tr. 450; Case, Tr. 72336-40.)

** The 701 incorporated many hardware, software, manufacturing and educational innovations. (See, e.g., Hurd, Tr. 86354-61.)

⁄ Indeed, Lockheed installed a 701 instead of a UNIVAC I in 1953-54 because it believed the 701 would better handle "both our scientific and our business work loads". (DX 9070, Ream, p. 33.)

(i) programs to assemble financial data and prepare quarterly financial reports (for Monsanto Chemical);

(ii) programs to do statistical analysis of seismic and well logging data for oil companies; and

(iii) a program to analyze returns during the 1956 election. (Hurd, Tr. 86352-54.)

GM used its 701 not only for "a wide variety of engineering and scientific computations," but also to prepare actuarial reports relating to pension plans for use in labor negotiations. (Hart, Tr. 80205-06.) North American Aviation started work on a payroll application using the 701. (Hurd, Tr. 86354.)

b. The IBM 650 By late Fall 1952, prior to even the first customer delivery of the 701, IBM's Applied Science group began pushing for a corporate commitment to manufacture a second, smaller computer system (which was later called the IBM 650). (Hurd, Tr. 86362.) According to Hurd, the number of firm 701 orders was increasing at that time from a low of six, and persons in Applied Science began to feel that "there was a need for a medium-priced general purpose computer", "in the rental range of $3,000 to $4,000 a month". They believed such a computer "could be marketed in quantities which were large when compared to the 701" and that it could be made "so easy to use that individuals from many different departments of a customer's organization would begin to wish to apply such a machine to the solution of their problems". (Tr. 86362.)

The proposal to build the 650 provoked great controversy within IBM, with the opposition being "even stronger than the opposition prior to the decision to build the 701". (Hurd, Tr. 86362.) The opposition was such within IBM that the 650 program "was stopped a few times, delayed a few times". (Hughes, Tr. 33904.) An estimate made "early in the program" was that IBM "might build 50" 650s. (Hughes, Tr. 33904; see also McCollister, Tr. 11017.) The momentum generated by a desire to aid the Korean War effort had passed by this time and the large-scale commercial feasibility of computers still had not been demonstrated:

> "Messrs. Roberts, Bury [Manager of Product Planning and Assistant Sales Manager, respectively, in the Electric Accounting Machines Division] and, perhaps, Rubidge [also from the Product Planning Department] continued to make statements such as 'You can never sell a machine except to scientists which rents for more than $1,000 a month'. Individuals from the Engineering Department . . . were arguing for the development of more powerful punched card machines. At a week-long engineering meeting at the Harriman estate, the debate continued without resolution twenty hours a day." (Hurd, Tr. 86362-63; see also Hughes, Tr. 33902-04.)

However, in the Spring of 1953, Thomas J. Watson, Jr., at the urging of McDowell and Hurd, approved a plan for announcing the IBM 650. (Hurd, Tr. 86363-64.) In establishing a price for the 650, forecasts were developed by the Sales, Product Planning, and Applied Science Departments.

"[F]orecasts from Sales and Product Planning were zero because the machine . . . could not be produced for $1,000 a month and, therefore, in their opinion, no customers other than Defense Calculator-like customers would buy it". (Hurd, Tr. 86363.)

On the other hand, the forecast from Applied Science was

"200 machines at $3,500 a month with the bulk of the machines to be used by scientists and engineers". (Id.)

Fifty more machines were forecast by the Washington Federal office for defense supply related applications--a type of business application. Based on a total estimate of 250 machines, a rental price was established of "$3,250 a month for the 650 Model 1 with 1000 words of storage and $3,750 a month for the 650 Model 2 with 2000 words of storage". (Hurd, Tr. 86363-64.)

The IBM 650 "magnetic drum calculator" was announced in early 1953 and first delivered to customers in 1954 with two models of a rotating magnetic drum main memory having a capacity of either 10,000 or 20,000 decimal digits. (Hughes, Tr. 34073; Hurd, Tr. 86364; DX 1402, pp. 1-2; Plaintiff's Admissions, Set II, ¶ 807.4.)* The 650 announcement stated that the "flexibility inherent in its stored program control makes [the 650] adaptable to both commercial and scientific applications". (DX 1402, p. 2.)

In contrast to IBM's projection of 250 orders for the 650, approximately 1,800 were in fact produced and

* For a list of the innovations introduced by IBM with the 650, see Hurd, Tr. 86365-68.

delivered to customers. (Hughes, Tr. 33905; McCollister, Tr. 11016-17; PX 1900, p. 6.) No other computer system at that time had been produced in anything like that quantity. The 650 accordingly was described by Hurd as computing's "Model-T" because it was the first general purpose computer system to be mass produced on such a scale. (Hurd, Tr. 86438; see also McCollister, Tr. 11278.)

IBM planners were also wrong in projecting that the 650's principal use would be for scientific applications. The 650, in fact, was used by customers for both business and scientific applications. Indeed, in Withington's opinion, it was used more frequently for business applications, in part because of its high-performance input/output peripherals. (Withington, Tr. 56901-02; Hughes, Tr. 33902, 33906-07, 34058-60, 71892-93; see also Case, Tr. 73192-94, 73273-80.)

Chrysler Corporation's use of the 650 illustrates its versatility. Chrysler installed three IBM 650s--two in its research department and one in its accounting department. The two research department 650s were used in "the support of the engineers in their calculations". Examples of these calculations included design study of gas turbine impellers for Chrysler's gas turbine engine, and the modeling of suspension systems, engine mounting systems and drive shaft systems. Chrysler's accounting department used its 650 to perform "standard accounting operations" such as payroll and cost accounting distribution. (J. Jones, Tr. 78763-64.)

Other customers used IBM 650s to do inventory control (Caterpillar Tractor); administrative applications such as payroll, inventory, purchasing and planning (DuPont's Savannah River Laboratory); statistical applications (Stanford University); College Admissions (MIT); and scientific applications (Purdue University). (Hurd, Tr. 86431-34; H. Brown, Tr. 82963-65, 82967-69.)

Among the reasons for the 650's unexpected success were the system's flexibility for both scientific and commercial applications, its reliability, its ease of installation and operation, its relatively low price, and its compact size. (Hughes, Tr. 33905-07; Hurd, Tr. 86436-37.) In addition, after its introduction IBM introduced several improvements to the 650. These included the addition of alphabetical capabilities, a printer, tape drives, the RAMAC disk drive (described below) and the SOAP assembler.*

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* Welke testified that SOAP (Symbolic Optimization Assembly Program) made it "easier . . . to write a program, because rather than use the actual machine instructions, . . . you could use a symbolic representation, which made it easier to write the instructions". "[T]he instructions were a little bit closer to being intelligible to human beings. . . ."

In addition to offering enhanced intelligibility, SOAP decreased the amount of time necessary for programmer productivity because "with SOAP you could write a list of instructions . . . and . . . then . . . have the machine do the optimizing of the sequence of those instructions. . . ." "SOAP took that second step and did it rather than having a human do it." (Tr. 17294-98; see also J. Jones, Tr. 78764-65.)

(Hurd, Tr. 86366-67, 86436-38; Perlis, Tr. 1334-35; Welke Tr. 17065, 17294-98.) As a result of the 650's flexibility and the introduction of the enhancements listed above, customers began to add more and more applications to their 650 systems--according to Hughes "they began to trust it more, and the more they trusted it, the more they used it, and I think it just grew like that". (Tr. 33906-07.)

In discussing the unexpected demand for the 650, McCollister said that it illustrated that

> "in the early days of the industry in all companies, there was really no clear understanding as to what the potential was for this class of equipment and how it would evolve or how rapidly it would evolve. . . . I think there was a solidly based understanding . . . that this was an important new tool that had very considerable potential, but I don't think anyone visualized how large this business would become, nor the great variety of ways and types of organizations in which and by whom it would be used." (Tr. 11017.)

c. <u>The IBM 702.</u> The 702, IBM's next general purpose computer, was announced in September 1953 and first delivered in early 1955. (Hurd, Tr. 86368; Plaintiff's Admissions, Set II, ¶ 807.5.) Fourteen 702s were installed during the mid-1950s. (Hurd, Tr. 86368.)

The 702 utilized the same type of circuit components, memory, pluggable unit design, and input/output as the 701. According to Hurd, most of the innovations which had been incorporated in the 701 were improved and carried over into the 702, and additional innovations were introduced. (Hurd, Tr. 86369.) However, the 702 was organized differently at the character level. (Id.) Specifically, its designers believed that by putting into the hardware of the computer itself, as contrasted to the software, "a facility for representing [directly] decimal digits . . . and alphabetical characters . . . the machine would be much more useful to businessmen." (Hurd, Tr. 87982.)

The 702 was used for a variety of commercial and scientific applications. For example, at the Atomic Energy Commission's Hanford facility, a 702 was used for inventory control as well as by engineers designing new equipment; at Chrysler, a 702 was used primarily to keep track of spare parts, but was also used for vibration analysis in designing new cars; at Prudential the primary application was maintaining life insurance policy files, but the 702 was also used for actuarial calculations; at Commonwealth Edison the primary purpose was to prepare bills and do associated accounting, but the 702 was also used by the Engineering Department to aid in designing power plants; and at General Electric, a 702 was used both for inventory control and for the design of turbine generators. (Hurd, Tr. 86459-60; 87649-50.)

6. <u>Other Early Entrants Marketing Computers Commercially.</u> In addition to IBM and Remington Rand, several other companies began marketing computers commercially in the early 1950s. Those companies, described in more detail elsewhere, included:

--Computer Research Corporation, "a small spin-off of the Northrop Aircraft Corporation" (subsequently acquired by NCR) (Oelman, Tr. 6121), which was marketing the CRC 107, 105 and CADAC 102-A. (Withington, Tr. 55983; DX 12655.)

--Consolidated Engineering Corporation, which soon spun off its computer division as Electrodata Corporation (subsequently acquired by Burroughs), was developing the Datatron 203/04.

--Raytheon (whose commercial computer operations were subsequently acquired by Honeywell) had developed the RAYDAC and was working on the RAYCOM.

--Bendix (whose commercial computer operations were later acquired by CDC) was working on the G-15.

--RCA was working on the BIZMAC.

--AT&T was working on the TRADIC (a transistorized computer).

In May 1954, John W. Mauchly wrote to Remington Rand personnel who had requested "a list of companies in the electronic computer field, arranged in rough order of probable importance with regard to patent matters". (DX 7604.)

Mauchly responded with the following list:

AT&T and Bell Telephone
IBM
RCA
General Electric
International Telemeter Corp.
Nat'l. Cash Register and Computer Research Corp.
Raytheon
Underwood and Electronic Computer Corp.
Ferranti
IT&T
Burroughs
Hughes
Logistic Research Corp.
Consolidated Engr. Corp. and Electro Data, Inc.
Bendix
Northrup
Librascope and Minnesota Electronic Corp.
Jacobs Instrument Company
Monroe Calculator
Marchant Calculator
Clary Multiplier Corp.
Friden Calculator
General Mills (?)*

Mauchly added that the names of aircraft companies, such as "Boeing, Lockheed, Douglas, Consolidated Vultee, etc." should "possibly" also be included, and that patents "may show up" from such research centers as the Rand Corporation, MIT, the University of Michigan, "or wherever computers are being built under government contract", and that other companies "might well be quite important", including Westinghouse, Telecomputing Corp., Potter Instrument Co., MacDonald Electronic, Intelligent Machines Research Corp., and Federal Tel. & Tel. Mauchly also noted that foreign companies (in

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* The question mark appears on Mauchly's list.

addition to Ferranti) were working on computers (for example, Elliot Bros. and Lyons Limited), and that Remington Rand might be interested "in components or devices emanating from smaller places" such as Reeves Instrument. (Id.; see also PX 1, p. 2.)

Of all the companies active in computers in the early 1950s, however, none made investments to develop and market computers commercially that were comparable in scope to those made by Remington Rand and IBM.

7. <u>Customer Ignorance, Uncertainty, and Fear.</u> In the early and mid-1950s, potential EDP customers (with the exception of certain research or defense-oriented departments in the government, large industrial corporations, universities, and national laboratories) had little knowledge about what computers were, how they worked, and what applications they could usefully perform. As Eckert expressed it, businessmen were "afraid of this strange new beast." (Tr. 905.)

Our reading of the record shows that early customers for computer systems faced at least five types of uncertainty: (a) almost every customer was a first-time user and for most of them the computer was an unknown and exotic tool; (b) acquisition of a computer entailed an investment several times larger than the most expensive electromechanical business machines;* (c) there was doubt as to whether the computer could perform the applications for which it was being acquired reliably over an extended period of time; (d) there was uncertainty as to the types of applications the computer could perform, and (e) there was a shortage of people qualified to program and operate computers.

Donald Hart, for example, described the situation at

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* For example, IBM's 704 was announced with a monthly rent of $15,500 and the 705 with a monthly rent of $14,000 for the CPUs alone. (DX 8955, p. 1; DX 8956, p. 1.) The 709 had a purchase price of $600,000. (DX 569-A, p. 3.)

General Motors.* Hart testified that in the early 1950s:

> "There was very little knowledge of computers anywhere within General Motors. I would say in 1952 there were perhaps three or four smaller groups within General Motors who really knew anything about computers other than what one might find in the newspapers at that period of time." (Tr. 80164.)

One of Hart's responsibilities at that time, as a member of GM's research department, was to make "tutorial" presentations throughout the corporation designed "to explain what a computer was, and how a computer was used for the solution of engineering and scientific problems, and to give some feeling for the way in which computers might be used by these various industries within the corporation for the solution of their engineering and scientific problems". (Tr. 80163.) Hart characterized his listeners' reactions as ranging "from general interest to great skepticism to an occasional reaction of enthusiasm". (Tr. 80166.) When asked to explain the reasons for the skeptical reaction, he replied:

> "Well, this was a new kind of device, a new approach to problem-solving, and many of the engineering groups that we talked to felt quite competent to deal with their jobs in the manner that they had been doing without these computers. And they failed to believe that computers were going to be of any value to them in carrying out their work, and to some extent I think it was looked upon as a scientific curiosity and perhaps a passing fad." (Tr. 80166-67.)

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* Hart first became involved with computers at the General Motors Research Department in 1951, when he helped build GM's first computer--a one-of-a-kind computer dubbed the SAMJAC (for "Slow as Molasses in January Automatic Computer"). (Hart, Tr. 80158-60; DX 3753 (Tr. 80186).) In 1954, the Research Department installed an IBM 701. (Hart, Tr. 80186.)

Hart believed that in the early to mid-1950s, "most of us who were working in the computer field, particularly within an industrial environment, were in about the same boat; namely, that we were a small island of expertise in a large organization that knew very little, if anything, about this field. So we all tended to look upon ourselves as missionaries."* (Tr. 80169.) Among the companies Hart identified as being in a position similar to GM's (that is, having at least some familiarity with computers) were other automobile manufacturers, aircraft companies, chemical companies and government laboratories. (Tr. 80170.)

For most potential or first-time users of computer equipment in the earliest years, the question was "Should we use a computer at all?" (Withington, Tr. 55521; see also McCollister, Tr. 11019.) Welke, who was an IBM systems engineer in the 1950s (Tr. 17004-05), described the uncertainty facing first-time computer users as follows:

> "I think for some people, if not all of them, getting their first computer was a rather traumatic experience for them. There was a lot of uncertainty. It was the first time that they had ever been doing anything like this. And it was a large financial commitment on their part as

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* Richard Bloch testified in a similar way about the uncertainty facing computer customers, whom he characterized as "pioneers":

> "In the earlier part of this period [the fifties and sixties], it had not been demonstrated conclusively that what we now know today as being an obvious major element in our society would ever even come to fruition, and that is the use of these machines to do all aspects, practically all aspects, of business processing and more." (Tr. 7753.)

well, not just for the equipment but to change all of their procedures in order to accommodate the equipment.

"So, yes, there was a lot of uncertainty, a lot of apprehension, a lot of nervousness. Certainly much more so then, you know, than now.

"I can remember when my customers got their first computer, we would be out there at the loading dock, or the unloading dock, the receiving dock, watching it, you know, come off the truck, helping to push it down the corridor, et cetera. . . .

"[T]he second, third or fourth computer is no longer that much of a trauma, it does not cause that much of a trauma." (Tr. 17378-79; see also R. Bloch, Tr. 7751-54; Welke, Tr. 17327-30, 17377-81; Goetz, Tr. 18537-38.)

8. <u>Expanding the Market for EDP Products and Services.</u> In addition to introducing many hardware and software advances in its early computers, IBM also used two marketing practices that proved to be especially valuable to technically unsophisticated computer customers, and that contributed substantially to the growth in demand for EDP products and services and to the success IBM achieved through participation in that growth.

a. <u>Short-Term Leases.</u> IBM and other suppliers used short-term leases to market computer systems, thereby shifting to themselves a large portion of the economic risk of investment in computer equipment at a time when computer technology was both new and rapidly changing. Leasing offered many customers three benefits:

> First, short-term leases helped customers avoid the risks of acquiring a computer system that did not satisfy their needs either because it did not work properly or because it did not meet the operational needs of the business. Specifically, short-term leasing offered customers the flexibility of disposing of or reconfiguring their computer systems. "[I]f the user was not satisfied with the equipment or services provided by the vendor, he could demand that the equipment be removed at once." (Hurd, Tr. 86415; see R. Bloch, Tr. 7675-76; McCollister Tr. 11088-89; Rooney, Tr. 12126-27; Welke, Tr. 17345-46; Withington, Tr. 55737,

55886-89; J. Jones, Tr. 78818; Spain, Tr. 88725.) One result was that leasing "fostered a relationship" in which a supplier "was required to respond rapidly to user needs" and was under constant pressure to keep its users satisfied. (Hurd, Tr. 86415; see Rooney, Tr. 12125-28; Beard, Tr. 8546-47; Welke, Tr. 19619; J. Jones, Tr. 79037-40; Spain, Tr. 88725-26.)

Second, short-term leases reduced the magnitude of the initial investment necessary to acquire the computer system and shifted that capital requirement to the manufacturer. (Norris, Tr. 6049-50; R. Bloch, Tr. 7675-76; Welke, Tr. 19619; J. Jones, Tr. 78818; H. Brown, Tr. 83139-40; Hurd, Tr. 86414; PX 1983, p. 3; DX 3909, pp. 3, 9, 13.)

Third, short-term leases helped customers avoid the risks of technological obsolescence, and enabled them to take full advantage of technological improvements in computer systems. (Norris, Tr. 6049-50; R. Bloch, Tr. 7675-76; J. Jones, Tr. 79036-37; H. Brown, Tr. 83137; Hurd, Tr. 86414; Spain, Tr. 88725; JX 3, p. 2; DX 3909, p. 17.) This was especially significant to customers because the EDP industry, from its inception, experienced rapid technological change. (Withington, Tr. 56637-40, 56459-60; Hurd, Tr. 86414; JX 3, p. 2; DX 7528, p. 17.)

H. Dean Brown testified about the benefits leasing offered customers: "With the option to lease he may acquire a machine that he would not otherwise acquire under any terms". (Tr. 83138-39.) Brown added that it was his opinion that leasing "has increased the use of computer systems [because it] has made computers available to users who would not otherwise acquire them". (Tr. 83139.)

John L. Jones, who was responsible for the computers installed at Chrysler from 1956-58 and at the Air Force Logistics Command from 1959-63, testified that in the 1950s, "leasing was considered to be a good way of acquiring [EDP] equipment because it did not represent the long-term commitment that was implied by a purchase." (Tr. 78818.) In addition, the AFLC (one of the largest government users) leased all of the computer systems installed when Jones was there because "there were no capital dollars available to purchase this equipment".* (Id.; see Norris, Tr. 6049; Rooney, Tr. 12498-99; H. Brown, Tr. 83139-40.) Indeed, although UNIVACs were initially sold and were not offered for lease, pressure from potential users forced

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* This does not mean that leasing was the only desirable way of acquiring EDP equipment. Certain customers were, from time to time, more favorably disposed towards purchase. For example, Fernbach, who was in charge of one of the most sophisticated computer installations in the United States, testified that "[v]ery early in time we, the laboratory [Lawrence Livermore], recognized that there was great virtue in purchasing over leasing. The cost over a period of even five years was less, the overall cost was less to the laboratory by purchasing." (Tr. 555)

Remington Rand to change its policy and offer UNIVACs for lease. (Eckert, Tr. 912-13.)*

b. Customer Support. During the 1950s, users and potential users demanded that manufacturers and suppliers of computer systems provide certain software, as well as customer education and training, and systems engineering support.** (E.g., R. Bloch, Tr. 7603-05, 7751-54; Beard, Tr. 10090, 10094; McCollister, Tr. 11041-43, 11370; R. Pfeiffer, Tr. 16008-09; Withington, 56782-86, 56789; J. Jones, Tr. 78797, 78802-09, 78816-17; Hurd, Tr. 86416; Spain, Tr. 88722; DX 4730, Goetz, p. 26.) McCollister, for example, testified about the need for suppliers of computer equipment to offer services and software support if they were to market their products successfully:

> "My recollection is that in the early installations of computers, which would have been the UNIVAC I and the IBM 701, that both of these manufacturers offered support to one degree or another to the users of these equipments, and both of these manufacturers offered what software was available at that time, which would have been such basic items of software as assemblers, utility routines, sort routines, and so on.
>
> "I think that this was a matter of necessity and that both of these manufacturers did this at that point in time." (Tr. 11042.)

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* NCR and CDC encountered similar customer demand, leading them to lease their computer equipment as well. (Norris, Tr. 5641-42; Oelman, Tr. 6155-56, 6159-60; DX 402, p. 3.)

** IBM's systems engineers assisted both the IBM salesman and the customer in understanding how a computer system could be utilized in meeting the customer's data processing needs and helped in the design of the system, its installation, and the customer's initial use. (Welke, Tr. 17007-11, 17069-70, 17372-73.)

And Hurd testified about the same period:

> "At the time IBM delivered the 701 in 1953, very few people in the United States had any experience with general purpose computers. The Applied Science Department therefore began a program of educating customers on how to use the 701 hardware and software and how to recruit and train personnel in-house." (Tr. 86361.)

McCollister believed that offering such support was a necessity for a supplier of computer systems because:

> "[the] people who were going to use the products in some cases certainly did not have that much experience or knowledge. Both the user and the manufacturer to a certain extent were pioneering, and therefore, this condition existed." (Tr. 11043, see Tr. 9341-42.)

As described by Ralph Gomory, IBM's Director of Research:

> "[t]he customers in those days had no sophistication. The people dealing with this problem were people like foremen in a paper mill, had no understanding usually of computers". (Tr. 98164.)

Similarly, according to IBM's Ralph Pfeiffer:

> "In 1956, the industry was obviously much younger, less sophisticated, computers were on the scene for only a matter of several years, depending on which one we are talking about, and the customers, in that time frame, needed to be educated, and needed to be supported in getting the total operation under way in a way that they don't need to be supported today." (Tr. 16008-09.)

John Mauchly, writing in approximately 1954 and 1955, expressed his concern with the shortage of people knowledgeable in computers:

> "[M]y conviction [is] that the market for large electronic office equipment is limited chiefly by the lack of education and information as to how such equipment could be used. There is lack of that information and experience within our company as well as among potential customers." (DX 7596, p. 1; see DX 7597, p. 10.)

> "It is everywhere recognized that there is a shortage of trained personnel for the application of electronic computers to the problems of business and industry. . . .
>
> "Everyone of us who has any contact with this situation is all too familiar with the distressing results of such a personnel shortage. The operating history of some of our [Remington Rand's] industrial installations might have been quite different, had there been a better supply of properly trained people." (DX 7597, pp. 1-2.)

Mauchly, indeed, thought that the shortage of trained personnel was going to get worse:

> "Let us suppose now that the IBM 650 machines . . . are to appear in the numbers indicated and at the times indicated by IBM. . . . Even if Remington Rand does not make another computer in the UNIVAC series for the next two years, the demand for programmers who are capable of setting up large problems on the 650 and other internally stored program machines, such as ElectroData and others are getting out, will accentuate and sharpen the present shortage." (DX 7597, p. 14.)*

John Jones agreed that "the knowledge of the user of computers at this time [was] . . . not extensive and broad," either with regard to "technical knowledge" of the computer or "the best way to organize applications for the computers". (Tr. 78816-17.) The vendors, he said, were "generally believed to have considerable expertise and knowledge in how to apply the computers to various applications", and users "demanded" support services from systems vendors to obtain "some expertise, or some assistance not easily or commonly available to the user." (Tr. 78816-17; see also Spain, Tr. 88722; DX 5413, Beutel, pp. 7-8.)

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* Withington testified that at most times during the history of the industry "demand for trained people has exceeded supply". (Tr. 56790.)

Welke commented on the importance he attached to IBM's efforts to educate customers during this period:

> "Q Do you have a judgment as to the degree of significance of IBM's educational efforts in training this early group of persons knowledgeable in computers? How important was it?
>
> "A Again, in retrospect, it was very important. The entire proliferation of computers seemed to have depended on that education, on that dissemination of information about it.
>
> "Certainly the users, the prospects were not in a position of knowing how to profitably use that computer without education. They had to be educated as to the use of it. It was an unknown tool.
>
> "Q And was creating this base of knowledge a prerequisite to IBM being able to lease computer equipment to people in that position?
>
> "A Yes. Not only to place it on lease, but to keep it on lease." (Tr. 17344-45.)

Richard Bloch testified that users in the 1950s and early 1960s demanded that manufacturers provide "total competence"--a "total data processing system", including the mainframe, the peripherals, "system support, software, and even assistance in applied programming": "It was at that time a total competence that had to be offered." (Tr. 7577, 7751-55.)

Bloch said users "demanded" "total competence" because:

> "[T]hey were taking quite a risk as it was in picking up equipment in the first place. . . . And these customers, if I were in their shoes, I would have insisted upon everything they did insist upon, because they were pioneers and they had to have these elements to have any chance whatsoever of even doing their pioneering in the early days." (Tr. 7753.)

According to Bloch, the elements "were not available elsewhere, and they had better be available from the manufacturer of the central equipment, otherwise the application would be doomed to failure". (Tr. 7751-52.)

In addition to meeting user demand, computer manufacturers found it to be in their interest to provide technical assistance and support to their users. By providing this support, computer manufacturers could enable customers to use their equipment properly, and to make more effective use of that equipment, which led to enhanced user satisfaction and more rapid growth in the use of electronic data processing. (McCollister, Tr. 9341-42, 11041-47, 11369-70; Welke, Tr. 17380-81.) As Mauchly wrote in 1955:

> "[I]t is a well-recognized principle, followed by Remington Rand as well as IBM, that expert assistance must be given to any customer to ensure that his equipment is properly utilized." (Dx 7596, p. 2.)*

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* Mauchly also recognized that a larger number of trained personnel would not only increase customer demand for EDP products but might reduce the labor cost of the computer manufacturers:

> "[W]e cannot hope that we shall be able to get the people we want at lower salaries unless the demand slackens, or the supply increases. The last thing in the world which we would want to happen, is to have the demand slacken, since this would mean a saturation of the market for computers. Consequently, the only way that we can ever hope to avoid paying higher and higher salaries for computer personnel, is to increase the supply to the point where it meets the demand. This is exactly the reason why Dr. Hurd and the IBM Organization feel that it is to the interest of their organization to promote in every way possible the training of people in applied mathematics and computer programming." (DX 7597, p. 15)

One way in which both IBM and Remington Rand addressed the problem described by Mauchly was to make computers available to educational institutions at reduced rates to facilitate training of students in

Goetz testified that manufacturers "wanted to provide as much software and as many facilities, whether it be programmers, or software packages, as quickly as possible to get a satisfied customer." (DX 4730, Goetz, p. 40.)

Norris testified that in the fifties and early sixties, many or most potential users of computers were unfamiliar with that equipment and it was "necessary to provide [such] users and potential users with training and education in the uses of electronic data processing equipment in order for manufacturers to market [their] equipment". (Tr. 6058.) "For a time", CDC successfully marketed the 1604 (its first computer system, announced in 1958 (Tr. 5608)) with only "limited" software to "that limited class of users who could substantially write their own software"; however, that policy did not persist, because CDC wanted to market more systems, and for the remainder of 1604 users obtained by CDC, "it was necessary in order to market to them a system to supply

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their use. IBM's program of educational allowances is discussed below at pages 437-50.

Mauchly explained why Remington Rand gave computers to universities:

> "It was believed, and I believed this, incidentally, that the more you had the general public and business men aware of what you could do with these computers, the more you enhanced the market, as we were saying, and that part of the good that we all wanted to accomplish was to get more people using more computers which in turn might benefit everyone, including the computer users as well as the computer vendors.
>
> "This is a process in which everybody benefits." (DX 7584, Mauchly, p. 160.)

them both with control programs and with a substantial amount of application software". Moreover, it was necessary to do that "on a continuous basis in order to expand . . . the customer's use of the machine" and "to induce the customer to purchase or lease additional and better forms of electronic data processing equipment". (Norris, Tr. 6061.)

According to Goetz,

> "Manufacturers made a concentrated effort to hire and train programmers beginning as early as 1953. When a computer sale was made, the computer manufacturer would 1) initially train the customer's own personnel in programming, and 2) provide continuing on-site programming assistance after delivery of the computer. The sale itself, however, was considered the 'computer hardware,' while all other services provided were specified simply as support for the 'sale.' The computer hardware business which emerged during the 1950's and gained momentum in the 1960's was soon recognized as a major and growing industry. IBM acquired a reputation as a marketing-oriented firm which wouldn't desert a customer after a sale was finalized. Thus 'providing programming assistance' became an important sales asset to IBM as well as all other manufacturers. Another fact which fostered customer assistance was that many companies frequently would not pay rent on their equipment until their particular applications were programmed. The capability for providing extensive 'programming assistance,' therefore, became a significant criterion for evaluating competitive computer manufacturers' proposals." (DX 1096, p. 1.)

According to Jacqueline Johnson, chief executive of Computer Generation and an employee of Sperry Rand and GE in the 1950s and 1960s, IBM "achieved its position of leadership" in EDP in part due to its emphasis on the provision of needed customer support:

> "The difference in IBM's marketing approach and those of competing vendors could be correlated to that of the chicken and the egg. The two critical aspects of success

were sale of the equipment and support of the equipment. Most vendors sold the equipment and then attempted to support it. IBM took the approach that they supported the equipment and then attempted to sell it. IBM created a strong customer following by so doing and a greater sense of customer loyalty than other vendors." (DX 3979, p. 16.)

During the 1950s, most computer vendors provided education, support, and certain software at no separate charge for their equipment. This practice came to be called bundling. Bundling, indeed, began at the "very start" of the computer industry: Univac included the cost of software, systems engineering, and education in its hardware prices from the time of its entry. (Welke, Tr. 17111; see McDonald, Tr. 3921-25, 4196-97; McCollister, Tr. 11041-42.) During the remainder of the 1950s, virtually "all the computer manufacturers marketed on a bundled basis". This "was standard practice" and applied to companies such as Univac, IBM, Honeywell, RCA, and CDC. (Spangle, Tr. 5092; Norris, Tr. 6066; R. Bloch, Tr. 7604; McCollister, Tr. 11041-44; Goetz, Tr. 17500-01; DX 4730, Goetz, pp. 26-28, 35-36, 38-44; Plaintiff's Admissions, Set IV, ¶ 238.)

The provision of necessary support at no additional charge beyond the price of the hardware was in response to customer demands because customers were not interested in acquiring computer hardware alone, but rather in acquiring a data processing service or capability. Thus, users were less interested in the price of the hardware than in the total cost of getting their jobs done reliably and consistently. (R. Bloch, Tr. 7577, 7603-04, 7751-55 (quoted earlier); J. Jones, Tr. 78796-97, 78808-09, 78815-17; DX 4088, Schelling, pp. 14-15; DX 8182, Bramson, pp. 12-13.) Hence, accordin to Welke, bundling offered users two kinds of advantages:

> "On the one hand, it gave the users a predictable cost that they could budget against. They knew that their system would cost them 'X' number of dollars a year or per month, and they could budget that amount and predict it. And by the same token, they also knew that the undefined problems that existed in data processing, in their computing world, would be covered as well." (Tr. 19225-26.)

> "It made it easier for [customers] to deal with [the] new technology. . . . It made it easier for them to use computers." (Tr. 17371.)

Welke explained how bundling made a user's costs more predictable:

> "[I]f I know that education, maintenance, the various support services are mine for the asking . . . that in whatever quantity I might need them they will be made available, then I have a predictable cost that I can allocate to computing I can say that, you know, my installation, my computer is going to cost me, you know, $15,000 a month or whatever it might be, 'x' number of dollars a month, and all of these things are included. It will be an operating system. You know, it will do my job for me. It is the solution to that data processing problem." (Tr. 19228.)

In a similar vein Withington testified:

> "Users, knowing they would have to pay for any and all assistance they received, would probably have been significantly more reluctant to undertake their initial experiment with data processing systems, general purpose ones, than they were, because as things stood at the time, they could all be sure of obtaining whatever support they needed or at least have a hope of doing so without having an unknown liability for future costs." (Tr. 56783.)

Withington testified that the provision of assistance without separate charge to computer users could "fairly be said" to have contributed to the growth of the computer industry. (Tr. 56782-83.) Welke testified that both the availability of support services from manufacturers, as well as their provision without separate charge, contributed to the growth of the EDP industry in the 1950s. (Tr. 17345, 17371-72, 19336.) Similarly, McCollister testified that "certainly in the early years of the computer industry, . . . the practice of the manufacturers of providing assistance to the users at no charge was of benefit to the users" of computers and "contributed to the further development of the industry itself" (Tr. 11369-70) and "to the enormous position of strength" that the United States developed in the computer field. (Tr. 11058-63; see Tr. 11041-57.) According to McCollister, separate pricing of the components of the bundled package:

> "might have tended to slow down somewhat the acceptance of equipment in the early years because it would have increased the cost to the end user, and in the early years it was a somewhat marginal situation at best in terms of cost savings that were effected through the use of computer systems as opposed to methods that were being used previously, because, keep in mind, this was before the technology had made computer systems equipment as cost effective as it subsequently became.
>
> "So, it might have made the installation of a computer system somewhat more marginal in the early years in a cost sense and therefore slowed down to some degree the introduction of equipment." (Tr. 11280-81)

During this period no one considered programming proprietary, and software was freely exchanged among users and manufacturers. * (See, e.g., DX 699, pp. 18-19.) Had manufacturers not made software available at no separate charge, users and the industry would have been denied considerable benefits. Writing in 1966, Donald Turner, then Assistant Attorney General in charge of the Antitrust Division, described how

> "growth in the software portion of the computer industry [had] been facilitated by a remarkably free and easy exchange of ideas, concepts, and programs. One of the notable features of the programming industry, indeed, has been the widespread establishment, sponsorship, and universal acceptance of joint user groups to facilitate the exchange of programs and algorithms. As a result, for the past twenty years, almost all basic ideas in computer programming have been available openly to all computer users." (DX 9110, p. 1.)

According to Turner, the "free interchange of programs" led to "an extraordinarily efficient use of scarce programming talent and has kept needless duplication of existing programs and techniques to a minimum." (Id., pp. 1-2; see also Perlis, Tr. 1997; DX 1096, pp. 1-2.)**

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* According to Goetz:

> "In the 1950's, programs were freely interchanged, since they were not viewed as property. Free programming support, free programs, and free user education became expected clauses to any hardware leasing or contractual arrangement." (DX 1096, pp. 1-2.)

** Similarly, the GAO stated in 1971 that the practice of manufacturers distributing their programs to users and serving as clearing houses for computer programs developed by others has "contributed to the relatively free dissemination of computer software and was undoubtedly a substantial factor in the growth of the computer industry". (Plaintiff's Admissions, Set IV, ¶ 236.1.)

IBM, more than Remington Rand or any other supplier in this timeframe, committed itself to growing the market for computers by educating customers and potential customers, as well as substantial numbers of people within IBM, about computers. In 1954, for example, John Mauchly wrote that

> "[Remington Rand] just [isn't] match[ing] the manpower which IBM is putting in the field to help their customers program problems and study applications on their equipment." (DX 7597, p. 11.)

III. IBM's COMMITMENT TO THE EDP BUSINESS: THE MID-1950s

9. <u>SAGE: IBM's Role and the Effect on IBM's Position in the EDP Industry</u>. In 1952, shortly after the Soviet Union successfully demonstrated its first nuclear weapon, the Air Force moved to develop and implement a computer-based air defense system for the continental United States. That system, called SAGE (Semi-Automatic Ground Environment), was intended to provide early warning of a Soviet air attack by tracking airplanes automatically as they travelled across North America and causing the dispatch of fighters in case of unauthorized entry. (Crago, Tr. 85956, 85962; see Hurd, Tr. 86371; Case, Tr. 72250-51.) SAGE was called "Semi-Automatic" because the design left to human operators certain tasks such as tactical decisions about weapons deployment and commitment. (Crago, Tr. 85956.)

Under the SAGE plan, the United States was to be divided into 24 radar-monitored sectors. Each sector contained a SAGE direction center, with a computer installation capable of monitoring that section's air space by processing radar input. (Crago, Tr. 85956.) The computers at each direction center, together with input/output equipment, were to be a part of the larger air defense system, which included additional SAGE computers and input/output equipment at three central "combat centers". (Crago, Tr. 85956, 85960.) The SAGE plan required the development of a large number of highly complex, interrelated devices, including sensors, communication links, displays, consoles, and computers. (Hurd, Tr. 86371-72.)

The SAGE concept grew out of work performed from 1945 through 1951 by MIT's Lincoln Laboratory under an Air Force contract. Lincoln Laboratory designed and built the Whirlwind, a one-of-a-kind, experimental digital computer system that used magnetic core memory (for the first time) and was a real-time digital computer system, receiving and transmitting data over telephone lines for instantaneous display on monitors. (Morse, Tr. 30963; Crago, Tr. 85961.) In 1951, the Whirlwind was tested in an experimental air defense system called the Cape Cod System. (Crago, Tr. 85961, 86010, 86023.)

In 1952, the Air Force authorized Lincoln Laboratory to discuss proposals from a number of companies to design and implement the SAGE computer system. (Crago, Tr. 85962.) To develop and manufacture the actual SAGE computers, it would be necessary to move from the Whirlwind prototype, which had been "designed so that it primarily could be experimented with, changed, modified and so on" (J. Jones, Tr. 78745-46), "to a reliable, repeatable, practical design and to manufacture, install and maintain several dozens of the systems--systems of unprecedented complexity which employed heretofore unproved technologies". (Crago, Tr. 85962.)

MIT recognized that the talents of a major industrial company were required for this transition from the Whirlwind prototype to the complete, operational system. After initiating inquiries with several firms, MIT chose to pursue discussion with a smaller group. These included RCA, Raytheon, Remington Rand, Sylvania and IBM. (Crago, Tr. 85962; Hurd, Tr. 86463-64.)

After conducting detailed discussions with each of these firms, MIT selected IBM, in October 1952, to work with Lincoln Laboratory on the preliminary design specification of the digital computer for the SAGE system. In April 1953, the Air Force awarded IBM a prime contract to develop more detailed design specifications for SAGE's digital computer. Shortly thereafter, IBM purchased and converted an old necktie factory in Poughkeepsie, New York, to undertake the SAGE development activity.* It also began an intensive collaboration with MIT's engineers, who commuted by air on a daily basis between Poughkeepsie and the Lincoln Laboratory near Boston. (Crago, Tr. 85962-63.)

In September 1953, the Air Force asked IBM to design, fabricate, support and maintain two prototype computers for the SAGE system. Finally, in February 1954, IBM was awarded the contract to "design, fabricate and maintain the digital computer systems for the SAGE system on a production basis". (Crago, Tr. 85962.) MIT had the responsibility for the overall systems design. (Hurd, Tr. 86370.) Western Electric had the responsibility for coordinating the activities of the prime contractors, as well as for designing

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* The factory was on High Street and the SAGE Project became known as "Project High" within IBM. (Crago, Tr. 85954, 85963.)

and building the SAGE centers, and scheduling, budgeting and testing the various parts of the SAGE system. (Crago, Tr. 85965.)

Based on a conversation with MIT's Professor Jay Forrester, head of the Whirlwind Project and a member of its Selection Committee (Morse, Tr. 30963; Hurd Tr. 86464), Hurd testified that the primary reason for IBM's selection was that MIT believed "IBM could mass-produce a high-quality reliable system". (Hurd, Tr. 86465.)* According to Hurd, IBM's selection "was based primarily on [the] assembly line kind of concept for quantity production and [on] the quality of [IBM's] people". (Hurd, Tr. 86466.)

IBM had three principal responsibilities on SAGE: first, to design, engineer, and manufacture the SAGE computer systems; second, to install and maintain (for round-the-clock operation) those computer systems at SAGE sites throughout the United States; third, to provide Air Force personnel with the training and manuals they needed to operate the SAGE computer systems. (Crago, Tr. 85960-61; Hurd, Tr. 86371.)

In February 1954, when IBM was awarded the contract to mass produce the SAGE computers, IBM purchased 200 acres of land and began construction of the necessary facility in Kingston, New York. Many engineers working on the IBM 701 and 702 were trans-

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* Recall that as of mid to late 1953, IBM was producing one 701 a month and was getting ready to produce and deliver the first of what was expected to be at least several hundred IBM 650 computer systems. (Hurd, Tr. 86345, 86363-64, 86435-36, 87183.)

ferred to work on SAGE. Also, a field engineering training course of approximately six months' duration was set up to facilitate SAGE's eventual installation and maintenance. The first trainees were experienced customer engineers; they then became instructors for newly hired employees and transferees from other IBM customer engineering assignments. At the peak of its activities on SAGE, IBM employed seven to eight thousand people on the SAGE project. (Crago, Tr. 85963-64.)

SAGE was an enormous undertaking. In addition to IBM, there were numerous subcontractors, including the Hazeltine Corporation, which made CRT displays (designed by IBM) for the SAGE terminals;* Bendix, which made the Long-Range Radar Input units (also designed by IBM), as well as "GAP Filler Input Mapper Consoles", used to eliminate irrelevant radar information before such information could be entered into the SAGE computer; the System Development Division of the RAND Corporation, which refined the air defense application programs initially written by MIT;** AT&T's Western Electric subsidiary, which coordinated the activities of other contractors, designed and built the SAGE centers and produced modems for the SAGE computer

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* Hazeltine was chosen over companies such as ITT, Bendix, and Raytheon. (Crago, Tr. 85964.)

** That division of the RAND Corporation grew so large while working on programming for SAGE that it was spun off in 1956 as a separate company known as the System Development Corporation. (Crago, Tr. 85964-65.)

system;* and Burroughs, which produced the Radar Data Coordinate Transmitters--hard-wired computers that processed data collected by radar units for transmission over phone lines to the SAGE direction centers. (Crago, Tr. 85964-65.)

As finally installed, each of the 24 SAGE direction centers contained two IBM-manufactured AN/FSQ-7 SAGE computers** and related input/output equipment. Each SAGE processor "was capable of simultaneously driving over 100 display consoles, accepting data from over 100 on-line operators and 12 remote sites, and providing output data to the same sites plus 25 teletypes". (Crago, Tr. 85956-57, 85959-60.)

In addition to the 24 direction centers, each of the three "combat centers" contained two IBM-manufactured AN/FSQ-8 SAGE computers and related input/output equipment. (Crago, Tr. 85956.) The two computers at each combat center had far fewer display consoles and much less input processing equipment than did the

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* Modems convert computer digital signals into analog signals that can be transmitted over telephone lines and reconvert those signals into digital signals which can be processed by a computer. MIT designed the modems and Western Electric produced them. (Crago, Tr. 85965, 85994.) IBM decided not to manufacture the modems itself and asked AT&T to do this. According to Crago, the decision was a "reluctant" one because he believed IBM would benefit greatly from manufacturing the modems itself. (Crago, Tr. 85992-93, 85997-98.) Crago testified that AT&T and Western Electric "benefited tremendously" from this undertaking. (Crago, Tr. 85994-99.)

** The "central computer" of the AN/FSQ-7 system was described in one article by three Lincoln Lab technicians as a "general purpose, binary, parallel, single-address machine with 32-bit word length and a magnetic core memory of 8192 words". (DX 5060, p. 5.)

direction center computers, because the "combat centers received data which had been already processed and transmitted by the direction centers. The function of the combat centers was to combine, summarize and display air defense information supplied to them by the direction centers over which they had supervisory control." (Crago, Tr. 85957-58.)

SAGE represented IBM's largest undertaking through the mid-1950s. (Hurd, Tr. 86372.) Hurd described the substantial risks IBM incurred by undertaking SAGE:

> "Many of the concepts had been tried only in a laboratory. There was no guarantee IBM could hire the numbers of people that would be needed to carry out its responsibilities. Failure to deliver the computers successfully, because the project was so massive, could have led to adverse financial repercussions and damage to IBM's reputation. Mr. Williams [IBM Vice President and Treasurer], for example, asked if a mistake in computation might result in the accidental destruction of one of our country's own airplanes, with the resultant financial exposure and publicity such an accident might entail. All of us were concerned in 1953 about the diversion of key engineering and systems persons and Applied Science persons who were barely completing the design of the 650, 701, and 702. Moreover, IBM would need to construct a completely new factory to build the SAGE computers and all of us in the highest management group wondered what would happen if the contract were cancelled in midstream." (Hurd, Tr. 86372-73; see Crago, Tr. 85970-72, 86059-60.)

Despite these risks, IBM expected to obtain substantial benefits from its involvement in the SAGE program and therefore undertook the commitment. Crago and his predecessor as Manager of IBM's SAGE program concluded in a 1954 analysis (DX 8948) that the benefits to IBM from SAGE were of three principal types:

(a) SAGE would directly contribute to IBM's current and planned commercial computer products,

(b) SAGE would obviate or reduce IBM's future expenditures on research and design work for its commercial computer products, and

(c) because of research and development done for SAGE, IBM would gain an economic advantage over competitors in marketing computer products. (Crago, Tr. 85980-81, 85985-87; DX 8948, pp. 2-15.)

Indeed, the 1954 report predicted that as a result of its SAGE involvement,

> "IBM will be recognized as the undisputed leader in the large scale, high speed, general purpose, digital computer field. If a competitor were performing on this contract, that competitor might gain enough advantage to force IBM into a relatively secondary position." (DX 8948, p. 15.)

In fact, SAGE did yield substantial technical, manufacturing, and educational benefits to IBM because IBM was able to effect the "successful integration into actual production computers of many of the most advanced concepts, designs and technologies known at that time". (Crago, Tr. 85966.) IBM's SAGE innovations are described in detail in the trial record. (See Case, Tr. 72251-54; Crago, Tr. 85966-79; Hurd, Tr. 86374-76; McCarter, Tr. 88357-60; E. Bloch, Tr. 91525-28, 91848-50; DX 5005, p. 9. DX 8939, DX 8940, DX 8946 and DX 8947 illustrate some of the patents received by IBM for this work.) Three of these advances are described as follows:

(a) SAGE was the first production-line computer to incorporate core memory. This represented a major advance because core memories provided a highly reliable and inexpensive means of storage. According to Eric Bloch, who was working on IBM's commercial core memory program at the time of the SAGE program:

> "Cores could be inexpensively fabricated, tested and assembled into core arrays, and the ability to access cores in multiple dimensions permitted a relatively small number of devices to access a large capacity memory thereby reducing costs and increasing reliability. The speed of magnetic core memories [was] much faster than the speed of Williams tube and magnetic drum memories . . . . Magnetic core memories also consumed less power and were more reliable than Williams tube and magnetic drum memories and could be assembled in larger capacities than Williams tube memories." (E. Bloch, Tr. 91466-67, 91526; see also Fernbach, Tr. 451; Plaintiff's Admissions, Set II, ¶¶ 808.0-.1.)

In manufacturing its SAGE computers, IBM developed a method of manufacturing uniform, high speed, reliable, and inexpensive core memory. These manufacturing techniques allowed IBM to make millions of cores with uniform electronic characteristics. IBM developed devices which partially automated the stringing of core planes, and it developed semiautomatic core testing equipment. (Crago, Tr. 85967-68; Hurd, Tr. 86374; see E. Bloch, Tr. 91527-28, 91530-33, 93299-300.) Core memories proved so successful they were used in virtually every computer system manufactured until they were replaced by semiconductor memories in the 1970s.* (Andreini, Tr. 48451-55; Case, Tr. 72346.)

(b) The SAGE system was designed to be extremely

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* For a list of IBM computers that used core memories, see E. Bloch, Tr. 91525.

reliable. Each computer was duplexed to prevent system failure--that is, at all times one of the computers actively performed air defense surveillance while the other was in a stand-by mode:

> "IBM took many new measures to assure that the extreme reliability and continuous operation requirements for SAGE were met. To assure continuous operation, any part of the computer system whose failure might bring down the system was duplexed. Every SAGE direction center was equipped with two complete computers. At all times, one of the computers was active in air defense surveillance while the other was in a standby mode ready to be switched over into the active mode within seconds. The active computer continuously transmitted changes in the air situation data to the stand-by computer . . . so that the air situation picture would not have to be regenerated when switchover occurred." (Crago, Tr. 85970-71; see also Case, Tr. 72251-53; Hurd, Tr. 86375.)

Real-time commercial systems implemented after SAGE often used the duplexing technique to guard against system failure. (Crago, Tr. 86048-50, 85975.)

(c) "SAGE was the first large, geographically dispersed real-time computer system". (Crago, Tr. 85975.) It was a precursor to dispersed real-time systems such as SABRE, the first successful airline passenger name reservation system (discussed later), motel and hotel reservation systems, auto reservation systems and "other types of systems where immediate response to the waiting customer is vital". (Id.)*

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* As Weil testified, the military was "very often concerned with controlling some external event, so that earlier than commercial computers, although commercial computers learned how to do this, too, the original consideration of developing the technology for handling what was referred to as real-time events, was derived from some of these specific military computer applications". (Tr. 7044.)

In addition to the technical and production advances IBM realized from SAGE,

> "[t]he several thousand engineering and programming and maintenance personnel who were hired to work on SAGE added greatly to the company's store of technical knowledge and expertise. These persons worked on developing and maintaining many of IBM's subsequent general purpose computer systems." (Hurd, Tr. 86377; see Crago, Tr. 85979-80.)

During the 1950s, more than one-half of IBM's domestic EDP revenues came from a combination of SAGE and the B-52 program undertaken during the Korean War. (DX 2609A, pp. 34-50.)*

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* We understand that DX 2609A has not yet been received in evidence. We rely on it because it represents IBM's sworn response to Court-ordered questions and there is every reason to believe it accurately reflects the information called for.

10. The IBM 704 and 705. In 1954, building on its work on SAGE, IBM announced the 704 and 705, substantially improved successors for the 701 and 702 respectively. At that time, although several 701s had been built and installed, deliveries of the 702 (announced in September 1953) had not yet even begun.

The IBM 704, announced in May 1954 and first delivered in 1955, was approximately two to three times as fast as the 701.* (Hurd, Tr. 86378; DX 8955, p. 1; Plaintiff's Admissions, Set II, ¶ 561.1; Plaintiff's Admissions, Set IV, ¶ 52.1.) The 705, announced in October 1954 and first delivered in 1956, was between two and three times as fast as the 702 depending on the application. (Hurd, Tr. 86378; DX 8956.)

Taking advantage of its work on SAGE, IBM used magnetic core memories in both the 704 and 705. (Hurd, Tr. 86377, 86529-32; E. Bloch, Tr. 91850.) In announcing the 704, IBM described it as "the first large scale commercially available computer" to employ magnetic core main memory.** (DX 8955, p. 3.)

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* The 704 represented an approximately 20-to-1 speed improvement over the UNIVAC I. (Plaintiff's Admissions, Set IV, ¶ 65.1.)

** As discussed above, the first use of large scale magnetic core memory was on SAGE, which became operational in early 1955. (Hurd, Tr. 88171-72, 88212.) By the time of the 704, some other computers used (or were announced with) small-scale core memories. For example, MIT's one-of-a kind Whirlwind and the RAND Corporation's one-of-a-kind JOHNIAC had some core memory, as did RCA's BIZMAC computer, which was first delivered to a customer in 1956, the year after the 704 was first delivered. (Beard, Tr. 8657-58, 8700-01; Morse, Tr. 30963; Crago, Tr. 85961; Hurd, Tr. 86374, 88156, 88169, 88171-72, 88213; PX 6088, p. 5) However, none of those computers had core memory of the capacity eventually available on the IBM

Hart described the 704, with its use of core memory, as a "major technological improvement." (DX 3753 (Tr. 80192).) Perlis characterized the 704 as a "creative masterpiece" (PX 299):

> "The 704 welded together some separate technologies, magnetic core tecynology [sic], vacuum tube technology [and] mechanical hardware for peripherals into one very excellent computer that in effect brought several important segments of American industry into the computer world: the aircraft industry, the oil producers, some of the chemical firms all came into computing at about the same time via the 704, and they all developed together, they developed . . . certain standard approaches to using computers together that had an enormous impact on the entire field." (Perlis, Tr. 1876.)

According to Professor Perlis, the 704

> "represented the first introduction of magnetic core technology into a commercial machine, to the best of my knowledge anyhow, and it provided a machine for that time of great speed that could be used in science and engineering problems. It seemed to fit very nicely into the use patterns and needs of an extremely large segment of the user population at that time and in effect, it defined pretty well what one meant by scientific and engineering computations in the United States in the period of years, when it came out in the middle fifties and on." (Tr. 1997-98; see also Case, Tr. 72345-47.)

The 704 and 705 continued a bifurcation in IBM's 700 series product line between computers, like the 701 and 704, thought to be oriented more towards scientific applications, and the 702 and 705, thought to be oriented more towards business applications.

704, which had one million bits of core. (Hurd, Tr. 88216; E. Bloch, Tr. 91529.) In 1953 Jan A. Rajchman, an RCA scientist who did considerable research on core memories in the early 1950s, wrote that the step from small-scale core memories (with tens of thousands of bits) to core memories with a million bits would "require great innovations in construction techniques and still further improvements in magnetic switching". (PX 6091, p. 16.) IBM manufactured all the cores used in the 704 and 705. (E. Bloch, Tr. 91529.)

(PX 5952 (Tr. 85606-07).) Both the 704 and 705, however, could handle both business and scientific applications and were used for both by customers. Withington, for example, estimated that some customers used the 704 up to 50 percent of the time to perform business applications, despite its "scientific" orientation. (Tr. 56894; see also Case, Tr. 72375-76, 78191-92.) Some examples from the record show the diversity of applications for which the 704 was used:

(a) North American used a 704 for payroll and cost accounting applications, as well as for making scientific engineering calculations in connection with the design of a new aircraft. (Hurd, Tr. 86543-49.)

(b) General Electric's Turbine Division used a 704 to aid in turbine design, as well as for inventory control of turbine parts. (Id.)

(c) John Jones testified that CEIR acquired a 704 for its service bureau operation, and that one of his jobs had been to develop subroutines "which made it quite easy to get decimal and alphanumeric information [generally associated with "business" applications] into and out of the machine". It became "obvious" to him at that time that a binary machine, thought to have a scientific orientation, could handle decimal and alphanumeric information "perfectly well". (Tr. 78731-33.)

(d) General Motors used a 704 primarily for a wide variety of engineering and scientific computations, but it was also used by its operations research group to develop prototype systems for the solution of business problems. (Hart, Tr. 80206-07.)

(e) The Savannah River Laboratory used a 704 to do both scientific and administrative applications, including "reactor calculations, experimental physics, criticality calculations and a library processing application." (H. Brown, Tr. 82968.)

(f) Union Carbide's Nuclear Division, which operated the Oak Ridge National Laboratory for the AEC, computerized some of the "business functions" of the Carbide General Accounting & Finance Division on an IBM 704 in the late 1950s and in the 1960s added material management, payroll, accounting and general ledger. (Plaintiff's Admissions, Set IV, ¶ 140.0-.1.)

(g) The White Sands Missile Range used an IBM 704, along with two Electronic Associates analog computers, to make one of the first large scale hybrid computers ever built. (Plaintiff's Admissions, Set II, ¶ 765.9-.11.)

(h) The U.S. Weather Bureau's General Circulation Research Section bought time on IBM 704s installed at the Joint Numerical Weather Prediction Unit and the National Bureau of Standards to run "primitive equation models" for meteorological studies. (Plaintiff's Admissions, Set II, ¶ 561.2-.7.)

The 705 was also used for a variety of business and scientific applications:

(a) Westinghouse used a 705 for "the engineering design of transformers, and from the engineering design exploded the application into bills of material preparation which instructed the shop floor people how to manufacture a transformer. . . ." (Rodgers, Tr. 16844.) In addition, Westinghouse used the 705 for payroll, cost accounting, check processing, inventory control and accounts payable and receivable applications. (Rodgers, Tr. 16844-45.)

(b) Harvard used a 705 to perform financial calculations for the administrative department and to perform calculations in the field of particle physics. (Hurd, Tr. 86547.)

(c) The Air Force Logistics Command used 705s (decimal machines) and Univac 1103s (binary machines) to perform the same principal application--"inventory control". (J. Jones, Tr. 78733, 78773-75; see also Case, Tr. 72375-76.)

The IBM 704 and 705, like other computers marketed in the mid-1950s, did not have operating systems. Donald Hart of General Motors described the problems of using computers in the early 1950s before operating systems were developed:

> "[W]ith the 701 it was necessary to schedule people to the computer one at a time to read in the cards at the card reader, wait for the computation to complete, print out the results, and then log off and let the next person approach the machine to repeat that process.
>
> "There was an inefficiency involved in that because the speed of the machine far exceeded the speed of the person who was trying to use it." (Tr. 80213.)

To deal with this problem, efforts were undertaken to develop an "operating system" which would provide "an automatic mechanism via software for executing one job after another without operator intervention". (Hart, Tr. 80213; see Perlis, Tr. 1848.) General Motors and North American Aviation jointly developed one of the first operating systems for use on their IBM 704s. (Hart, Tr. 80213-14.) Their operating system "quadrupled the throughput of the 704 computer by eliminating several steps of manual handling". (_Id._)*

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* In the mid-1950s users of IBM 704 computers formed one of the first users groups, SHARE. SHARE's goal was "to provide a forum by which these people could get together and engage in joint planning and to share the process of preparing for this new equipment". (Hart, Tr. 80134.) Through SHARE, IBM users influenced IBM's product development. For example, in the late 1950s, SHARE members began jointly to develop an operating system called SOS, for "SHARE Operating System". (Weil, Tr. 7220; Case, Tr. 73152.) At SHARE's request, IBM took over further development of SOS and in the early 1960s released IBSYS, an operating system for the 7090/7094 series of computer systems. (Weil, Tr. 7220; Case, Tr. 73152.)

The Department of Justice itself has recognized the importance of user groups in the growth of the computer industry. Writing in 1966, Donald Turner, head of the Antitrust Division, took note of the "widespread establishment, sponsorship and universal acceptance of joint user groups to facilitate the exchange of programs and algorithms"in the 1950s and early 1960s. He said that those groups had contributed to making "almost all basic ideas in computer programming . . . available openly to all computer users". (DX 9110.) Other user groups formed in the 1950s included Guide (Welke, Tr. 17360) and USE. (Welke, Tr. 17361; Schmidt, Tr. 27223.)

11. <u>FORTRAN.</u> John Backus of IBM was responsible for the development of FORTRAN, an algebraic, high level programming language developed initially for the 704 and aimed at the solution of engineering and scientific problems.* (Fernbach, Tr. 519-20; McCollister, Tr. 11040; Case, Tr. 72963-64, 72973-74; Hart, Tr. 80189 (DX 3753), 80214-17; Hurd, Tr. 86378-79; Plaintiff's Admissions, Set II, ¶ 836.0.) Introduced in 1957 (Plaintiff's Admissions, Set II, ¶ 836.1), FORTRAN was the first high level language compiler to be produced (Case, Tr. 73021-23), and has been described as an "extraordinarily important development" and a "major advance"

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* There are three levels of programming languages: machine level, assembly level, and higher level. Machine level language is "the very basic language of the computer, basic ones and zeroes, and it is the instruction level of the computer when it is ready to execute the programs". "There is a one-to-one relationship between machine level and assembly level, but [assembly level] is a more convenient language for describing the instructions that you want the computer to process". (Goetz, Tr. 17651.) "Assembler [sic] language is a mnemonic language representing on a one-for-one basis the machine language itself. The language that the computer executes is machine language. Assembler is a programming language". (Enfield, Tr. 19948-49.) A high level language is a programming language which is more like English than is machine language, but is not directly executable by a computer. A program written in a high level language is translated by a special program called a compiler into machine instructions that the computer then uses to do its work. (Perlis, Tr. 1349, 1352; Spangle, Tr. 5124; Case, Tr. 72957; Hurd, Tr. 86408.) High level languages are also called machine independent languages since, given suitable compilers, programs written in those languages can be run on machines of different designs and different architectures and built by different manufacturers. (Case, Tr. 73016, 73019.) Withington testified that:

> "70 to 80 percent of all the programming, or, more specifically, lines of code for programs, are written in higher level languages." (Tr. 57676-77.)

(Perlis, Tr. 1857, 1973), an "enormous contribution" (Gomory, Tr. 98322-23), a "major technological improvement" (DX 3753 (Tr. 80192)), "an important innovation" (McCollister, Tr. 9401), an "outstanding contribution" and an "enormous advance".* (Palevsky, Tr. 3259, 3262.) "Mr. Backus has been given many industry awards for that innovation" (Case, Tr. 73021-22), including the National Medal of Science from President Ford. (Gomory, Tr. 98322-23.)

FORTRAN was an "enormous advance" in a number of ways:

First, FORTRAN made programming easier and enabled many more people to use computers. For example, prior to FORTRAN, General Motors Research Laboratories

> "had been attempting to have engineers and scientists learn to write programs, their own programs for discussion [sic] on the computer. With the types of programs that were available on the 701 and initially on the 704, this was difficult. We are dealing with some form of an Assembly language or an interpretive system which required a great deal of attention to detail, it required pretty much that the person writing the program become a computer expert.
>
> "A few of our users managed to do this, but many others found that this was too difficult a hurdle to get over and required the services of a professional programmer to write their programs.
>
> "We were looking for a way by which we could in fact move this program development process more out into the hands of the users and FORTRAN provided us

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* Professor Perlis described the development of FORTRAN, a "creative masterpiece" (PX 299), as requiring a "major effort":

> "FORTRAN, its 25,000 lines of code when it was built, was an immense system, and the fact that it worked was a real tribute to the people who built it." (Perlis, Tr. 1887.)

> with the potential opportunity to do this." (Hart, Tr. 80215-16.)

McCollister testified that FORTRAN

> "made it easier for the person with a problem to solve to write down the solution which he wished the computer to make of that problem, it saved time and effort on the part of the person who was writing the program in FORTRAN." (Tr. 11040.)

Professor Perlis testified that with the development of FORTRAN, as well as other programming languages developed later, the size of the population competent to use computers was increased by "an enormous factor." (Perlis, Tr. 1999-2000.) FORTRAN, he said, provided engineers and scientists "with a language that was directly attuned to their abilities in the way they thought about problem-solving"; "they found FORTRAN to be just what they wanted for expressing the problems that they had in mind". (Perlis, Tr. 1857.) FORTRAN, together with early operating systems, facilitated the development of an "open shop", where a computer user could "do his own program independent of the professional programmers associated with the computer installation". (Hart, Tr. 80216) The user could "begin using computer services without the necessity of becoming a trained computer programmer". (Case, Tr. 73023.)

Second, by making programming faster and easier, FORTRAN made it less expensive. At General Motors, for example, "FORTRAN . . . decreased programming time by a factor of 5". (DX 3753 (Tr. 80189).)

Third, FORTRAN facilitated cooperation and information exchange among computer users. According to Professor Perlis:

> "[FORTRAN] formed a kind of glue that brought together large numbers of people from different industries who used the computer for different purposes, who now in a sense could almost speak to each other in common language.
>
> "Although they didn't speak to each other in FORTRAN, they spoke to each other about what they did in FORTRAN, and also, I think, FORTRAN . . . gave an enormous impetus to IBM, because FORTRAN, when it came in in 1956 was associated with IBM and with IBM computers." (Tr. 1857.)

Although FORTRAN was originally intended for scientists and engineers, Case testified that

> "other people have used the FORTRAN language for a wide variety of applications. There are payroll programs written in FORTRAN, there are accounts receivable programs written in FORTRAN, there are process control programs written in FORTRAN, indeed, I am not aware of any major application or any significant application area which has not had application programs for that area written in the FORTRAN language. . . . [T]oday more FORTRAN programs are written for business-oriented applications than are written for science and engineering kinds of applications." (Tr. 72973-76, 72985-86.)*

FORTRAN was widely accepted by users, and beginning in approximately 1958, other computer manufacturers began to develop FORTRAN compilers.** (Perlis, Tr. 1973, 2000; McCollister, Tr. 11309; Case, Tr. 72974.) That development had a further benefit for

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* Professor Perlis testified:

> "I think in many areas FORTRAN is used . . . as the language vehicle for writing every program in any area whatsoever. . . . It depends on the particular installation but [FORTRAN] certainly . . . has been used for all past aspects of computing, including artificial intelligence, business processing, et cetera." (Tr. 2000-01.)

** FORTRAN was so widely accepted and used that it became the first national standard programming language in 1966. (DX 13656; DX 13655.)

users in that they could then take a FORTRAN program running on an IBM 704, for example, and transfer it to a different computer (made either by IBM or one of its competitors) with, in many cases, very little difficulty.* (Case, Tr. 72971-72.) FORTRAN is still one of the most widely used higher level languages. (Perlis, Tr. 1973, 2000-01; Case, Tr. 72974; Hart, Tr. 80216-17.)**

12. As Hurd testified, the "development and installation of the 704, 705 and 650 finally ended the IBM debate . . . as to

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* Weil testified, for example, that GE was "relatively successful in converting user programs from the [IBM] 7094 and 7090 to [GE's] 600 line" in the mid-1960s:

> "[G]enerally speaking, the users with what software aids . . . we provided them were able to convert their applications.
>
> "Now we were helped in this by a very deliberate making of our FORTRAN compiler compatible with the FORTRAN language on the 7090 and 7094 and FORTRAN was very widely used in this class of application at that time.
>
> "So FORTRAN's applications were recompiled and executed on our system with relatively little difficulty". (Weil, Tr. 7037, 7015.)

** Following the development of FORTRAN, IBM began to develop COMTRAN, a higher-level language which would be oriented toward business, rather than scientific problems. (Withington, Tr. 56512-16.) At about the same time, however, a group of users, led by the Department of Defense, decided to develop a problem-oriented, but machine-independent common language for business problems. (DX 3717, p. 1.) The project was sponsored by the Department of Defense, and in May 1959, the Department convened a conference to develop such a language. Although many manufacturers attended that conference, more than half of those attending were users or consultants. (DX 3727, pp. 4-5.) The group adopted a name, CODASYL (the Committee on Data Systems Languages) (DX 3717, p. 1), and developed a higher level language called COBOL (Common Business Oriented Language). COBOL specifications were published by the Department of Defense in 1960 and again (with clarifications and corrections) in 1961. (J. Jones, Tr. 78856-57, 78864-65; DX whether IBM should enter the computer business". T. Vincent Learson, who was named IBM's first Director of Electronic Data Processing Machines in 1954 to coordinate the development of the 705, was appointed IBM Vice President of Sales, reporting to the company's Executive Vice President, Mr. LaMotte, in 1955. Hurd replaced Learson as Director of Electronic Data Processing Machines. (Hurd, Tr. 86379.) Thomas Watson, Jr., who had become IBM's President in 1952 (Tr. 25848), assumed the responsibilities of Chief Executive Officer in 1956.

3719; DX 3720.) COBOL specifications "could be used by any user to write his programs for his applications" and by vendors to develop compilers that would translate "common language program[s] into the specific machine language for the various classes of machines". (J. Jones, Tr. 78868.)

COBOL became one of the most widely used programming languages in the world; it became a national standard in 1968. (J. Jones, Tr. 78870-71, 79681-82; PX 3594A.) User demand for COBOL compelled IBM to abandon its work on COMTRAN. (Withington, Tr. 56512-16.)

13. The IBM 305 RAMAC. In September 1956 IBM announced the 305 RAMAC which it characterized as "a revolutionary new 'in-line' data processing system". (Hurd, Tr. 87274-78; PX 6072.)* The 305 RAMAC was first delivered in 1957. (Hurd, Tr. 86380, 87276; Haughton, Tr. 94861.) It was the first computer system to incorporate a disk drive--one of the most significant innovations introduced into the EDP industry. (McCollister, Tr. 9592; Spitters, Tr. 54313; Withington, Tr. 56494; Case, Tr. 72675-76, 72693-95; Hurd, Tr. 86380-81.) Indeed, the heart of the 305 RAMAC was the 350 disk drive, which could store a total of five million alphanumeric characters. (PX 6072, p. 1.)**

The disk drive was a major innovation because it introduced a new technology that allowed rapid, random access to large amounts of data, thereby making the computer a more effective tool for performing a wide variety of customer applications requiring "immediate access". (McCollister, Tr. 9591; Spitters, Tr. 54313.) Prior to the introduction of the disk drive, tape drives and magnetic drums had been

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* The 305 was a general purpose computer used primarily for business purposes. For example, an Air Force base used RAMAC for supply problems and Caterpillar Tractor used it for inventory control of the parts used in the manufacture of their tractors. (Hurd, Tr. 86380, 86552, 86554, 87275-78.)

** The 350 disk drive was subsequently attached to other IBM computers, including the 650, 7070, and 7074. (Hurd, Tr. 86557-58; PX 1002, p. 2; PX 3982, p. 1849; DX 4769.)

the two principal methods of electromechanical data storage. Drums permitted random access to data, but data could only be stored on the outer surface of the drum's cylinder. By contrast, disk drives increased substantially the "volumetric efficiency" of data storage because data could be stored on the many disks that were, in effect, slices of a drum. (Haughton, Tr. 94862, see also Tr. 94806-07, 94968-69.) Tape drives, of course, permitted only sequential access to data. The 350 disk drive's average access time was 200 times faster than the average access time of tape drives available at that time; where a tape drive would take perhaps a minute to find some particular data, the disk file would access it in a fraction of a second. (Hurd, Tr. 86558-61, 86568-69; see also Rooney, Tr. 12142-44; Navas, Tr. 39674-75.)

In the 350 disk file, data was recorded on and read from fifty disks that were not removable from the disk file structure except perhaps by a customer engineer. Each disk in the 350 measured two feet in diameter, and the whole stack of disks stood two feet high. Recording and reading was performed by means of two heads, one for either side of one disk. The heads were moved from disk to disk by retracting them outside the array of disks and moved linearly along the array until reaching the disk with the desired data and there inserted into the disk stack. (Haughton, Tr. 94807-08, 94859-60.) The heads were moved in these two dimensions by an electromechanical actuator, an IBM innovation. (Haughton, Tr. 94833, 94862.) A single motor drove the pulleys and clutches that controlled the actuator. (Haughton, Tr. 94833, 94892-94.)

Because the RAMAC disk revolved so fast, the head would damage the disk media if the two came in contact. (Haughton, Tr. 94822.) To prevent this, IBM successfully reduced to practice an innovative scheme by which air pressure from a compressor was pumped into the space between the head and the disk to maintain a constant distance ("flying height") between the two. (Haughton, Tr. 94809-10, 94822, 95098.) To illustrate the problem IBM had to overcome, Haughton analogized it to trying to maintain a distance of only four inches between a football field and a two-mile wide disk revolving underneath it. (Tr. 94875-77.)

Metropolis, then Director of the Institute for Computer Research at the University of Chicago, wrote to IBM in 1963 that the

> "development of disk files represents a real triumph for IBM in the computer field. By solving the problem of very large storage capacity with fast access times, IBM has succeeded in combining the virtues of both magnetic tapes and drums and has thus provided a new dimension of possibilities in coping with the ever increasing demands in modern computing." (DX 25.)

Withington described how IBM's disk efforts gave it a competitive advantage over its competitors:

> "[Prior to 1965], alternatives [to disks] were being experimented with, such as particularly magnetic card devices, and also I think no one realized the degree to which the transaction processing mode of use was going to prove popular. I believe only IBM among the major competitors at the time offered an alternative

between magnetic card devices and disk drives, with developments proceeding along both lines. A number of the other manufacturers committed themselves almost entirely to the magnetic card devices, sometimes also using magnetic drums.

"When it became apparent that the class of magnetic card devices was not going to be successful in the marketplace, for reasons of reliability, and that the disk drive was a critical product, many of IBM's competitors were left for a while without a satisfactory option."* (Tr. 56240-41.)

IBM was the leader in developing disk drive technology in the 1950s,** and it was not until "several years after the

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* As described later, during and after the period of the announcement and initial delivery of RAMAC, other companies developed and marketed different kinds of random access auxiliary storage devices. For example, RCA offered a device called RACE, which utilized short strips of magnetic tape, NCR offered a device called CRAM, which recorded information on magnetic cards, and Sperry Rand offered a large magnetic drum called FASTRAND. (E.g., McCollister, Tr. 9593-94; Withington, Tr. 56469, 56487, 56511; Case, Tr. 72788-89; Hurd, Tr. 86561-64.) IBM itself developed and marketed the 2321 Data Cell Drive in 1964, which contained up to 10 interchangeable data cells, each containing 200 plastic strips which could be extracted mechanically and wrapped around a cylinder to be accessed like a magnetic drum. (Withington, Tr. 56468; Case, Tr. 72786-88; DX 912-A, pp.1,2,9.) Ultimately, none of these products was commercially successful, in part because of poor reliability. (Withington, Tr. 55958; Case, Tr. 73536; Hurd, Tr. 86561-64.) Withington testified that Data Cell, RACE and CRAM were major product failures. (Tr. 56468-69, 56511, 58534.) He testified that if he had been advising Sperry in the early 1960s, he would have advised Sperry to "[d]rop [FASTRAND] and get on with competitive magnetic disk drives as fast as possible". (Tr. 56487.) Withington believed that Sperry's not moving immediately to disks had a substantial effect on Sperry's marketing of general purpose computer systems. (Id.)

** Although there was other experimentation with random access disk devices, none was marketed commercially in this timeframe. (Haughton, Tr. 95109-12, 95132-33.)

RAMAC was first delivered to customers" that IBM's competitors provided disk drives "comparable in performance or reliability to the RAMAC" (Hurd, Tr. 86381)*, and by that time, as will be discussed later, IBM had introduced additional improvements to the disk drive, including the first removable disk pack.**

Prior to the introduction of the disk drive, real time applications were only feasible on computer systems such as SAGE, which would not have been a practical or effective answer for the ordinary user. (Beard, Tr. 8996-97.) The disk drive--especially after innovations which IBM introduced with its second generation disk drives--made transaction and other types of on-line processing feasible for EDP customers. (McCollister, Tr. 9591; Withington, Tr. 56246-47, 56253-54.)

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* In fact, it could be said that IBM's competition did not even metch RAMAC. Bryant was the second company to deliver a disk drive. (Ashbridge, Tr. 34865.) It, like RAMAC, was a fixed disk. (Ashbridge, Tr. 34866.) But it had "severe problems"; users had the problem, for example, of poor reliability. (Beard, Tr. 9009-10; Withington, Tr. 56494-95.)

** IBM has been from the start the technological leader in disks. (Hindle, Tr. 7452; Case, Tr. 72764-65; Haughton, Tr. 95088-89.)

14. IBM's 1956 Consent Decree. On January 25, 1956 IBM consented to the entry of a Final Judgment "before any testimony has been taken . . . and without trial or adjudication of any issues of facts or law" in an action commenced by the United States on January 21, 1952. The Final Judgment provided, in part:

(a) Users and prospective users of IBM tabulating and EDP machines offered by IBM for lease and sale were to be given "an opportunity to purchase and own such machines at prices and upon terms and conditions which shall not be substantially more advantageous to IBM than the lease charges, terms and conditions for such machines" (Part IV, ¶ (a));

(b) IBM was to offer (i) to sell to the lessee of any IBM tabulating or EDP machine that machine at a formula price which would decline with each year of the machine's age (Part IV, ¶ (c)(1)); (ii) to sell new standard tabulating and EDP machines manufactured and offered for lease or sale at a price having "a commercially reasonable relationship to the lease charges for such machine" (Part IV, ¶ (c)(2)); and (iii) to sell any new special purpose tabulating or EDP machine to the user for whom it was designed and produced by IBM at a price having "a commercially reasonable relationship to the lease charges for such machine" (id.);

(c) IBM was enjoined from acquiring any used IBM tabulating or EDP machine otherwise than as a trade-in or a credit against an account receivable (Part V, ¶ (a)) and was ordered "to solicit . . . from dealers in second-hand business machines orders for the purchase of any [such] used IBM" machines so acquired, subject to a price limitation (Part V, ¶ (b));

(d) IBM was (i) "to offer to render, without separate charge, to purchasers from it of tabulating or electronic data processing machines the same type of services, other than maintenance and repair services, which it renders without separate charge to lessees of the same types of machines" (Part VI, ¶ (a)); (ii) "to offer . . . to maintain and repair at reasonable and nondiscriminatory prices and terms IBM tabulating and electronic data processing machines for the owners of such machines"* (Part VI, ¶ (b)); and (iii) to offer to sell repair and replacement parts to owners of, or persons engaged in maintaining and repairing, IBM tabulating or EDP machines (Part VI, ¶ (c));

(e) IBM was enjoined for 10 years from entering into any lease for a standard tabulating or electronic data processing machine for a period longer than one year, unless the lease was terminable after one year by the lessee upon no more than three months' notice (Part VII, ¶ (a));

(f) IBM was enjoined from "requiring any purchaser of an IBM tabulating or electronic data processing machine to have it

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* IBM was not, however, required to maintain such machines if they had been altered or connected by mechanical or electronic means to another machine "in such manner as to render maintenance impractical". (Part VI, ¶ (b).)

repaired or maintained by IBM or to purchase parts and sub-assemblies from IBM" (Part VII, ¶ (c));

(g) IBM was enjoined from requiring any lessee or purchaser to purchase tabulating cards from IBM (Part VII, ¶ (d)(1));

(h) IBM was enjoined from "engaging in the service bureau business except on a nondiscriminatory basis for the Service Bureau Corporation and for service bureaus operated by other persons" (Part VIII, ¶ (a));

(i) for five years from the date of the Final Judgment IBM was to provide an opportunity to obtain training in repair and maintenance to anyone (other than employees of other equipment manufacturers) engaged or proposing to engage in the repair and maintenance or distribution of IBM tabulating or EDP machines (Part IX, ¶ (a));

(j) IBM was to grant "unrestricted, non-exclusive license[s] to make, have made, use and vend tabulating cards, tabulating card machinery, tabulating machines or systems, or electronic data processing machines or systems under, and for the full unexpired term of, any, some or all IBM existing and future patents" (Part XI, ¶ (a));

(k) IBM was enjoined from suing "any person for acts of infringement of existing patents alleged to have occurred prior to the entry of [the] Final Judgment except by way of counter-claim in any action brought by any person against IBM" (Part XII);

(l) IBM was enjoined from engaging in any agreement or plan with any other manufacturer, seller, distributor or repairer of tabulating and EDP machines or systems to divide sales or manufacturing territories, allocate markets among manufacturers or limit import or export of tabulating or EDP machines or systems (Part XV, ¶ (a)); and

(m) IBM was enjoined from conditioning the sale or lease of any standard tabulating or EDP machine upon the purchase or lease of any other standard tabulating or EDP machine (Part XV, ¶ (b)). (U.S. v. IBM, 1956 CCH Trade Cases, ¶ 68,245 (S.D.N.Y. 1956))

In light of the present litigation, two parts of the 1956 consent decree are of particular interest. First, apparently recognizing the value of the customer education, software and related support which IBM provided without separate charge to lessees, the Department of Justice required IBM to provide the same types of services, also without separate charge, to purchasers. Second, the requirement that IBM sell its EDP products as well as lease them led later to the growth of the computer leasing companies.* (See Friedman, Tr. 50384-85.)

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* The record also discloses that the plaintiff does not assert that IBM has violated the consent decree. (Tr. 13037; Tr. 36957-59.)

15. The IBM 709. The IBM 709 electronic data processing system was announced on January 2, 1957 and was first delivered to customers in 1958. (Hurd, Tr. 86382-83; PX 4714.) The announcement described the 709 as having "speed and flexibility" which made it "outstanding in the processing of large-scale scientific, engineering, management, and business problems". (PX 4714, p. 1.) The 709 was approximately three times faster than its predecessor, the 704. (Case, Tr. 72526-27.) It was also program compatible with the 704; "existing 704 programs" could "be run on the 709 without alteration, except for changes in input-output routines and floating point overflow-underflow". (PX 4714, p. 2.) In addition, the 709 offered magnetic tape interchangeability with the tape equipment used on the 704. (Id.)

The 709 was the first computer to use a channel, a device IBM patented.* (Perlis, Tr. 1844, 1998-99; Case, Tr. 72381, 72704; Hurd, Tr. 86408.) Channels were described by Perlis as devices "for linking together the main core storage or memory storage of the computer with the auxiliary storage of the machine". (Tr. 1998.) Channels allow "input-output and computing to proceed in parallel". (Perlis, Tr. 1844; PX 4714, p. 4.) According to Case, a

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* "The SAGE computer used an input/output break system, which was a forerunner of the modern-day channel." (Crago, Tr. 85978.)

"channel, together with the main memory that it works with, is something like a staging device that enables the relatively slower peripheral devices to put information into main memory which is not yet going to be used by the processing element but later will be needed by the processing element. The channel allows that relatively slow transfer to occur at the same time that the CPU is processing other work which has previously been transferred into main memory." (Tr. 72381.)

The channel was described by Perlis as being "to all intents and purposes a computer" (Tr. 1998); it performed processing that previously had been performed by the main CPU. (Enfield, Tr. 20797; J. Jones, Tr. 78714-16, 79055-61; DX 854, p. 2.) The channel increased the speed with which applications could be performed. (Hurd, Tr. 86382.) Because the channel allowed the 709 to read, write and process data simultaneously, it cut in half the time necessary to perform typical file maintenance applications (PX 4714, p. 4); this encouraged, and made more desirable, the development of operating systems to schedule and coordinate the parallel operations. (Perlis, Tr. 1844, 1846-49.) Because channels greatly increase the efficiency with which a computer can be used, they are a part of most modern computer systems. (Perlis, Tr. 1848-49; Case, Tr. 72704.)

The 729 magnetic tape unit was another innovative product introduced with the 709. The 729 allowed for the first time in EDP applications nearly immediate validity checking of data written on the magnetic tape. This was accomplished by means of a two-gap head which wrote in the first position and read in the second. (Hurd, Tr. 86382; PX 4714, p. 1; see also Plaintiff's Admissions, Set II, ¶¶ 810.3, 923.1.) According to Hurd, "[p]rior to the first delivery of the 729 in 1958, in all tape drives . . . it had been necessary to stop the tape and backspace for the purpose of checking or to rerun the whole tape. The dual reading/writing capability of the 729 greatly increased the effective speed and reliability of tape operations." (Tr. 86382.)

Other features announced with the 709 included a large capacity magnetic core storage that had the ability to store the equivalent of 327,000 decimal digits, three index registers, which gave the 709 automatic indexing facilities, a larger and more powerful instruction set, high-speed arithmetic, allowing arithmetic and logic instructions to be executed at approximately 42,000 per second, and automatic floating point arithmetic. (PX 4714, pp. 1-2.)

Withington testified that even though IBM's 709 systems had a "scientific" orientation, they were employed for business data processing "as high as half the time". (Tr. 56891-92.) Hurd testified, for example, that at Oak Ridge, a 709 installed in the accounting department was used for accounting and clerical applications. That same 709 was also used to simulate gaseous diffusion plants. (Tr. 86576-77; see also Case, Tr. 72375-77.)

In 1958, shortly after the 709 was first delivered, transistorized computer systems became widely available. (Norris, Tr. 5611-13, 5733-37; see below.) As a result, the 709 was competitive for only a short period, prompting Withington to classify it as a major product failure "in financial terms". (Tr. 56465.) He reached this conclusion because, "while the 709 was a good design, it was built employing vacuum tubes for at least most of its logic at a time when the transistor was rapidly becoming usable, and IBM was forced to replace the 709 quite quickly with the 7090, which was a transistor machine". (Withington, Tr. 56465; see also E. Bloch, Tr. 91677-80.) The 7090 obsoleted the 709 within two years of the 709's first delivery. (Withington, Tr. 56466.)

16. By 1955-57, IBM was well on the way to transforming itself from a manufacturer and vendor of unit record equipment to a manufacturer and vendor of computer products and services. IBM recognized the importance of computers and decided to concentrate principally on them roughly 10 years before any of the other firms (including Remington Rand) who had been similarly situated in the early 1950s.

IBM's U.S. EDP revenues in 1952 were $30,838,000. In 1957, they were $353,367,000 and by 1963, they had risen to $1,244,161,000. (DX 3811.)

17. Remington/Sperry Rand. The story of how Remington Rand* failed to capitalize on its early preeminent position in EDP is a tale that centers on the lack of direction and attention management gave to the computer business. Remington Rand's management failures were, at bottom, attributable to two errors. First, Remington Rand's management refused to commit, and to risk, sufficient resources in the computer business; and second, to the extent that Remington Rand did commit resources, those resources were often poorly managed and only modestly effective.

a. Remington Rand Lacked Commitment to EDP. The principals of Eckert-Mauchly and ERA had agreed to be

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* On June 30, 1955, Remington Rand merged with the Sperry Corporation and became the Sperry Rand Corporation. The combined revenues of the merged companies were $699 million in fiscal year 1955. (DX 60, p. F-15.) Following the merger, Sperry Rand was in the following businesses, in addition to the computer business:

(a) military equipment for ships, including gyroscopes, instruments, etc.;

(b) radar devices for military purposes;

(c) hydraulic equipment;

(d) farm machinery;

(e) shaving equipment;

(f) typewriters;

(g) office machinery and office equipment; and

(h) microwave equipment. (Eckert, Tr. 966-67.)

acquired by Remington Rand because they felt that it had both the resources and the desire to commercialize (i.e., produce and market) their early EDP products and to push forward with the design, production and marketing of new products. (DX 280, p. 3; DX 7584, Mauchly, pp. 37-38.) In short, they believed that Remington Rand would be able to capitalize on its early leadership position in EDP.

According to William Norris, who joined Remington Rand when it acquired ERA:

> "Remington Rand faltered at the crucial time when it had a chance to take over the computer market. The hesitation was the result of Jim Rand [who was head of Remington Rand in the early and mid 1950s] being too old to be able to carry through on a great opportunity". (DX 305, p. 1.)*

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* John W. Lacey, Vice President for Corporate Development of CDC, described James H. Rand as "an autocratic, iron-willed manager" who "never really understood the business". He also complained of Rand's "lack of adequate financial support". He continued:

> "Around the middle of 1955 Jim Rand was about to retire and he sold out the business of Remington Rand to the Sperry Gyroscope Corporation whose President was Mr. Vickers. Shortly after the acquisition Jim Rand retired and Marcel Rand, his son, became the President of the old Remington Rand organization within Sperry. Marcel Rand was inadequate to the task and never gained enough self-confidence to be an effective manager." (DX 280, pp. 3-4.)

In his testimony Norris agreed that Remington/ Sperry Rand was "unable to recognize the extent of the commitment that was necessary to the computer systems business to make it successful", failed to make the "financial commitment that was necessary," and failed to "commit the time of the senior management of the Corporation in order to solve the problems that were involved in designing and manufacturing and marketing computer systems at that time". (Tr. 5721-22.) In addition, Sperry was handicapped further by an "unwillingness to take risks" in their EDP business (Norris, Tr. 5846-47), a course which Norris stated could mean (as it did here) "being too late in the marketplace with a new product". (DX 284, pp. 4-5.) In Norris' view, IBM was "fortunate" and "luck[y]" that Sperry "faltered" when it did and "didn't do enough" to respond to emerging competition from IBM. (DX 305, p. 1; Tr. 5722-23.)

Henry Forrest who, like Norris, joined Remington Rand when ERA was acquired by it (DX 13526, Forrest, pp. 43-44) and who was its liaison representative with customers in the Washington, D.C., area and who was involved with Remington's (earlier, ERA's) 1100 series computers (Id., pp. 43-45), testified that, while the 1103 and its successor, the 1103-A, met with success in the marketplace "to the extent that the company supported it", there "could have been a more resounding success had there been more properly supported facilities, more investment in marketing and more over-all support of the program to cause more machines to be sold". (Id., pp. 90-91.) Forrest testified that Remington Rand

> "did not mount an adequate sales effort, and did not choose to create the kind of organization that [had] all the parts--such as support people, the manufacturing facilities--to meet the market that then existed for that class of high technology machine". (Id., p. 91.)

Moreover, Remington Rand failed to provide available resources for ongoing research and development work; it failed "to invest in the market, if you will, and plan ahead for the kind of market that was then clearly evident". (Id., pp. 98-99.)* According to Forrest, in the 1950s "you had to keep pushing away at research and development expense, engineering expense, and associated costs", because the state of the art was constantly expanding; a computer such as the 1103 or 1103-A (which Forrest thought were "the world's best machines" when they were introduced in the early 1950s (id., p. 98)) would soon be obsoleted by something else. (Id., pp. 100-01.) According to Forrest, it was not because of lack of available resources that Remington Rand did not support

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* Forrest described evidence of the "market" then evolving as comprising not just "isolated conversations, ones and twos, but . . . a groundswell of computer using need generally . . . certainly in the Government and it would appear at that time a need in the industrial and commercial areas that would follow . . . we had no strain in selling our wares". (DX 13526, Forrest, pp. 98-99.)

its computer business: "[T]hey had the resources to do the kind of respectful program that I would have wanted them to do" but "they chose not to put proper moneys in the Univac Division". (Id., pp. 101, 103-04.)

In Forrest's view, Remington Rand "should have made a timely go decision at the same time that IBM did and should have supported it"--but they did not. (Id., p. 104.)

Dissatisfaction with Remington/Sperry Rand's management, and its lack of commitment to EDP, was not confined to the Minneapolis/St. Paul, ERA-related group. In Philadelphia, within the Eckert-Mauchly group, Dr. John Mauchly was complaining about Remington Rand's failure to capitalize on the UNIVAC I. Mauchly, who wrote that in 1951-53 it was "a gamble . . . whether any UNIVAC System would ever be sold to a commercial customer", noted that Remington Rand exercised "extreme caution in expenditures for UNIVAC sales and promotion." (DX 7597, p. 4.) Discussing the shortage of qualified personnel in Remington Rand's computer division, Mauchly stated:

> "Back of almost any superficial reason seems to be the fundamental one that Remington Rand has not been willing to pay sufficient expenditure for any phase of the electronic computer sales program." (DX 7597, p. 2.)

Similarly, Mauchly wrote in approximately 1954:

> "Month after month, from 1950 up to the present, there have been countless problems which have reinforced the basic theme, that we are suffering serious losses of efficiency and consequently not giving IBM all the competition we

should give them, as a result of all sorts of efforts which try to save a dollar and result in wasting a hundred dollars." Id., p. 6.)

As to whether there was a commitment by Remington Rand to expanding the marketing of computers, Mauchly later testified:

"I think I saw a lot of effort from time to time, but I'm not sure I could describe them as a commitment. In other words, the efforts were not well coordinated or definitely stated as the goal which was being pursued in a rather sensible way, instead it seemed as if they were random thrusts." (DX 7584, Mauchly, p. 34.)

Richard Bloch, who was head of Raytheon's computer division through 1955, attributed Remington Rand's loss of EDP leadership to IBM in the 1953-55 timeframe to management. Remington Rand was less dedicated to the EDP industry than IBM, and it was less effective in organizing those resources it chose to apply. (R. Bloch, Tr. 7742-43.)

H. Dean Brown described DuPont's (Savannah River Laboratory) choice between UNIVAC and IBM equipment in 1956 as follows:

"The first general purpose electronic digital computer system installed at Savannah River was the IBM 650, which was installed in 1956. . . . I was part of an evaluation group of four people who selected [that system] . . . .

" . . . The evaluation group rejected UNIVAC for three reasons:

(a) the performance of the IBM computer systems we were considering was better in terms of programming ease, reliability and the maintenance that IBM provided;

(b) UNIVAC as an organization lacked commitment to the computer business; and

(c) we at SRL [Savannah River Laboratory] wanted to make use of the ability of IBM representatives, who impressed us with their understanding of our problems and their willingness to work with us. My contacts with those IBM employees were the basis of my conviction that IBM had the commitment to computers which UNIVAC lacked." (Tr. 82963-65; see also J. Jones, Tr. 79344).)

Examples of the ways in which Remington Rand's lack of commitment to support its EDP operations restricted its growth include: its failure to support the marketing of its EDP products, its failure to support adequately the development of new products and its failure to hire and retain qualified employees.

(i) <u>Inadequate Marketing.</u> Just after Remington Rand bought Eckert-Mauchly, a small group that included John Mauchly drew up a plan for training sales personnel in electronic computer equipment. Mauchly described the subsequent events as follows:

> "We wanted to have about a dozen persons with sales and business systems background selected and trained . . . as a nucleus for an expanding sales program. If this had been done, then we would have been ready in 1951, when the Census Bureau UNIVAC was in operation and others were being made ready for delivery, to capitalize on the five-year lead which we then had over IBM. . . . However, our plan for training a sales staff at that time was brushed aside with one comment--this would be entirely too expensive." (DX 7597, pp. 2-3.)

Mauchly estimated that Remington Rand might have been able to sell an additional 15 UNIVAC I's (at approximately $1 million each) if it had spent the $300,000 necessary to implement this training program--"a quite reasonable price to pay for the immense lead which this would represent over our competitor". (Id.)*

Remington Rand also failed to retrain its punch card salesmen to market UNIVACs. Instead, Rand set up a marketing force that Mauchly thought was neither "proper" nor "effective" and that was understaffed. (DX 7584, Mauchly, pp. 27-28.) Moreover, punch card salesmen got no remuneration if they somehow sold a UNIVAC. Indeed, they would lose commissions if a UNIVAC displaced Remington Rand's unit record equipment. In short, Remington Rand's punch card machine salesmen were given "negative incentive[s]" to sell UNIVACs. (DX 7584, Mauchly, pp. 101-03.) A potentially valuable marketing resource was thereby dissipated.

Mauchly testified:

> "I didn't feel that the Remington Rand management . . . had a very good understanding of what kind of a business they had acquired and . . . of how to market any product which might emmanate [sic] from that business, nor how to manage the business most effectively so as to cause it to answer the needs of a market even if they identified that market.
>
> ". . . .
>
> ". . . [T]he IBM Company was doing what I would call an aggressive job, both in marketing and in development of the things to market, and I felt that the Remington Rand Company was losing a position which was in their

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* Indeed, after UNIVAC I passed the Census Bureau's acceptance test, no advertising campaign took advantge of that fact. Instead, the company took an ad in the Scientific American which told (presumably scientific readers) "how wonderful the UNIVAC was for commercial business problems". (DX 7584, Mauchly, pp. 99-101; for the advertisement, see DX 12610.)

> favor by being unwilling to do some of the things which seemed obvious to us should be done, and sometime [sic] doing things which seemed obvious to us should not be done. . . ." (Id., pp. 97-99.)

John Jones, of the Southern Railway Company, added:

> "[T]here was not, in my view and the view of many others at that time, a strong marketing effort put on by Univac to try and expand and increase this market." (Tr. 79344.)

Jacqueline Johnson, President of Computer Generation, who worked at Univac and GE during the 1950s and 1960s, testified that Univac lost its position as industry leader because it "lacked the ability to market the products that it manufactured" and "lacked the management skills to be able to implement the proper marketing programs". (DX 3979, Johnson, pp. 15-16.)

Remington Rand's lack of support for education of both its own employees and customers in the application of EDP products led John Mauchly to write in 1955:

> "The immense advantage which Remington Rand had over IBM in 1951 has gradually been lost. We are not losing the battle of hardware but the battle of applications research and education." (DX 7596, p. 1.)

Mauchly was critical of Remington Rand's efforts to train its own employees and said a "conspicuous difference between the IBM training plans and those of Remington Rand" had long been evident:

> "IBM has tried to train people in all its branches by sending them to their courses at Poughkeepsie along with customers. We occasionally have representatives from branches attend initial seminars, but so far as I

know, we have done almost nothing to provide a large staff of branch-based people who are familiar with UNIVAC applications and able to advise potential customers, or help actual customers. We have considered this 'too expensive' or 'impractical'. During the last few years IBM has made an intensive effort to provide not one but several representatives in each of their major branches, and they are, in general, requiring persons of mathematics or engineering background, preferring people with advanced degrees. The IBM branch in Philadelphia is hoping to get five or six such people for this area. The men already here in Philadelphia are competent mathematicians who are able to deal with a variety of applications intelligently." (Id., pp. 2-3.)

Elsewhere Mauchly elaborated on the theme that Remington Rand was "losing out to IBM on the broad educational thought":

> "While we look with a somewhat vacant stare at a mathematician and wonder whether or not he would be useful to us, IBM is hiring mathematicians and scientists . . . and giving them carte blanche to work on anything they find interesting. When an engineer at MIT does a master's thesis on a problem involving engineering computations, IBM hires him. We don't even know the computational application exists." (DX 7597, p. 7.)

Mauchly was also critical of Remington Rand's lack of efforts to expand the computer market by educating potential customers. He made the following comments about a speech by IBM's Cuthbert Hurd in approximately 1954:

> "[Dr. Hurd said that] IBM recognizes the need for them to contribute funds toward educational programs in the computer field. . . .
>
> "He went on to say that universities should be trusted to run their training in the best interests of all. . . . He spoke against too much pressure from the industry for vocational courses and in favor of a broad and liberal education.
>
> "[S]uch words mean nothing if not followed up by deeds. However, we know that IBM does follow such words by deeds. In fact, through the Watson Scientific

> Computing Bureau, established many years ago, they have been practicing long in advance of this particular preaching. . . . I reported to you not so long ago the talks now going on between the University of Pennsylvania and IBM, aimed at providing better University training in Applied Mathematics. . . . IBM would not expect any specific commitment from the University in return. The graduates of this Applied Mathematics Department would not be required to do anything for IBM. . . . [However,] a greater demand for computing equipment and a corps of enthusiastic exponents for enlarging the scope for computing activities would automatically be built up. It will make little difference whether all of these graduates insist on using IBM equipment. The main thing is to swell the number of persons who are not only active in the use of computers, but who in turn infect others with the possibilities of application and hence enlarge the computer market." (DX 7597, pp. 17-19; emphasis in original.)

(ii) <u>Lack of Product Developments.</u> Remington Rand's failure to commit adequate resources to its computer business manifested itself in its slowness in developing new and improved EDP products. An example of this shortcoming was the delay in producing a successor to the UNIVAC I.

Soon after first delivery of the UNIVAC I, it "became clear to the engineers" that the UNIVAC I would be greatly speeded up if it had a faster memory. (J. Jones, Tr. 79342; DX 7598, pp. 1-2.) Although the UNIVAC I began to face competitive pressures from IBM computer systems, Remington Rand felt that it could not spare the resources necessary to develop enhancements for the UNIVAC I. Instead, it directed its efforts toward developing a successor system. (DX 7598, p. 1.) As described by Jones, "it was a long time [1957] before the UNIVAC II came out. By that time already more advanced machines were on the market, such as . . . initial models of the [IBM] 705 and the 704". The "initial year to two-year lead Univac had by having a machine that was available and operational before other machines began to appear no longer was a lead. . . . I would say in my view it was many years before Univac really again caught up in the sense of having machines which were of comparable power available to the competition." (Tr. 79344.)*

Richard Bloch believed that by 1953 or 1954, and certainly by 1955, technological leadership in the computer industry had passed from Sperry Rand to IBM. (Tr. 7742.)

In addition to a successor for the UNIVAC I, the Eckert-Mauchly Division also wanted to produce a small computer aimed at a larger number of customers. According to Mauchly, "a lot of the effort [of] Eckert and others in the Philadelphia area was occupied in trying to get a recognition of the fact that smaller computers meeting a larger market was a very important endeavor for the Remington Rand organization". (DX 7584, Mauchly, p. 55.) Rand's management did not strongly support this request. (Id.) Rand's hesitation contrasts unfavorably with IBM's decision

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* Henry Forrest similarly testified that the UNIVAC II was not "a good cost performance . . . machine. I don't think it had the best features of what was required and what was sold then in the market . . . [such as IBM's] 700 series machines." (DX 13526, Forrest, p. 95.)

to back the 650 even before the first 701 had been delivered. (See "The IBM 650" above.)

In 1956--two years after first delivery of the IBM 650--Sperry Rand did deliver a small computer (the File Computer) about which Mauchly testified:

> "[N]o one in Philadelphia had either proposed such a device, or was asked whether such a device should be built, but there were elements in the Remington Rand management who decided that that device was something that they would like to have for the punch card sales people to sell because they were not allowed to sell UNIVAC equipment." (DX 7584, Mauchly, p. 62.)

The File Computer, developed in Minneapolis/St. Paul (<u>id.</u>), was "a medium-priced magnetic drum machine comparable in general nature to [Electrodata] Datatron 205 and the IBM 650". (Withington, Tr. 56479.) According to Withington, the File Computer was a "major product failure" because it was "deficient in price performance . . . partly because its primary file storage device was . . . [a] magnetic drum" and "also because at least part of its programs . . . had to be on external plug boards, which was inconvenient for the users". (Withington, Tr. 56478-79.) A third shortcoming of the File Computer (as well as other Rand computer systems through the mid-1950s) was that the tape drives used metal rather than plastic tape, even though "it became evident as early as 1954 or 1955 that the plastic tape was superior". Metal tapes were the only ones available for the File Computer through 1958. (Withington, Tr. 56488-89.) Mauchly testified that Sperry Rand received "something like 200 orders" for the File Computer. However, it was his belief that there came a time when "they tried to reverse the process, get rid of some of these orders" and therefore only about 100 File Computers were actually delivered. (DX 7584, Mauchly, p. 65.)

Sperry's failure to produce new products extended to software as well as hardware. In 1955 Dr. Mauchly wrote concerning problems in programming:

> "Before Remington Rand purchased Eckert-Mauchly, a considerable fraction of the programming activities at Eckert-Mauchly were in the nature of research.[*] In the early years, it had to be so, because such research was necessary for the development of the UNIVAC System. Unfortunately, the first attempts at a simplified automatic coding system . . . were put aside because of the pressure brought about by the need for various specific demonstrations to potential customers. The partially completed system, known as the short-order-code, has been used by our engineers, but has never been properly exploited or provided with a satisfactory manual which would enable others to use it easily. For five years I have maintained that the completion of the original plans would be of great benefit to us." (DX 7596, pp. 6-7.)

(iii) <u>Loss of Key Employees.</u> It was widely recognized in 1954-55 that because of the complexity of the early computers, the "market for computers [was] limited more by the inability to get trained people than it [was] by the

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* According to Mauchly, in "the computer business . . . research is a gamble; but it is a necessary gamble, in order to have any reasonable possibility of keeping ahead of one's competitors". (DX 7596, p. 6.)

inability to manufacture the equipment". (DX 7597, p. 10.) Yet, throughout the mid-1950s, key Sperry Rand employees were leaving to start their own companies or to go with competitors or users. According to a 1969 Business Week article "heedless budget-cutting, managerial infighting, and a series of wrong-headed decisions forced many of the company's key people to leave. Middle management was gutted, competition strengthened, and many promising marketing and product development projects slowed or stopped." (DX 105.)

William Norris testified that Sperry's failure to focus its concentration and efforts on the EDP business was one of the reasons he left in 1957 to form CDC. (Tr. 6010.) Norris believed that a firm was more likely to be successful in the computer business if it concentrated its resources in that business (as CDC did*). (Id.) Norris had other reasons for leaving Sperry as well, arising in part out of the persistent conflict and lack of coordination among the Eckert-Mauchly group in Philadelphia, the ERA group in Minneapolis/St. Paul and top management, described more fully below.

Norris was not alone in leaving Sperry Rand because of dissatisfaction with the management of its EDP business.

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* As described in some detail below, CDC almost immediately began to earn profits and grew rapidly in the EDP business.

Describing this period several years later John Lacey (who was Vice President for Corporate Development at CDC) wrote:

> "The creative and scientific people of ERA who had participated in the earliest stages of the development of the computer industry and who had such high hopes for their own personal and professional futures became extremely frustrated. After five years with Remington Rand and Sperry Rand and after giving it every bit of professional and management effort that they could muster during that entire period, Norris, Mullaney, Cray, Keye, et al decided to leave Sperry Rand and started Control Data Corporation." (DX 280, p. 4.)

Henry Forrest, who also left Sperry Rand to join CDC, recalled that around this time, people he worked with at Sperry "were talking about trying to still seize an opportunity in the computer business, and when I heard this opportunity talked about, I expressed interest in it". (DX 13526, Forrest, p. 115.) Indeed, he said, the idea of seizing such an opportunity "was a common thought of anybody who was concerned about Remington Rand's lack of forceful position and approach to the computer business". (Id., pp. 115-16.)

The problem of qualified people leaving Sperry Rand's computer business extended to levels beneath top management. John Mauchly complained about his inability to keep or retain qualified people responsible for "pioneer[ing] developments in automatic programming . . . envied by [Remington Rand's] competitors". (DX 7595, p. 3.) In 1954 he wrote:

"[S]ome of the members of [Dr. Hopper's*] staff have already left for positions with users of IBM equipment, and those of her staff who still remain are now expecting attractive offers from outside sources. . . . The Eckert-Mauchly Division has not, however, been able to make offers sufficiently soon enough, or good enough, to prevent the depletion of her staff, because there is no budget allowance in the Eckert-Mauchly Division for such personnel." (DX 7595, p. 1; see DX 7584, Mauchly, p. 71.)

On the shortage of qualified people within Remington Rand, Mauchly wrote in 1955:

"[I]t is a well-recognized principle, followed by Remington Rand as well as IBM, that expert assistance must be given to any customer to ensure that his equipment is properly utilized. Remington Rand has been rendering such assistance, but its ability to do so has been seriously hampered by the lack of well-trained and very experienced personnel. Whenever I have been given the opportunity to comment, I have stated that the Electronic Computer Department has been struggling valiantly to do the best job it could with an extreme scarcity of qualified people." (DX 7596, p.2.)

And:

"Our own Electronic Computers Department has keenly felt this problem which has been accentuated because some of those who are most experienced and best able to train others have been absorbed by companies who have bought UNIVAC Systems and need topnotch people to ensure efficient operation." (DX 7597, p. 1.)

Mauchly felt that persons in his division were not adequately compensated and that Sperry's salaries were low compared to

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* Dr. Grace Hopper headed a group working on automatic coding and program compiling techniques in the Engineering Department of the Eckert-Mauchly Laboratories. (DX 7597, p. 8.) She had a "world reputation" for her work. (Id., p. 9.) She is now a captain in the United States Navy. (J. Jones, Tr. 79342.)

"industry standards", making it difficult to recruit and keep personnel. (DX 7584, Mauchly, pp. 71-73, 112-113; DX 7597, pp. 9-10.)

b. Conflict Among Remington/Sperry Rand's Divisions. Throughout the 1950s Sperry Rand did not integrate its two principal computer efforts (i.e., Eckert-Mauchly and ERA).* They both attempted to pursue the same areas and develop similar products. (DX 280, pp. 3-4.) It also resulted in unnecessary duplication of research, engineering, product development, manufacturing and marketing expenditures which, in turn, raised EDP's demands on the corporation's financial and technical resources. (See DX 8; DX 7584, Mauchly, pp. 18-23.) Mauchly testified about the lack of interaction between Sperry's Philadelphia and Minneapolis computer groups:

> "[F]rom our point of view . . . we would have helped them more than they could have helped us, but I'm afraid they had the same type point of view. They . . . didn't want to pay much attention to what we had to say." (DX 7584, Mauchly, p. 21.)

The effort at integration was "not as effective as it should have been". (Id., p. 19.) As Mauchly testified:

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* Sperry Rand actually had three competing centers of computer development. The third, based at Norwalk, Connecticut, was an outgrowth of Remington Rand's business machine operations. (DX 7584, Mauchly, pp. 16-17, 23; DX 280, p. 3.)

"Well, Eckert and I and other people in the Philadelphia Division made some trips to Minneapolis, and people from Minneapolis and/or Saint Paul came to Philadelphia, but the information exchanged was not as great as it could have been, and the use that was made of the information was pretty minimal." (Id., p. 20.)

Norris described the situation leading up to his 1957 departure as follows:

"I left Sperry-Rand because of turmoil. This turmoil was made up of confusion, indecision, conflicting orders, organization line breaches, constant organizational change, fighting and unbridled competition between divisions." (DX 272, p. 2; see Norris, Tr. 5707-09.)

And Lacey added:

"Rand now had three laboratories in Norwalk, Philadelphia and St. Paul all attempting, essentially, to pursue the same markets and develop similar products. . . . And throughout the years 1953, 1954 and part of 1955 the whole activity with respect to computing in Remington Rand was extremely uncoordinated.

"During this period Eckert-Mauchly developed the Univac I and Univac II Computers. The Norwalk Laboratories while they competed heavily for the necessary financial resources, were not very successful in producing computer products. Constant battles ensued between Philadelphia and St. Paul and these were never really adequately solved." (DX 280, p. 3.)

Sperry Rand's "political" battles continued even after Norris and his associates left to form CDC. Indeed, Eckert believed that as late as 1963 "different diverse groups of Univac act[ing] to protect their own political interests" prevented UNIVAC from developing its product line effectively. (DX 10, p. 1.)

The evidence in this case offers overwhelming support for the conclusion that Sperry Rand lost its early preeminent position in the EDP market because of repeated managerial hesitation and incompetence. In describing this period of Sperry's EDP history, it has been said that Sperry "snatched defeat from the jaws of victory". (DX 105 (a <u>Business Week</u> article dated November 22, 1969); see also McDonald, Tr. 3813; J. Jones, Tr. 79339-44.) The performance of IBM's management was superlative in comparison to the management of Sperry Rand.

18. Other Companies. The record of this case establishes that the extent and depth of IBM's commitment to the EDP business was unique in the mid-1950s. For example, as described in more detail below:

(a) Honeywell's Datamatic Division designed and delivered only one computer system prior to 1958, the D-1000. It produced and marketed approximately 10 of these systems.

(b) General Electric had only one major involvement in the EDP business prior to 1960--ERMA, commissioned in 1956 by the Bank of America to perform a variety of retail banking applications. GE itself recognized later that it failed to capitalize on its ERMA experience.

(c) NCR acquired CRC in 1953 but failed to deliver a new computer system between 1954 and 1959.

(d) RCA's first digital computer, the BIZMAC, was commissioned by the Army and first delivered in 1956. RCA installed only six BIZMACs and did not deliver another computer system until 1959.

(e) Philco delivered several one-of-a-kind computer systems during 1955-57 but failed to announce a commercial computer until 1958.

(f) Burroughs acquired Electrodata in 1956 and by 1957 cumulative installations of Burroughs' small E-101 and the Datatron 205 computer system (comparable to the IBM 650) approximated 200. In addition, Burroughs developed its capacity to produce several computer systems for the military.

(g) Bendix built only two commercially available computer models, the G-15 and G-20, in the 1950s and 1960s. Its computer business was acquired by CDC in 1963.

With the exception of IBM and Remington/Sperry Rand, the preceding companies were the most active manufacturers and vendors of commercial computer systems in the mid-1950s. The brief sketches suffice to establish that as of 1957 none had made a commitment to EDP that came even close to approaching the commitment made by IBM.

IV. THE SECOND GENERATION

19. STRETCH. In the early 1950s IBM had undertaken projects to develop advanced computers at the request of the federal government. SAGE was one such project; another had been NORC, a one-of-a-kind vacuum tube computer which, when it was delivered in November 1954 to the Naval Ordnance Research Department, was the most powerful computer in the world. (Hurd, Tr. 86385-86, Case, Tr. 72255-56; DX 7257, Walker, pp. 15-16.) At the NORC dedication ceremonies in December 1954, Dr. John von Neumann gave a speech describing the importance of NORC and efforts like it to build the most advanced computer possible:

> "The last thing I want to mention can be said in a few words, but it is nonetheless very important. It is this: In planning new computing machines, in fact, in planning anything new, in trying to enlarge the number of parameters with which one can work, it is customary and very proper to consider what the demand is, what the price is, whether it will be more profitable to do it in a bold way or in a cautious way, and so on. This type of consideration is certainly necessary. Things would very quickly go to pieces if these rules were not observed in ninety-nine cases out of a hundred.
>
> "It is very important, however, that there should be one case in a hundred where it is done differently and where one uses the definition of terms that Mr. Havens quoted a little while ago. That is, to do sometimes what the United States Navy did in this case, and what IBM did in this case: to write specifications simply calling for the most advanced machine which is possible in the present state of the art. I hope that this will be done again soon and that it will never be forgotten."*

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* We recognize that Dr. von Neumann's speech was not received

In 1954 the Atomic Energy Commission's Lawrence Livermore Laboratory requested bids to build another advanced, high-speed computer. (Dunwell, Tr. 85528-29, 85555.) IBM was interested in Livermore's request because it wanted to develop a computer which would "stretch the technology and the skills of the IBM company". (Brooks, Tr. 22717.) IBM and Remington Rand were the only firms to submit proposals to Livermore. The Remington Rand proposal was chosen, primarily because of its early delivery date. (Dunwell, Tr. 85528-29, 85555.) To satisfy this contract, Remington Rand ultimately built and delivered its LARC computer. (Fernbach, Tr. 509-10.)*

In 1955, the AEC's Los Alamos Laboratory also expressed an interest in acquiring a high-speed computer. IBM responded by bidding essentially the same computer it had previously proposed to Livermore. This time, in November 1956, its proposal was accepted. The contract called for IBM and Los Alamos to share in the design of the computer, which became known as STRETCH, and subsequently was renamed the IBM 7030. (Dunwell, Tr. 85530-31; Hurd, Tr. 86386-87; see also Fernbach, Tr. 509-10.)

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in evidence in this case. Typed and printed copies were marked as DX 8989 and 8963, respectively, and were offered but not received. We nonetheless rely on the speech because it is a contemporaneous statement by a respected pioneer of the computer business who was familiar with the NORC project. (See also Case, Tr. 72255-56; Hurd, Tr. 86601-02.)

* Ironically, LARC was delivered 27 months late. (Eckert, Tr. 974; Plaintiff's Admissions, Set IV, ¶ 53.4, 82.0(d).)

IBM's goal in designing STRETCH was to "stretch" the state of the art, to produce the best computer possible with the technology and knowledge then available, and "to build the fastest possible machine". (Case, Tr. 74591; Dunwell, Tr. 85736; Hurd, Tr. 86387.) According to Dunwell, the STRETCH design team worked "against the abilities of the IBM Corporation [and] against the abilities of technology" (Tr. 85736):

> "The STRETCH Project involved exploring the unknown and rethinking and redesigning almost every aspect of earlier IBM computer systems." (Tr. 85536-37.)

Among the STRETCH project's specific objectives which had never before been achieved in a general purpose computer were: (a) to offer performance 100 times faster than IBM's then most powerful commercial computer, the 704;* (b) to be equally capable at both data manipulation and computation; (c) to use transistors rather than vacuum tubes;** and (d) to utilize computer-aided design as a development tool. (Hurd, Tr. 86388-90.)

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* Dunwell testified that though IBM had established the goal to improve computer performance one hundredfold, it "had chosen this as a round number, not knowing whether the result would prove to be somewhat less or somewhat more. Our goal related only to the speed with which given problems could be solved . . . not merely arithmetic speed." (Tr. 85538.)

** Shockley, Bardeen and Brattain of Bell Telephone Laboratories invented the transistor in 1947-48. For their accomplishment, they received the 1952 Nobel Prize in Physics.

Bendix, Fairchild, GE, General Transistor, IBM, Motorola, Pacific Semiconductor, Philco, RCA, Raytheon, Texas Instruments, Transistron and Westinghouse were among the early companies that licensed Bell's transistor patents. (Fernbach, Tr. 469-70; Case, The shift from vacuum tubes to transistors marked the beginning of the "second generation" of computer products. (Fernbach, Tr. 459; Case, Tr. 72244-45, 72281; Hart, Tr. 80224; E. Bloch, Tr. 91480-82; Plaintiff's Admissions, Set II, ¶¶ 807, 809.) This transition was expected to be especially difficult because engineers would be forced to redirect their thinking away from the more traditional vacuum tube technology. (Dunwell, Tr. 85536.)* Nevertheless, IBM (along with several other companies at about the same time) thought it was essential to make the switch to transistors because, according to Dunwell:

> "[T]he development of vacuum tube machines [had been carried] about as far as it could go. . . . [L]arger and more complex machines were required for the solution of the problems presented to IBM by its customers, but . . . those machines could not be built at a cost that was acceptable to those customers using vacuum tube machines. . . . IBM laboratory leaders . . . recognized that the transistor was faster, smaller, used less power, avoided cooling problems, was more reliable and was inherently less costly. It was evident to me that a transistor machine would be physically different in every way from

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Tr. 72258; E. Bloch, Tr. 91485-86.) Nevertheless, a great deal of work remained to be done before transistors could be used in computer equipment. As Bloch testified:

> "By 1953 transistors had been used in hearing aids and radios, but not in EDP equipment. The work necessary to design transistor circuits to perform the switching function previously performed by vacuum tubes had not been done, nor were transistors then capable of being suitably packaged and produced in quantity at a low enough cost and high enough reliability to make them a cost-effective substitute for vacuum tubes." (Tr. 91485.)

* Indeed, IBM ultimately prohibited its engineers from doing any work with vacuum tubes, instructing them to use transistor technology exclusively. (Dunwell, Tr. 85528-50; E. Bloch, Tr. 91889.)

early vacuum machines." (Tr. 85527; see also Fernbach, Tr. 470-71; E. Bloch, Tr. 91482, 91678-80; Plaintiff's Admissions, Set II, ¶ 809.3, 809.4.)

IBM recognized that the "cost of developing transistor technology would be enormous". (Dunwell, Tr. 85527.) It chose to enter into contracts with Los Alamos and the National Security Agency in part to receive some independent financing for these high costs and in part to work with a partner who would help "define the characteristics for a high-speed general purpose computer based on the problems which that partner wished to solve."* (Hurd, Tr. 86387; see Dunwell, Tr. 85527-28.) In fact, as discussed below, STRETCH did "set the standard" for IBM's transistorized 7000 series of computers announced beginning in late 1958 as well as contribute to the 360 family of computers announced in 1964 (as will be discussed later in more detail).

IBM accepted significant risks when it signed the STRETCH contract. Specifically, the Los Alamos contract was for only $3.5 million whereas the projected engineering cost of STRETCH was $15 million and the estimated cost of building the first STRETCH machine was an additional $4.5 million. (Hurd, Tr. 86630.) IBM senior management initially objected to the idea of making STRETCH

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* The NSA wanted a computer to perform large-scale cryptography applications. (Hurd, Tr. 86388.) After completing work on an NSA contract to develop computer components, IBM received a contract for a STRETCH system that also included two one-of-a-kind devices labelled Harvest and Tractor. (Dunwell, Tr. 85535-36, 85656-57; DX 8924.) The NSA's STRETCH computer system was installed in 1961 or 1962. (Hurd, Tr. 86388; see Dunwell, Tr. 85939.)

for Los Alamos at a $3.5 million price. Hurd obtained authorization to proceed after pointing out that:

> "Livermore had entered into a contract with Univac . . . for . . . LARC and that machine, although in my opinion [it] would not be as powerful as STRETCH, was priced at $3-1/2 million. And I thought it would be extremely difficult, since Livermore and Los Alamos were two sister laboratories within the AEC, to obtain much more than the $3-1/2 million and [I] also reminded [IBM management] that under [an] agreement given before[,] I had had preliminary [discussions] with Los Alamos about the $3-1/2 million." (Tr. 86632.)

Hurd favored acceptance of this contract because he believed that if STRETCH could be produced successfully, IBM would be able to sell between 20 and 30 machines. (Tr. 86631.)

IBM delivered its first STRETCH computer system to Los Alamos in April 1961. (Dunwell, Tr. 85537.) STRETCH was subject to various types of criticism after it was first delivered. For example, some IBM employees thought the machine failed to meet its design goals (Dunwell, Tr. 85555-56) and IBM even cut the contract price in half for that reason. (Fernbach, Tr. 510-11.) In particular, there was dispute as to whether STRETCH was actually 100 times faster than the IBM 704. (Hurd, Tr. 86390; 86642-51.)*

Another criticism of STRETCH from within IBM was that it cost too much to build. (Dunwell, Tr. 85555-56.) STRETCH, in

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* Dunwell, however, testified that STRETCH did meet its performance goal. He testified that critics misunderstood the goal because they focused on the arithmetic speed of the CPU rather than upon the speed at which problems could actually be solved on a STRETCH computer system. (Dunwell, Tr. 85552, 85740-45, 85797-99, 85883-86.) In 1966, at an IBM Awards Dinner, Thomas J. Watson, Jr. apologized to Mr. Dunwell for earlier criticisms of STRETCH. (Tr. 85831-33.)

1959, was estimated to have cost $25.4 million to develop and one source suggests that IBM's financial losses totaled $40.7 million. (DX 4767, pp. 31, 33; PX 5942.) Such losses appear to have arisen in part from the fact that:

> "IBM was developing componentry that had not previously been used in IBM computers, and at the same time IBM was developing a system design that was different from those of earlier IBM computers. Good system design requires a thorough knowledge of the components which will be used. . . . As [the STRETCH] engineers . . . got into the STRETCH system design [they realized] that the performance of the transistor components would fall below [their] expectations. That was eventually overcome by modifications to the system design, but those modifications made the system design more complex than had originally been anticipated." (Dunwell, Tr. 85550.)

According to Withington, STRETCH taught the computer industry that the complexity of components "was becoming so great as the computers evolved that it was necessary to be more cautious than had been necessary in earlier years in designing and delivering complex central processing units". (Tr. 56464-65.)

Despite these criticisms, there is no dispute that STRETCH was responsible for many advances in the state of the art of computer technology. Fernbach testified:

> "It was highly parallel in structure, in architecture, so that many operations could be performed simultaneously, thus speeding up the machine.
>
> "It set a standard for the entire 7000 series of computers for memory. It had a disk that was extraordinary, that was a very high performance disk drive. The peripherals were far advanced over what had been available at that time." (Tr. 515-16.)

H. Brown testified that:

"STRETCH is one of the most capable and reliable machines that I have ever had the experience to work on." (Tr. 82970; see also Dunwell, Tr. 85741-43.)

IBM reaped substantial technological fallout from STRETCH in terms of both how to organize large-scale machines and how to develop components and incorporate new manufacturing techniques. (Case, Tr. 73606-08; Dunwell, Tr. 85539-49, 85894; Hurd, Tr. 86592-96; E. Bloch, Tr. 91485-89; DX 3171.) Among STRETCH developments incorporated subsequently in IBM's second generation computer systems were SMS component technology, printed circuit cards, and improved back panel wiring. Erich Bloch, Vice President of the Data Systems Division and General Manager of IBM's East Fishkill plant, described IBM's efforts to understand and manufacture semiconductor components in considerable detail. IBM worked not only "to understand semiconductor technologies . . . but also to tool for the manufacture of these devices" in order to improve the reliability and reduce the costs of what "was at that time a novel technology":

"Second-generation EDP equipment manufactured by IBM utilized packaging for discrete components (<u>i.e.</u>, transistors, diodes, resistors and capacitors) called Standard Modular Systems ("SMS"). A complete circuit consisted of discrete components packaged together on standardized cards ("SMS cards"). SMS cards were manufactured by IBM in a standard size and had printed circuit patterns on which the discrete components were mounted. . . .

"SMS packaging was . . . designed at IBM. . . . Discrete component packaging available from other suppliers . . . at the time was not as satisfactory because it had not been optimized for use in EDP equipment. EDP equipment required higher reliability than consumer products using similar or the same components. It required a high rate of production with exact replication and tolerances. . . .

"Among the improvements which resulted from IBM's development and use of SMS packaging were in the areas of uniformity, reliability, serviceability and ease of manufacture. Uniformity of SMS components resulted in savings in engineering design, recordkeeping, cost of purchased and manufactured components and cost of stocking spare parts. Reliability improvements resulted from controlling the manufacturing process for individual SMS circuits, the manufacturing process of assembly and the precise use of the components. Serviceability improvements came about because service personnel were able to become familiar quickly with the limited number of SMS circuits. During the period 1957 to 1960, IBM's SMS innovations in automation of manufacture included the ability to put printed wiring on the circuit card (fully automated by photograph and chemical process steps), automatically to insert components into holes in the card, automatically to solder components to printed wiring (by passing the card over molten solder) and automatically to interconnect socket pins on back panels (by the then recently developed Bell Laboratories technique known as wire-wrap)." (Tr. 91485-89; see also Case, Tr. 72268-69; Hurd, Tr. 86394, 86594-98.)

In addition to improved componentry STRETCH contained architectural features which were forerunners of features included in the System 360--8-bit byte, emphasis on alphabetic characters, a combination of decimal and binary arithmetic, the combination of fixed and variable word length operation, a common method of attaching peripherals, and advances in magnetic tape recording and handling technology.* (Case, Tr. 73606-08.)

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* Indeed, STRETCH proved that the artificial distinction between "scientific" and "commercial" computers no longer needed to be perpetuated, thus clearing the way for the 360. (Case, Tr. 74591; Dunwell, Tr. 85545; Hurd, Tr. 86394, 86408, 86648-49, 87986-87.) For a discussion of the technological innovations introduced with STRETCH, including many which were later incorporated in System 360, see Dunwell, Tr. 85539-49; DX 3171; DX 4767.

Many of IBM's engineering/scientific employees believed that the fallout from STRETCH was of far greater value than any financial loss. (Gibson, Tr. 22593; Case, Tr. 73606-08; Dunwell, Tr. 85549-50, 85791-92; Hurd, Tr. 86595-98; JX 10, p. 2.) In addition, Joseph Smagorinsky, Director of the National Oceanographic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory, testified to the value of STRETCH's technological fallout:

> "IBM has been screaming that they lost money on STRETCH, but that is a downright lie. . . . Yes, here's an example of where if IBM does cost accounting on the STRETCH itself they are absolutely right. If they do cost accounting across the company and learn what STRETCH did for them on other parts of their line which were money-makers--
>
> "Q You're saying that STRETCH was not a loser because if you view it realistically, the technological fallout was so beneficial to IBM that it was a winner?
>
> "A Yes." (DX 5423, Smagorinsky, p. 94)

Smagorinsky added that the 7090 and the 1400 series came completely from STRETCH: "Even the very low part of the [IBM] line benefited from STRETCH technology." (*Id.*, p. 94)

20. IBM's Second Generation Commercially Available Computer Systems. By the late 1950s, IBM and its competitors introduced their second generation, or transistorized, computers.

Norris claimed that the CDC 1604 was the "first solid-state, large-scale computer" when it was announced in April, 1958.* (Norris, Tr. 5608, 5611, 5916; see also Fernbach, Tr. 471; JX 24.) Philco announced a large-scale transistorized computer, the TRANSAC 2000, in 1958, which it claimed was the first transistorized computer. (DX 13683, p. 13; see also Fernbach, Tr. 471.) RCA announced its transistorized 501 computer system in December, 1958 (which was also claimed to be the "first completely transistorized" computer (PX 343, p. 1), followed by the 301 and the 601 in 1960. (PX 344A.) NCR announced its 304, (manufactured by GE), which Hangen called the "industry's first all-solid-state system". (DX 372, p. 2; see Weil, Tr. 7172-73.) Honeywell announced its transistorized M-800 computer system in late 1958, followed by its smaller 400 in 1960. (DX 13674, pp. 10-11.)

These machines rapidly replaced vacuum tube machines. As Withington testified, the Burroughs Datatron 220, "the last vacuum tube computer ever announced", "came to a sudden and permanent end" with the introduction of transistorized computers, which offered

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* Norris agreed, however, that IBM delivered its 7090 transistorized computer prior to first delivery of the 1604. (Tr. 5737, 5923.)

"sharply superior" price/performance.* (Withington, Tr. 55918, 56500; see also Case, Tr. 72258, 72261.)

a. <u>IBM's 7000 Series.</u> The 7070 and 7090, announced in September and December 1958, respectively, were IBM's first second generation computers. (DX 571-A; DX 572-A.)

The 7090 was initially developed in response to an Air Force request for computers to be used in the DEWLINE air defense system. (Dunwell, Tr. 85536; Hurd, Tr. 86394-95.) Four 7090s were delivered to the Air Force in November and December, 1959 (Hurd, Tr. 86395; see also Plaintiff's Admissions, Set II, ¶ 838.1), making the 7090 the first large transistorized computer system to be delivered commercially. (Norris, Tr. 5737.)

The 7090 "became the vehicle by which the componentry of the STRETCH system [including transistors, circuits, pluggable units, cards, frames, power supplies and memories] became a part of

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* In March 1963 the General Accounting Office noted in a report to Congress that:

> "Transistors are but a fraction of the size of vacuum tubes, require less power, generate less heat, and are generally more reliable. The diminutive size of transistors has led to miniaturization of circuitry so that whole circuits can be placed on small card forms. In contrast to the vacuum tube systems, the solid-state systems are more compact, require less floor space and reinforced flooring, require less special power and air-conditioning facilities, are more easily maintained, and operate at faster speeds and with greater versatility. Today, suppliers offer a broad range of solid-state equipment that can be applied to many operations throughout Government, as well as business and industry." (DX 7566, pp. 10-11.)

the IBM product line". In fact, most of the components used in the first 7090s came directly from the supply of parts being collected to produce the first STRETCH, and engineers working on STRETCH were diverted to the 7090 development program. (Dunwell, Tr. 85536; Hurd, Tr. 86395; see also E. Bloch, Tr. 91682, 91862.) Indeed, Smagorinsky stated that the 7090 came completely from STRETCH technology. (DX 5423, p. 94.)

The 7090 used the system design of the 709 and was program compatible with it (and also had a compatibility feature for 704 programs). (Hart, Tr. 81935; Dunwell, Tr. 85536; DX 572-A, p. 1.) It offered five times the computing speed of the 709, eight I/O data channels, automatic priority processing, new high speed core storage and FORTRAN. (DX 572-A.) Because of these improvements, the 709 was rendered obsolete almost immediately.* (Withington, Tr. 56465-66.)

Beard, who (at RCA) was involved in evaluating computer systems for use in BMEWS ("Ballistic Missile Early Warning System") described the 7090 as "a leading scientific computer", and "very successful", and the 7090 was in fact used in BMEWS. (Tr. 8450, 8709; see Weil, Tr. 7026-27.) The 7090, however, was not limited to "scientific" applications. For example, in 1963 American Airlines

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* In discussing IBM's second generation computer systems, Withington was asked: "What happens . . . in the computer industry if a manufacturer does not supersede existing products with new ones incorporating later technology?" He replied: "He will fail to attract new customers and, after a while, will slowly lose his existing ones." (Tr. 56522.)

used two 7090s to implement the first airline on-line passenger name reservation system (developed jointly by IBM and American Airlines). (Welke, Tr. 17314; Case, Tr. 73278-79; O'Neill, Tr. 76005-08; DX 4109: Welch, Tr. (Telex) 2921.) According to O'Neill, that system, called SABRE ("Semi-Automatic Business Research Environment"), was one of the first real time commercial applications, with terminals spread across the nation, and because of this "the term SABRE became generic with . . . real time processing".* (Tr. 76005-06; see Crago, Tr. 86152.) Development of SABRE was a "very extensive effort", involving an estimated 1000 man-years, in which both American Airlines and IBM played "major roles". (O'Neill Tr. 76005-08, 76231, 76776.) Sometime thereafter Pan Am (with IBM) developed a similar system utilizing an IBM 7080 and, later, Delta Airlines (also with IBM) developed a system using IBM 7074s. (O'Neill, Tr. 76007; see DX 5154: Heinzman, Tr. (Telex) 3343-47.) SABRE was based in significant part on SAGE (the first large real-time system) and had many characteristics in common with it. (Hurd, Tr. 86537-40; see Crago, Tr. 86152-53.)**

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* Welke characterized SABRE as "one of the great undertakings of mankind". (Tr. 17313.) Portions of it are today in the Smithsonian Institute. (O'Neill, Tr. 76007-08.)

** "[SABRE and SAGE] were analogous in the sense that each one of them used remote terminals and each of them used telephone wires to communicate from those remote terminals to the central processor which did its processing and then sent back the results over the telephone wires." (Crago, Tr. 86152; Hurd, Tr. 86537-39.)

Both systems had a general systems design referred to as "Command and Control", and the software used in SABRE was similar to that used in SAGE. (Hurd, Tr. 86537-38.)

The IBM 7070 was the second IBM second generation computer system to be delivered. It offered both variable and fixed-word logic as well as automatic floating decimal arithmetic. (DX 571-A.) Like the 7090, it used STRETCH components. (Dunwell, Tr. 85894.) The 7070 was considered to be "business oriented". (Withington, Tr. 56500.) The IBM 7074, announced in 1960, was an improvement over the 7070. Compared to the 7070, the 7074 had six times faster internal processing speeds, two times faster through-put for most applications, and ten to twenty times faster scientific computing. The 7074 was a truly modular system and offered complete compatibility. Every applied program written for a 7070 could be used on a 7074 without reprogramming and without loss of efficiency. (DX 4769, p. 1.)

IBM also introduced the 7080 (delivered in 1961), a transistorized version of the 705 and compatible with it, and the 7040 and 7044 (delivered in 1963). (Norris, Tr. 5923-24; J. Jones, Tr. 78804-05, 79625.) The 7080, like its predecessor the 705, was thought to have a business orientation, whereas the 7040 and 7044 were thought to have a scientific orientation. (Case, Tr. 73276, 73282.) Nevertheless, the 7080 was sometimes used for scientific or engineering applications (Case, Tr. 73282, 73327), and the 7040 and 7044 were sometimes used for business applications, in part because of their excellent COBOL compiler, which Jones labeled "the best COBOL compiler that was available at that time".* (J. Jones, Tr.

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* The development of COBOL, a business-oriented higher level programming language, was discussed above at pages 89-90.

78982.) Case testified that several customers used the 7040 and 7044 for "no purpose other than business or [commercial] . . . computing." (Case, Tr. 73277, see also Tr. 74258-59, 74594; J. Jones, Tr. 78984.) The 7040 and 7044 were hardware and program compatible, so that a user could readily move from the 7040 to the larger 7044. However, those machines were not compatible with the earlier 705, so that the conversion from a 705 to a 7044 could require a substantial effort. (See J. Jones, Tr. 79008.) Jones made such a conversion because of the advantages he anticipated his company would reap by using the 7040. (J. Jones, Tr. 78980-83.)

In 1962 IBM introduced the 7094 and, later, the 7094-II as compatible upgrades to the 7090. (Hart, Tr. 80208.) According to Withington, the CDC 1604 and the UNIVAC 1105 were among the computer systems competitive with the 7094. (Tr. 56904.)

Weil testified that General Electric "carefully targeted as one of the markets for the GE 600 system the installed base of IBM 7090's and 7094's", in part because they were "at that time by far the leading scientific and engineering computer[s] in the field". (Tr. 7026.)

b. <u>IBM's 1400 Computer Series.</u> The IBM 1401, announced in October 1959 (DX 573), was an extremely popular computer. The total number of 1401 installations, between 15,000 and 20,000, dwarfed that of all earlier machines.* (Hurd, Tr. 86383.) Indeed, Withington testified that although the 1401 "became obsolete, as far as new sales were concerned, approximately at the time of the announcement of the System/360 because the Model 30 of that system competed against it," the 1401's "popularity was so great that . . . it continued in manufacture for some time after that". (Tr. 57339.) According to Jack James, President of Telex Computer Products, who was an IBM salesman in Buffalo in the late 1950s, the 1401

> "provided a major breakthrough, from a price/performance standpoint, in that it brought the entry point . . . I mean the lowest [priced] configuration that a customer [could] order and practically install. It brought that . . . entry point down significantly lower than had existed in prior systems that were available, and ultimately proved to be one of the large volume computer systems that were marketed in the early 1960's." (Tr. 35017-18; see also Beard, Tr. 8708-09.)

The 1401 was the successor to, but was not compatible with, the 650. However, according to Withington, the 1401 "was a much better product",** and was "very successful". (Tr. 55916; see James, Tr. 35017.) As it evolved in the marketplace, the 1401 "became available in at least dozens of different models with at least dozens of different peripheral equipment options". (Withington, Tr. 56171.)

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* To put this feat in context, the GSA has estimated that through the end of 1960, only 6,000 general purpose computers had been installed in the United States (531 of which were installed in the federal government). (DX 925, p. 13; DX 4589, p. 7; DX 4590, p. 17.)

** The 1401 could execute seven times as many instructions per second as the 650. (Plaintiff's Admissions, Set II, ¶ 928.3.)

IBM introduced a number of CPUs compatible to the 1401 CPU, enabling users to upgrade their CPUs without changing their peripheral equipment. Such modularity had not been possible with the 650. (Withington, Tr. 56173-74.)*

Certainly one reason for the 1401's popularity was the IBM 1403 printer introduced with it. The 1403, which Fernbach described as a "very fine" product (Tr. 547-47A), was a high speed chain printer that operated at 600 lines per minute (compared with a typical speed of 150 lines per minute for prior machines (Plaintiff's Admissions, Set II, ¶ 931.1)) and "was generally accepted as the highest quality printer in the industry for years." (Case, tr. 72861, 72923-24; see Hurd, Tr. 86384-85.) Withington testified that the 1403 "represented a very large step forward in the functionality and price/performance of high speed printers available for computer systems". (Tr. 56251.) He believed the 1403 gave IBM "a tremendous advantage" which gradually waned by 1963 or 1964 as competitors began to offer "satisfactory alternatives to it".** (Tr. 56252.)

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* Withington believed that manufacturers of computer systems such as IBM were "responding to a competitive necessity" when they developed "different modular types of equipment that could be configured together into models offered to the user". (Tr. 56174.)

** In 1964 Control Data started developing a printer patterned after the design concept that IBM had introduced with its 1403. CDC completed initial development of this product in approximately mid-1968, almost 10 years after IBM had delivered its first 1403 printer. (G. Brown, Tr. 52634.) Nevertheless, CDC experienced significant problems getting its printer to work reliably. (G. Brown, Tr. 52635-36; See DX 1709; DX 4733, Justice, p. 292; DX 4742, Kevill, pp. 366-69.)

He testified that the 1403

> "introduced a new basic printing technology, that of the chain printer, in which the characters move laterally across the line of print on a chain. This proved markedly superior to the other technologies in use at the time in that higher quality print was produced and the cost of printing at what was then considered a high speed was lower using this technology.[*]
>
> "In addition, the 1403 also had some attractive features in terms of carriage control, forms feeding and the like." (Tr. 56253; see also Hurd, Tr. 86384-85; Plaintiff's Admissions, Set II, ¶ 810.1, 839.1.)

O'Neill testified:

> "When most manufacturers were developing and selling drum type high speed printers, IBM had developed and sold the chain printer [the 1403] which was a perceptibly better quality printer than the other manufacturers". (Tr. 76227.)

O'Neill believed the 1403 made IBM a "technological leader" in impact printer products. (Id.) The 1403 was so successful that it was a major factor causing sales of 1400 computer systems to far exceed IBM's expectations. (Case, Tr. 72929.)

The 1401 was used in numerous applications.

> "[In addition to being] used by customers as a stand-alone computer system[, t]he 1401 was also used, as early as 1960, as part of an off-line tape-to-print facility in computer installations containing [7000 series machines], which were larger than the 1401. By 1961, the 1401 was being used to communicate between machines such as the 7090, 7080, 7010, 7040 and 7044, which were larger than the 1401, and high speed input/output devices." (Hurd, Tr. 86383-84.)

For example, Weil testified that a "1401 might be used as an offline

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* The 1403 eliminated the "wavy line" problem associated with earlier printers. (Case, Tr. 72922-24; Hurd, Tr. 86384.)

editing and printing station in conjunction with the 7090 or 7094. [The 1401] was by far the most widely used system associated with a 7090 or 7094 as an auxiliary." (Tr. 7035.) Fernbach testified that when Livermore acquired its first 7090 it also purchased two 1401s. One of these was used essentially as "a card-to-tape converter, as a peripheral device to the 7090". After several years this 1401 was no longer needed to perform this task, so it was used by Livermore's Data Processing Services Group primarily as a printer controller. (Fernbach, Tr. 547-48.) Jones testified that the Southern Railway did its revenue and accounting work on an IBM 705 with two 1401s that did "peripheral processing" for the 705; i.e., the 1401s did card-to-tape and tape-to-print operations. (Tr. 78953.) The Southern Railway used another 1401 in stand-alone mode, with six associated tape drives, to perform accounting work, and another 1401 to do peripheral work for an IBM 70[illegible]4. (J. Jones, Tr. 78954.) Indication of the 1401's great popularity is offered by the fact that in 1972 American Airlines was still using two 1401s as part of an installation performing accounting and financial work.* (O'Neill, Tr. 76269.)

IBM's competitors recognized that the 1401 offered competition to most of their computer systems, both large and small. For example, a December 1959 business review prepared by RCA's electronic data processing division stated:

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* In addition to the 1401s, that American Airlines installation had an IBM 360/30, an IBM 7074 and an IBM 360/65. (O'Neill, Tr. 76269.)

"The introduction of the IBM 1401, in particular, has been important since it has had the effect of making the 7070 computer more competitive, and it has also given IBM a substantial amount of business in the small computer area which we have not yet entered. . . .

". . . .

"A major competitive move developed in the announcement by IBM of their 1401. This low level system was announced as an independent low-cost system as well as a direct coupled adjunct to the IBM 7070. Significant improvements in performance per dollar cost on card reading-punching and printing highlight the system. . . .

". . . .

"Early reaction to the IBM 7070 was not as favorable as originally anticipated. However, the range of this system was substantially enhanced by the October 5 [, 1959] announcement of the IBM 1401. The 1401 as an adjunct to the 7070 permits both a price reduction and an increase in performance. The IBM 7070 with the 1401 is now offering a stronger level of competition in the $20,000 to $25,000 monthly rental range.

"The 1401 standing alone is also a stronger competitor in the $3,000 to $10,000 range and competes with the Rem-Rand Solid-State 8090 as well as the RCA 502. Competitive marketing strategy calling for 'doubling up' on these systems at a single site is noted. In other words, an IBM proposal to use two 1401's presents a problem in the low end of our 500 series." (PX 114, pp. 4, 25, 27.)

Eckert testified that the UNIVAC III faced competition from smaller IBM 1400 Series computers, because a customer "could probably use several of these 1400 machines to do the work of a UNIVAC III, and if this was the choice of a customer to do it that way, it could be regarded as a competitor." (Tr. 838.)*

The 1401 proved so successful that Honeywell developed the

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* See also Withington, Tr. 55506 (1401 an "effective competitor" to the smaller Datatrons).

Honeywell 200 computer system, which was "incompatible with Honeywell's earlier products" but "which was compatibl[e] with IBM equipment, in particular, the very widely used IBM 1401. . . . The Honeywell 200 system was designed to appeal to present users of IBM 1401 computer systems and to be compatible with their programs so that users could convert with minimal effort to Honeywell."* (Withington, Tr. 55866-67.)

Similarly, GE targeted its 400 series (announced in 1963) at the 1400 family because

> "it was our belief that this was the most widely installed small business machine at that time and, hence, represented the largest user base for us to attempt to convert." (Weil, Tr. 7035, 7181.)**

Other members of the 1400 series included the 1410 and the 7010, which James Hewitt, IBM Vice President of Information Systems who was an IBM salesman in the late 1950s, described as "[g]eneral purpose data processing equipment of moderate capabilities". (Hewitt, Tr. 2250, 2253.) The 1410 was 2 1/2 times as powerful as the 1401 and was upward compatible with it. (Hughes, Tr. 34024.) The 7010 was "the largest machine in the 1400 line". (Withington, Tr. 57341.)

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* Honeywell offered a conversion program for the 200 called the "LIBERATOR" which provided the "ability to convert [1401] programs automatically or under the machine control . . . so that they could run on the 200". (Spangle, Tr. 5021-23; see R. Bloch, Tr. 7605-06; McCollister, Tr. 11237.)

** GE offered a 1401 simulator (a combination of hardware and software) which "permitted programs from IBM 1401 either to be run or to be converted easily to the 400". (Weil, Tr. 7031-32.)

c. <u>The IBM 1620 Computer.</u> The IBM 1620 was a small computer that was lower in price, had less capacity and was slower than IBM's 7080 or 7090.* (Hurd, Tr. 87431; see Navas, Tr. 39167; G. Brown, Tr. 50993; O'Neill, Tr. 76265; DX 8962, p. 1.) It could "be used alone or to support IBM 650, 700/7000, or other systems". (DX 8962, p. 1.) Hurd recommended that IBM produce such a computer on the basis of "a series of joint studies with customers looking toward the field of process control".** (Tr. 87432.) Based on his contact with potential customers, Hurd recognized that IBM did not have a computer of the appropriate size and capability and therefore suggested that the 1620 be built. (Hurd, Tr. 87428-32.) The 1620 was used by colleges and universities to perform a variety of business and scientific applications. (Brueck, Tr. 22003; Teti, Tr. 36374-75; Navas, Tr. 39163-65; PX 1322 (Tr. 29750); PX 1396, p. 2.)

In 1961 IBM announced that the 1620 CPU would be employed as part of its 1710 computer. (PX 6125, p. 1.) In addition to the 1620, the 1710 included an interrupt feature incorporated in

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* The 1620 was "about as powerful as the ENIAC" but required only "about one-eighteenth as much floor space and required approximately one percent of the power". (Plaintiff's Admissions, Set II, ¶ 568.2.)

** These customers included Standard Oil of California, Standard Oil of Indiana, Inland Steel and DuPont. (Hurd, Tr. 87432.) Computers used in process control are intended "to improve the efficiency of production processes [in factories of various kinds] and to assist in preventing malfunctions or even disasters". (Hurd, Tr. 86397.)

hardware and a device connecting to analog measuring devices. (Hurd, Tr. 86399; PX 6125, p. 1.) According to Hurd, some customers of the 1710 who had acquired this computer system to perform process control applications also used it to perform accounting functions such as preparing data for payroll applications and for engineering and manufacturing applications. (Tr. 86400.)

In comparison with IBM's first generation computers, its second generation computers occupied less space, required less air conditioning, consumed less power (see DX 571-A, p. 1), and offered greatly improved price/performance, greater speed and throughput and substantially more functionality. (Welke, Tr. 17305, 19298; Andreini, Tr. 47728-33.) Moreover, IBM started to introduce modular peripherals and CPUs which allowed the customer to configure a substantial number of computer systems. (See, e.g., Withington, Tr. 56173-75.) In addition, some of these computers were compatible with a corresponding first generation product and with some of the other second generation computers. (DX 572-A, DX 4769, DX 4774.) Nevertheless, as the 1960s progressed, one deficiency became increasingly apparent: IBM's computer systems were not compatible over a broad range of size and speed categories. (E.g., JX 38, pp. 2-3.)

d. IBM's Second Generation Disk Drives. The two new disk drives introduced with IBM's second generation computer systems--the 1301 and the 1311--embodied fundamental innovations that maintained and, indeed, enhanced IBM's superiority in direct access storage technology, a superiority that greatly contributed to the competitiveness of IBM's second generation computer systems in the early 1960s and that laid the foundation for the critical contribution of disk storage to the success of System 360.

In June 1961 IBM announced the 1301, which had four times faster access speed, five times greater bit density, two and a half times greater track density, ten times greater total storage capacity and more than seven times faster data transfer rate than the 350 RAMAC disk file. (Haughton, Tr. 94824, 94829; DX 3554-D.)

Two principal innovations were embodied in IBM's 1301:

(a) The 1301 was the first commercially available disk file with hydrodynamic slider bearings to maintain the spacing between the head and the disk recording media.* This "very significant innovation" (Haughton, Tr. 94863) eliminated the need for the external air supply used in the 350 RAMAC disk to maintain the spacing between the disk head and the recording media.** (Houghton, Tr. 94853.) The RAMAC disk drive had a "fairly extensive compressor system" that was "roughly the size of a home washing machine" in order to maintain the spacing between the _two_ heads of the RAMAC over the recording media of _fifty_ disks. (Haughton, Tr. 94854.) In contrast,

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* The Autonetics Division of North American Aviation also did research on slider bearing technology, but did not deliver commercially any machines embodying that technology. Haughton, Tr. 95126-27, 95133.)

** Elimination of the air compressor system also simplified the disk design and thus reduced manufacturing costs. (Haughton, Tr. 94828.)

the 1301 disk drive had one head per recording surface, 100 heads in all. (Haughton, Tr. 94875.) Without the slider bearing technology, it would have taken "a courtroom full of air compressors to supply enough air to keep [the 1301 heads at the right distance over the disk surfaces]". (Haughton, Tr. 94828-29.)

Not only did the slider bearing technology make practical having one head per recording surface, it also permitted a nearly fourfold reduction in the height at which the disk head "flew" over the disk recording surface. (Haughton, Tr. 94875-76.) This was important because "the key to dense magnetic recording is to get the magnetic recording element . . . as close as possible to the media that you want to record on or retrieve data from". (Haughton, Tr. 94877.) Thus, the engineering advances that precipitated lowering the disk head flying height on the 1301 permitted greater disk and track densities and increased disk capacity. (Haughton, Tr. 94877, see Tr. 94823-25, 94875-78.)

(b) The 1301 was the first commercially available disk file with an hydraulic actuator. (Case, Tr. 72737; Haughton, Tr. 94856.) The RAMAC had a mechanical actuator that was designed to retract the head from one disk, move along the axis of the disks, and go in on another one of the fifty disks. In contrast, the 1301 hydraulic actuator only needed to move the arms holding the heads in and out since there was a head for every recording surface. (Haughton, Tr. 94826-28; see Case, Tr. 72738.) As a result, the access speed of the 1301 was substantially faster than RAMAC. (Case, Tr. 72738.)

The configuration of one disk head per recording surface with an hydraulic actuator created a "comb" effect of one arm per space between disks. The "comb" effect afforded higher access speeds and greater precision in positioning. (Haughton, Tr. 94825-29.) By electronic switching, the 1301 heads could be employed in a serial fashion, so that simply by moving from head to head without moving the disk actuator, large blocks of data could be read sequentially in a continuous stream similar to tape drives. (Haughton, Tr. 94830-31, 94863-64; see Case, Tr. 72830-35.)

Announced in October 1962, the IBM 1311 disk drive was a "smaller capacity, lower entry cost device" than IBM's previous disk drive products and featured the first removable (and interchangeable) disk pack. (Haughton, Tr. 94834, 94864; see Case, Tr. 72739; PX 4252, p. 1.) The removability feature "was a great step forward for the business at that point in time". (Haughton, Tr. 94864.) According to Case,

> "[t]he value of [the removable disk pack] was that the cost of storage was substantially reduced because just the disk pack could be removed and put on a shelf for long-term storage; whereas, in prior devices since the disks could not be removed if the information was going to stay there a long time, it was associated also with the electrical and mechanical parts of the disk drive". (Tr. 72740.)

Withington testified that the removable pack was a benefit to users "[b]ecause it permitted computer system users to run an application for some period of time for which the programs and files were stored on one or more removable packs and then upon completion of that application's operations, to remove the packs, put them in storage, put other packs on, and proceed to another application." (Tr. 56247-48.)

The 1311 combined the disk drive's fast random access capability with the tape drive's advantage of permitting data to be transported from one system to another and extra packs to be stored on the shelf, resulting in lower cost storage. (Haughton, Tr. 94864, 94874-75, 94943; DX 421, p. 9.) According to Laurence Spitters, former President of Memorex, "the first replaceable disk storage file was a just outstanding technological development in the computer industry". (Tr. 54313.) Its value would be fully realized when IBM introduced the System 360.

Disk pack removability raised many substantial engineering and manufacturing difficulties.* Nevertheless, IBM not only solved these problems but was able to introduce a product that had finer tolerances than any of its predecessors. (Haughton, Tr. 94875-77.) The 1311 disk drive proved to be of great commercial value because it was affordable for use on IBM's smaller second generation computer systems, including the 1400 series and the 1620. (PX 4252, p. 1; see also Withington, Tr. 56245.) The 1311 and its removable pack "turned out to be very popular among users". (Withington, Tr. 56247.)

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* These problems included increased contamination exposure, increased spindle precision requirements, increased pack precision requirements, aggravated thermal expansion problems, actuator accuracy, increased head alignment problems and increased vibration tolerances. (Haughton, Tr. 94833-42, 94864-72; DX 9340-A.)

21. Sperry Rand. In the late 1950s and early 1960s Sperry Rand participated in the remarkable growth of the computer business.* However, the record confirms that Sperry continued to suffer from many of the managerial and organizational difficulties previously described. Thus, even though Sperry expanded its product line to include smaller computers, introduced new UNIVAC and 1100 series computer systems, produced a new real time computer system, and produced several special-bid computer systems for scientific customers and the military, Sperry Rand's relative standing among EDP companies continued to deteriorate. Despite the expansion of Sperry Rand's product line, Withington testified that between 1955 and 1963 the company was "slow to introduce successor or improved models" at the time technology was changing fastest, and "middle-range Univac customers" left Univac "for IBM or some other supplier offering substantially more modern products". (Tr. 57678-79.) As a prelude to discussing Sperry Rand's product introductions, it is useful to assess the source of many of its post-merger managerial problems.

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* As reported in Census II, Sperry Rand's U.S. EDP revenues from 1957 to 1963 were as follows:

1957	$ 45,665,000
1958	62,393,000
1959	80,554,000
1960	106,625,000
1961	140,161,000
1962	120,236,000
1963	145,480,000

(DX 8224, p. 624.)

Sperry Rand was one of the first conglomerate firms in the United States. (See Eckert, Tr. 966-67; PX 6119.) Conglomerates have had a mixed record of business performance within the United States. Virtually all conglomerates have discovered that the only way to manage organizations that engage in highly disparate and dynamically changing businesses is to set up individual profit centers.

Sperry Rand, however, had no computer-related profit center from approximately 1959 or 1960 through 1964.* Instead, Sperry divided the principal line components of the corporation according to function (e.g., marketing, finance and production) rather than product segments (such as computers). (McDonald, Tr. 3787-91.) For example, the person in charge of manufacturing computers was also in charge of manufacturing "office products such as typewriters and equipment, filing cabinets and general business products". (McDonald, Tr. 3788-90.) A different person "headed up all of the marketing activities for computers and office equipment". (McDonald, Tr. 3791.) According to Robert McDonald (who was General Manager of the Univac Military Department in the early 1960s and who became president of a consolidated Univac Division in 1966):

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* In 1964 Sperry reorganized its computer business on a profit center basis. (McDonald, Tr. 3791-93.)

> "[T]he corporation [in the period 1960-63] was set up on an engineering basis with a manufacturing head in charge of the manufacturing activities and a marketing man in charge of the marketing activities.
>
> "Now, that is not a computer company." (Tr. 3787.)

Throughout the early 1960s, Sperry Rand's computer operations also experienced rapid turnover in senior management. (Eckert, Tr. 1008-13; McDonald, Tr. 3785-88; PX 4829, p. 20.) According to Withington, that turnover was one of Sperry Rand's "two great drawbacks" in the early 1960s:

> "The first of these is the lack of a consistent product policy. Successive computers, although often technically advanced, rarely complemented one another or provided reasonable successors to obsolescent products. . . .
>
> "The second problem has been an inability to assemble a smoothly working, reasonably permanent management team. The turnover has always been high". (PX 4829, p. 20.)

a. <u>LARC (the "Livermore Advanced Research Computer").</u> In 1954-55, Remington Rand won a competition with IBM to obtain a contract with the AEC's Livermore Laboratory to "make a leap ahead in using advanced components" to build a computer with "as much power as possible." (Fernbach, Tr. 508-09; Eckert, Tr. 825-27.)* The purchase price of that first LARC was $3.5 million. (Fernbach, Tr. 508-09, 511.)**

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* This is also discussed above in connection with IBM's STRETCH.

** When the LARC was later offered to other potential customers, the price was twice as high, $7 million. The reason for the higher price was that "in ordering the first of a kind, one often gets a price break." (Fernbach, Tr. 511.)

Sperry Rand did not deliver LARC until 1960, approximately 27 months behind schedule. (Plaintiff's Admissions, Set IV, ¶¶ 53.4, 82.0(d).) One reason for that delay was that in 1956-57 Sperry Rand decided to transfer engineers off LARC to help solve problems that were delaying the design and manufacture of the UNIVAC II, Sperry Rand's successor to the UNIVAC I. According to Eckert:

> "There had been some difficulty with the UNIVAC II, and we had to make a decision as to whether to delay LARC and put the manpower we had on LARC over to correct the problem of UNIVAC II, or . . . whether to leave the manpower remain on LARC so it wouldn't be delayed and let the UNIVAC II schedule be delayed.
>
> "Dr. Fry made a decision to delay LARC, and push harder on UNIVAC II." (Tr. 974.)

Sperry, in dealing with the AEC, reported that the 27-month delay was caused by:

> "1. disappointment by Sperry Rand in the performance of production run components furnished by its suppliers, which in many cases failed to meet the exacting requirements of LARC;
>
> "2. underestimation by Sperry Rand of the engineering and other technical complexities involved; and
>
> "3. the institution by Sperry Rand of a budgetary curtailment on LARC which was imposed as the result of impairment of working capital, the 1957-1958 recession and the large monthly losses incurred on the LARC project." (Plaintiff's Admissions, Set IV, ¶ 82.0(d).)

Apparently only one other LARC was produced.* (Eckert, Tr. 827.) The 27-month delay of LARC, in Eckert's view,

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* Eckert testified that Remington Rand had other customers "who were interested in buying LARC's for commercial use, one of them being one of the large insurance companies". (Tr. 836.) In addition, other sales had also been possible to Livermore iteslf. (Fernbach, Tr. 511.)

cost Sperry Rand LARC sales; writing in 1961 about "[l]oss of LARC sales", Eckert stated:

> "We had no nerve on this. After the great setbacks due to Fry's dragout policy and Dr. Teller's anger at the delays produced, plus no gut on the corporation's part, we flunked." (DX 8, p. 2.)*

Sperry Rand lost "several million dollars" on LARC. (Eckert, Tr. 1101.) Withington testified that LARC "developed a very poor reputation for reliability", agreed it was a major product failure (Tr. 56477) and added that LARC's "concentration on magnetic drums, after it had become apparent to the rest of the industry that magnetic disks were superior," contributed to its failure. (Tr. 56454-55.)

Fernbach testified, however, that LARC did advance the state of the art:**

> "[LARC] had parallel features. It was not quite as advanced in that respect as the STRETCH was. But it did have some very fine features other than that. It really consisted of two processors. One, the central processor, operated on the arithmetic portion of the problem, whereas the I/O processor, took care of all the requirements for input and output while the operations were going on in the central processor, so in a sense it was a dual machine using a common memory to carry out its work.

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* Shifting resources away from LARC not only hurt LARC, but also failed to solve the basic problem with the UNIVAC II described earlier: it was too late in getting to the marketplace.

** Sperry Rand developed principally hardware for LARC. It did write certain "I/O processor" software for LARC, but the AEC was not satisfied with it and rewrote it. In fact, the Livermore Laboratory wrote all of the applications software and much of the rest of the LARC software. (Fernbach, Tr. 518.)

"It also had a fixed read-only memory for the I/O processor.

"It also had some advanced peripheral devices such as its drums, which were designed in such a way there was essentially no lost time in accessing information on a drum that had to be fed into central memory." (Tr. 516-17.)

Eckert described how work done for LARC benefited Sperry Rand's other EDP products:

"The circuit development ideas of LARC found their way into a machine called the UNIVAC III [delivered in 1962], which followed LARC. Not only just the circuits themselves, which were improved somewhat, with somewhat better transistors, but the modular board construction and the sockets and plugs, and many of the things that we learned about LARC enabled us to build a much better UNIVAC III than we would have been able to construct.

"Also some of the things that we learned about improving tape units went into even further improvements in the tape units for UNIVAC III." (Tr. 836-37, see also Tr. 1100-01.)

b. <u>The "Solid State Computer".</u> As described earlier, in 1956 Sperry Rand first delivered a low cost computer known as the File Computer, developed by the Minneapolis/St. Paul group. About that same time, the Philadelphia group was developing its own "low-cost" computer, called the Solid State Computer.* (Eckert, Tr. 817-18.)

The Solid State Computer was marketed commercially in Europe, but not in the United States, beginning in 1957-58. (Withington, Tr. 56480; DX 14221-A, p. 6.) Customers in the

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* The Solid State Computer was not fully transistorized. Instead its circuits were made from a combination of transistors and magnetic core amplifiers. (DX 14221-A, p. 6.)

United States were aware of the Solid State Computer and tried to get Sperry to make it available in the United States. Sperry, however, withheld it from the domestic market for a year or more, according to Withington, to protect its base of installed equipment. (Withington, Tr. 56479-81.) Withington testified that:

"I can remember users explicitly saying that they wanted it, and that the company refused to give it to them." (Tr. 56481.)

In 1957-58, the Solid State Computer compared favorably to the IBM 650, which had been on the market since 1953. (Hughes, Tr. 33902-03; DX 1402.) Although IBM had introduced enhanced peripherals for 650 attachment (Hurd, Tr. 86436-37), the CPU was nearly obsolete. When Sperry Rand finally started marketing the Solid State Computer as the SS-80 in the United States, it had lost its competitive advantage, because its principal competition was not the 650, but the IBM 1401, announced in 1959. According to Withington, "most" of the people who would have been customers earlier for the Solid State Computer ordered IBM 1401s instead. (Tr. 56481-82.)*

In 1960 and 1961, Sperry tried or considered various means of making the Solid State Computer more competitive with

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* Even with the delay in marketing the SS-80 in the United States, the SS-80 was still, according to Withington, Sperry Rand's "most successful computer" in the late 1950s and early 1960s, with "about 600 installations at one time." (PX 4829, p. 20.)

the IBM 1401. For example, Sperry attached a random access device (the RANDEX II) to the Solid State Computer, but did so "ineptly". Eckert wrote in 1961:

> "Randex II stores 200,000,000 pulses. We ineptly hooked it to U.S.S.C. [Univac Solid State Computer] and lost 75,000,000 of the 200,000,000 pulses. No accessor speed improvement in the last 20 months. No cost reduction, thus high rent. Result - almost no sales. I.B.M. now is cheaper, faster, for same storage. A lead was possible but we dropped the ball." (DX 8, p. 5.)

Univac also considered speeding up the memory available for the Solid State Computer, but by April 1961, that had not been done:

> "Core Memory for U.S.S.C. This was investigated at least three times in the last 1 1/2 years, by Sales, Engineering, and Product Planning. Now at this late date we have decided to do something. We now face whether at this late date it is worth doing . . . .
>
> "There is [also] no adequate tape speed up program to match the core memory speed up for the U.S.S.C. I have been scrambling around this last two weeks trying to make up for this failure of Engineering and Product Planning. I have found some very good things that can be done in time and at rather low engineering cost to help round out the U.S.S.C. This is, however, the 'last drop' that can be squeezed from the U.S.S.C. and <u>we must not lose sight of this.</u>" (DX 8, p. 2, emphasis in original.)

In 1964, Withington wrote that Sperry Rand "did not and still has not" "provide[d] successors [to the SS-80] convenient in both programming compatibility and price," with the result that "the number of SS80 installations must have shrunk considerably, with most lost to competitors." (PX 4829, p. 20.)

c. <u>1105.</u> In 1958 Sperry Rand's Minneapolis organization completed development of its 1105 "Scientific Model" (an expansion of the 1103-A), first delivered in early 1959. (PX 6119, p. 35; DX 14221-A, p. 9.) The 1105 was expected to be used on "engineering and scientific applications" involving "large-volume data handling problems". (PX 6119, pp. 35, 37.) Customers, however, used the 1105s for other types of applications as well. For example, the Air Force Logistics Command used four 1105s to do principally inventory control applications (J. Jones, Tr. 78732-33, 78780-81); and the Bureau of the Census installed two 1105s "to handle the vastly increased volume of requests for special surveys and business statistics, and to provide . . . analyses of [the 1960] decennial census." (DX 14221-A, p. 9.)

d. <u>New Large Scale Computers and Related Peripherals.</u> As early as 1955 individuals within Remington Rand recognized that:

> "[C]ustomers for electronic data-processing equipment are interested in what is loosely known as 'compatibility'. As time goes on we are going to get more and more pointed questions regarding the compatibility of various units in our UNIVAC line. Even though compatibility is <u>not</u> well defined, we should, as a part of our long-range planning, strive toward more compatibility of our various units." (DX 7608, p. 1, emphasis in original.)

In approximately 1958 or 1959, Eckert unsuccessfully attempted to get Sperry Rand to consolidate its overlapping, non-compatible product lines and to develop only one large-scale computer system. According to Eckert:

"Back when Mr. Schnackel was president of Univac [some time in 1958-59], it was proposed that we build a 490, a UNIVAC III and an 1107. I strongly opposed this idea and told Mr. Schnackel that I didn't care which of the three we built (although the UNIVAC III was my proposal), but that a real time I-O system and floating point should be available on whatever we build and that because of the engineering and software problems, we should certainly build no more than one large scale computer. My feelings of course, were the same as those that must have developed later in IBM and produced for IBM a more or less unified 360-370 line. Unfortunately, the political nature of Univac prevented a resolution of this problem and we went ahead and built three logically unrelated machines." (DX 10, p. 1, emphasis in original; Eckert, Tr. 1018-19.)

In 1960, by which time Sperry Rand's computer operations had been fragmented and organized with other unrelated businesses under functional headings, such as "manufacturing" and "marketing", Sperry Rand announced UNIVAC III, the UNIVAC 1107, and the 490 Real-Time System. (McDonald, Tr. 3787-93; DX 60, pp. 5-6, 9; DX 14222, p. 19.) In early 1961, Eckert described in some detail the adverse consequences of that decision:

"[We are building] [t]hree machines where one (with a choice of two arithmetic units) would have done the job. The Univac III, the 490, and the 1107.

"A single 'speed up' of circuits would have later been possible for LARC, Univac III, and its variations. The way things have been managed four projects would be needed to up date these machines. . . .

"1. Three 4 microsecond memories have been designed, a 27 bit (Univac III), a 32 bit (490), and a 36 bit (1107). The last two have no checking - a horrible omission.

"2. We have three types of new circuits and circuit cards, all uselessly different from LARC. This means different card testers, production set ups, backboard wiring routines, and all the rest.

"3. We have three different casework designs - you know about this - in spite of Philadelphia using a former St. Paul man to do the work.

"4. We have two complete sets of synchronizers for all the peripheral equipment under way.

"5. We have three complete sets of "software" under way.

"A loss of 10 months in Univac III delivery - three months due to foolish redesign of the LARC circuits - 7 months due to trying for final test at the factory . . . . In any case 4 microsecond memories are obsolete before we deliver anything, even when we stand advised on them. IBM already had 2 microsecond memories." (DX 8, p. 2.)

In a description of other "Engineering Shortcomings" mostly incurred in 1959-61 and "Believed to be Avoidable", Eckert described the "Horrible Peripheral Mess at Norwalk" as causing Sperry to have five printers where "one printer frame and case, with 2 actuator assemblies would have handled all this at half or less of the cost of what we have and are doing." (DX 8, pp. 2-3.) The same situation existed for card readers (with six of seven projects described as "a waste") and punches ("I would say Remington Rand has wasted at least 2 to 3 millions of dollars on unworkable or unfinished punches"), as well as mass storage. (DX 8, p. 4.)

With respect to disk drives, Eckert described how Sperry had started to develop a "disc unit, much like I.B.M.'s Ramac"; that device had "[w]orked but was given up as too intricate in comparison to present drum approach." (DX 8, p. 5.) In 1959-61 St. Paul made several more attempts but finally "dropped" much of its disk work. (Id.) Withington testified that Sperry Rand marketed its large FASTRAND drum memory beginning in 1960 and for four or five years thereafter to compete with disk drives offered by other manufacturers. (Tr. 56486-87.) In Withington's view, Sperry's marketing of its computer systems was substantially affected by its lack of competitive disk drives. (Tr. 56487-88.)*

Eckert also described how little "real exploratory work" was being "pushed" at Sperry in 1961 with the exception of thin film memory, and even that was being done in "a crazy hap-hazzard [sic] way": there were five groups working on thin film memory at St. Paul and two more at Philadelphia but they "usually don't believe each other and will not usually use same design of test equipment." (DX 8, p. 6.) With respect to circuitry, no "real progress" was being made.**

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* Withington testified that he would have advised Sperry to "drop it [FASTRAND] and get on with competitive magnetic disk drives as fast as possible." (Tr. 56487.)

** Manufacturing costs were also not being controlled. Eckert described how, as a result of "a rush ill considered standardization and partly due to poor lay technicians at both Norwalk and St. Paul", Sperry was using unnecessarily expensive components. (DX 8, p.4.) These problems persisted. In 1965, Sperry's Product Line Task Force reported:

> "UNIVAC cannot manufacture equipment at costs as low as can be achieved by IBM . . . . Our manufacturing cost situation is in bad shape compared to IBM". (DX 15, pp. 2-3.)

"This is really sad since three fourths of our large machines and almost one half of our small machines costs are in logic circuits, etc. We have the people but no overall guidance, no program. We just do the simple next obvious step stuff the whole way and never really get ahead." (DX 8, p. 6.)

The new computer systems Univac began to deliver in 1962 and 1963 can be described as follows:

(i) The UNIVAC III was not compatible with either of its predecessors, the UNIVAC II or the UNIVAC I, nor was it compatible with the 1100 series computers or the new 490. (Eckert, Tr. 902, 905-06; McDonald, Tr. 3801.) In its 1962 Annual Report, Sperry Rand compared the UNIVAC III to the UNIVAC I as follows:

"Though remarkable in their day, ENIAC and the UNIVAC I Computer seem primitive in comparison with the equipment that Sperry Rand is now introducing. The first UNIVAC III System, a large solid-state computer, is scheduled for delivery in July . . . . It will be 60 times as fast as the UNIVAC I System and will have 32 times as much memory. But so rapidly has the computer art advanced, that the UNIVAC III System rents for less than the early machines." (DX 69, p. 5.)

Customers ultimately installed approximately 100 UNIVAC III's. (Eckert, Tr. 1021; DX 10, p. 1.)

(ii) UNIVAC 1107. Sperry described the UNIVAC 1107 "Thin-Film Memory Computer", delivered first in 1963, as "the first commercially available EDP system utilizing magnetic thin-film memory", with "one of the largest total memory capacities ever delivered to a commercial user". (DX 13912, p. 21.) Although

Sperry's 1100 series computers were described as "scientific", in its 1962 Annual Report (PX 6119, p. 35), Sperry added:

> "Computer programming techniques--characterized as software--have made significant advances in keeping pace with the technological improvements in computer hardware . . . . [B]y utilizing sophisticated programming in the new computers, interchange-ability between scientific and business type computers may be achieved". (DX 69, p. 6; see also Plaintiff's Admissions, Set II, ¶ 502.1.)*

NASA's Goddard Space Flight Center used an 1107 to process data received from satellites and rockets. Those data were recorded initially in analog form on magnetic tapes at remote data acquisition stations. They were then converted into digital form by the Goddard Space Flight Center STARS lines, which began operation in November 1960. The digital tapes from the STARS lines were processed on a UNIVAC 1107 and also on IBM 1401 and 7010 general purpose digital computers. (Plaintiff's Admissions, Set I, ¶¶ 206.0-

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* Similarly, Eckert testified that the "natural evolution of the hardware developments were such as to blunt some of the differences that we saw historically" with respect to computers oriented towards "business" or "scientific" applications.

> "We began to see lower costs and more reliable forms of logic which came about through solid state device[s], magnetic amplifiers, transistors, and so on. That meant that one could afford more logic in the machine, at a given price level, so that the question of whether we had a little extra logic in there to be able to do both the things you like for business and . . . for scientific and . . . for statistical purposes, for all these different purposes, it became possible to put enough in there to perhaps satisfy everybody." (Eckert, Tr. 863-65.)

206.14.) (Both IBM and UNIVAC tape drives were used for digital output on the STARS line. In 1964 Goddard demonstrated that when running the STARS output tape performance of the IBM tape drives "was superior to that of the UNIVAC tape drives on the UNIVAC 1107 computer". (Plaintiff's Admissions, Set I, ¶¶ 206.16-.21.)) The Bureau of the Census and other commercial users also used 1107s. (DX 13912, p. 21.)

Eckert testified that much of the 1107's development expense had been paid by the government, since "the preliminary developments on the 1100 line starting with the 1103, 1105" were paid for by the government and "[c]ertainly [much of] the background and training of all the people that developed [the 1107] originally came from Government expense" and "taking the 1100 line as a whole . . . there were substantial contributions . . . from the Government." (Eckert, Tr. 1019-23.)

(iii) UNIVAC 490. Sperry Rand's UNIVAC 490 "Real-Time System" was based on what Sperry described as its "military counterpart", the UNIVAC 1206 "Military Real-Time Computer." (Eckert, Tr. 1024-25; DX 14222, pp. 19-20.)

According to Sperry, the 1206 and the 490 were developed "to meet the needs of industry and government for a computer that can solve problems or answer questions virtually as soon as they are posed, or in 'real-time'". (DX 14222, pp. 19-20.) The UNIVAC 1206, for example, was intended to be used (among other things) to "record all the information that is sent from a rocket in flight and [to] send guidance signals back to the rocket". (DX 14222, p. 20.) The commercially available 490 performed both "business" and "scientific" applications. (DX 59, ¶ 6.) Eastern Airlines, for example, used the 490 to perform an early reservations application, and Westinghouse Electric used it to perform message-switching applications. (DX 13912, p. 20.) Both the 490 and the 1206 were binary machines. (Eckert, Tr. 1024-25.)

e. Military projects. Sperry Rand supplied many computers to the military, including both its commercially available computers and a number of computers ruggedized or made radiation-resistant in accordance with military needs.* Henry Forrest,

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* Examples of computers developed by Sperry especially for the military include:

(1) A ground-based computer system, developed for the Army in conjunction with Bell Laboratories for use in the Nike-Zeus anti-missile program, and described by Sperry as "general purpose". (PX 6119, p. 16; DX 69, p. 11.)

(2) The UNIVAC 1218, a successor to the 1206, described by Sperry in its 1963 Annual Report (DX 13912 , p. 21) as "a medium-scale, general purpose unit, designed to meet stringent land-based and shipborne military specifications". The UNIVAC 418 is the commercial version of the "hardened" UNIVAC 1218. (DX 5654, Webster, pp. 348-50; see also DX 9088.)

who left Sperry in 1957, testified that the computer products that Sperry developed for the military were "significant" and "contributory" to other Sperry computer products.* (DX 13526, Forrest, p. 97.)

f. Gemini Committee. In 1963, Eckert became chairman of Sperry's "Gemini Committee" and once more tried unsuccessfully to get Sperry to deal with the problems created by the proliferation of non-compatible, overlapping product lines. (Eckert, Tr. 1013-17.) According to Eckert:

> "Again the groups from the different diverse groups of Univac acted to protect their own political interests and the only thing that really happened was that no successor to the UNIVAC III was developed (where we had about 100 customers at the time)." (DX 10, p. 1.)

By contrast, as described below, IBM management, as early as March, 1961, addressed head-on the problem of proliferating, non-compatible product lines. (See, e.g., DX 4773, p. 3.) The result was the December 28, 1961 SPREAD Report (DX 1404A, (App. A to JX 38)), which led to the April 1964 announcement of System 360.

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* A government analysis of Sperry's UNIVAC 1218, 418 and 500 computers, which were described, respectively, as "a small general purpose militarized computer", "a small general purpose computer . . . used primarily as a communications processor", and a computer "utilized for industrial control", concluded:

> "An examination of the detailed block diagram of these three machines will reveal immediately that they are, in fact, identical in design. The main frames of these machines do not vary at all. There are differences in the input/output sections with 1218 being the larger of the group. It is obvious that Univac developed this one basic design and then made minor alterations on it to fulfill additional requirements." (DX 9088.)

22. Other Companies. Set forth below are profiles describing in some detail the EDP activities of the following firms through the late 1950s and early 1960s: American Telephone and Telegraph, Raytheon/Honeywell, RCA, General Electric, Electrodata, Burroughs, National Cash Register, Philco, and Control Data.

These profiles establish that during the early and mid-1950s several firms, in addition to IBM and Sperry Rand, either extended their prior involvement in EDP or entered the business for the first time. Contracts with the U.S. government often provided the principal stimulus. However, none of the firms which had been in existence prior to the mid-1950s made substantial commitments of their own resources to EDP in that timeframe. Hence, as of the mid-1950s none of these firms was able to project itself on a sustained basis as a major EDP supplier.

In the late 1950s and early 1960s the importance of other firms in the EDP industry began to change rapidly. Some large, established firms chose to limit or reduce their EDP activities; others finally made the decision to commit sufficient resources to establish a sustained presence in the market and a few newly-formed, small firms dedicated to the computer business laid the foundation necessary to become successful computer companies. For example:

--American Telephone and Telegraph was favorably situated to enter the EDP business at the start of the 1950s--Bell Laboratories insured that it would be a technical leader and Western Electric was the nation's largest manufacturer of electronic products. However, in 1956 the Department of Justice and AT&T signed a consent decree partially restricting its subsequent participation in the EDP industry.

--Raytheon, as a result of work for the U.S. government, was "one of the prime centers of [EDP] technological development" in the early 1950s. (R. Bloch, Tr. 7570.) However, because it did not wish to risk its corporate funds to develop its EDP potential, Raytheon had exited the business by 1957.*

--Honeywell entered the EDP business by acquiring Raytheon's EDP operations. In the late 1950s Honeywell developed a sizeable range of compatible computer systems.

--Burroughs was "propelled . . . into electronics and thence . . . into data processing" by "[e]xperience with military contracts" during and following World War II. (DX 10283, p. 1.)

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* By 1960, Raytheon had re-entered the computer industry with the purchase of Garlynn Engineering Company which produced "a variety of peripheral equipment for computers and data processing equipment". (DX 10901, pp. 16-17.) In 1964, Raytheon acquired the Packard-Bell Computer Division. (Plaintiff's Admissions, Set II, ¶ 973.0(e).) Raytheon remains active in the EDP business today with subsidiaries such as Raytheon Data Systems Company (manufacturers of data terminals and distributed processing systems) and Raytheon Service Company (an equipment maintenance supplier). (DX 12379, pp. 9, 23.)

Although it had a substantial and sustained commitment to the military throughout the 1950s and early 1960s, and acquired in 1956 an important independent manufacturer of commercially available computer systems, Electrodata, Burroughs was slow in introducing transistorized computers and as a result "effectively left" the commercial EDP business for a period in the early 1960s. (Withington, Tr. 55918-19.)

--National Cash Register acquired "one of the earliest manufacturers of medium-priced general purpose systems" in 1953. (Withington, Tr. 55983.) However, NCR failed to deliver a major new computer system until 1959.

--RCA had an early start in the computer business, but delivered only nine computer systems commercially prior to 1960.

--Control Data Corporation was formed in 1957 by disgruntled Sperry Rand employees. In 1960 CDC delivered, primarily to government laboratories and agencies, the first of a line of transistorized, high-performance computer systems. CDC was a well-established supplier of computer systems by 1963.

23. <u>American Telephone & Telegraph.</u> In 1950 American Telephone and Telegraph Company, with assets exceeding $11 billion (DX 14208, p. 24), was the largest firm in the United States. In addition to its enormous size and financial resources, AT&T owned Western Electric Company and Bell Telephone Laboratories. (*Id.*, p. 34.) Western Electric was in its own right one of the largest industrial companies in the United States with sales of over $758 million (*id.*, p. 17) and the manufacturer of most of the telephone equipment used by the Bell System operating companies as well as equipment sold to other organizations, including the United States government. (*Id.*, pp. 17-18.) Bell Telephone Laboratories was considered to be the premier privately owned scientific organization in the United States at that time with a commitment to basic research in the physical, mathematical and behavioral sciences to support its applied development efforts.

AT&T had long been involved in the development of electromechanical computing equipment and during the course of that work had "made significant contributions to the computer field."

> "The earliest large electrical computers were built at Bell Telephone Laboratories. The first large digital computer, for example, was completed in 1940 from components and techniques normally used in dial switching systems. It was demonstrated that year to mathematicians at Dartmouth College using a data communications link between Hanover, New Hampshire and the computer located in New York City. Analog

computers designed by Bell Telephone Laboratories were used to control and direct the fire of anti-aircraft batteries early in World War II. During the 1943-47 period, the Bell System supplied several digital computers to various agencies of the Federal Government." (DX 10448, p. 14;* see also DX 6888, pp. 3, 4, 120-22; DX 10447, p. 6; Plaintiff's Admissions, Set II, ¶¶ 799.0, 799.2.)

Having the greatest expertise on the reliability of relays, plugs and connectors, the company was consulted in connection with the design of the ENIAC. (Eckert, Tr. 767-69.) In addition, AT&T did substantial research in electronic logic and has claimed that it "produced more than half of all the large [electrically operated digital computers] made" prior to 1950. (DX 10447, p. 6.)**

Thus (in 1968), AT&T's Chairman described the "nationwide dial system" as being "like a giant computer. . . . Our common control switching systems, in big cities, nearly 40 years ago, were probably the first exemplars of real-time data processing." (DX 10447, p. 3; see DX 10448, p. 19.)≁ The techniques of message

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* We are aware that DX 10448 has not been received in evidence; however, we believe that it is reliable evidence for the proposition that Bell Telephone Laboratories was deeply involved in the development of computers in the 1940s and 1950s because it is a formal statement submitted to the Federal Communications Commission (FCC) by the Bell System in response to an FCC Notice of Inquiry (Computer Inquiry I).

** The Langley Research Center, for example, procured a "Bell relay computer prior to 1950" to be used "to provide results of theoretical studies". (Plaintiff's Admissions, Set IV, ¶¶ 325.0-.1.)

≁ "Circuit switching is a technique that has been used practically since the beginning of telephony. . . . The nationwide Direct Distance Dialing (DDD) network is made up of all of the existing dialing systems, long distance and exchange, forming a huge circuit switching network. It is, in effect, a giant computer, containing all of the elements of a computer, i.e., control, processing, memory, input and output units." (DX 10448, p. 19.)

and circuit switching used in the AT&T dial network are used "to perform the essential communications function of routing information from its point of origin to its intended point of destination". (DX 10448, p. 17.) According to AT&T, "[t]he function of general purpose computers programmed to perform message switching is similar to the function of these types of message switchers". (DX 10448, p. 18.)

In a list of over 20 companies in the EDP field "arranged in rough order of probable importance with regard to patent matters" prepared by John Mauchly in 1954, AT&T ranked first and IBM ranked second. (DX 7604, p. 1.) Some examples of AT&T's pioneering work in electronics follow:

(a) Bell Labs employees invented the transistor (Fernbach, Tr. 469; Ashbridge, Tr. 34861; Withington, Tr. 58524-25; Case, Tr. 72258; Crago, Tr. 86184; DX 6888, pp. 3, 123-24) for which three later shared the Nobel Prize. As described by AT&T:

> "Probably the most dramatic contribution to computer technology however, was the invention of the transistor in 1947 at Bell Telephone Laboratories. Until then, the limitations of the vacuum tube appeared to be the practical deterrent to the evolution of large scale computers." (DX 10448, p. 14.)

AT&T began regular production of transistors in 1952. (DX 14209, pp. 20, 22.)

(b) As stated in an article listing Bell System innovations, in 1954 AT&T demonstrated TRADIC, which it described as the "first general purpose transistorized digital computer". (DX 6888, p. 121.)

(c) AT&T is credited with having operated the first time-sharing system around 1950. (DX 5333, p. 6.)

In 1956 a final judgment settled the antitrust suit the U.S. government had brought against AT&T in 1949. The decree provided, in part:

"The defendants [AT&T and Western Electric] are each enjoined and restrained from commencing, and after three (3) years from the date of this Final Judgment from continuing, directly or indirectly, to manufacture for sale or lease any equipment which is of a type not sold or leased or intended to be sold or leased to Companies of the Bell System, for use in furnishing common carrier communications services, except equipment used in the manufacture or installation of equipment which is of a type so sold or leased or intended to be so sold or leased; provided, however, that this Section shall not apply to . . . equipment manufactured for the [United States], or for [the United States'] prime or sub-contractors for the performance of contracts with [the United States] or sub-contracts thereunder.

"After three (3) years from the date of this Final Judgment, the defendant Western [Electric] is enjoined and restrained from engaging, either directly or indirectly, in any business not of a character or type engaged in by Western or its subsidiaries for Companies of the Bell System, other than (1) businesses in which defendant AT&T may engage under [the next] Section . . . hereof, . . . and (3) any business engaged in for [the United States] or any agency thereof.

". . . .

". . . AT&T is enjoined and restrained from engaging, either directly, or indirectly through its subsidiaries other than Western and Western's subsidiaries, in any business other than the furnishing of common carrier communications services; provided, however, that this . . . shall not apply to (a) furnishing services or facilities for the [United States] or any agency thereof, (b) experiments for the purposes of testing or developing new common carrier communications services, . . . or (g) businesses or services incidental to the furnishing by AT&T or such subsidiaries of common carrier communications services." (U.S. v. Western Electric Co., [1956] Trade Reg. Rep. (CCH) ¶ 68,246 (D.N.J. 1956).)

The consent decree limited AT&T's ability to compete in certain parts of the computer business. However, AT&T continued to manufacture computer products for the United States government, for use in "common carrier communications services" (id.) for the Bell operating companies, and through its Teletype subsidiary to commercial customers as well. AT&T's products included computer systems, terminals, modems, and data sets.*

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* Examples of AT&T's post-consent decree EDP research activities are found in DX 6888, pp. 3-4, 99, 107, 111-17, 120-22, 123-30.

"Modems convert computer digital signals into analog signals that can be transmitted over telephone lines and reconvert those analog signals coming off telephone lines to digital signals which can be processed by a computer." (Crago, Tr. 85965.) Modems are "central to the operation of geographically dispersed computer systems". (Crago, Tr. 85976.)

A data set "[m]akes possible centralized data processing operations [by] reduc[ing] the need for separate data processing equipment at other locations . . . [and] [o]ffers an economical means to operate data communications. . . ." (DX 6890, p. 3.) A data set "[t]ransmits and receives business machine codes over regular telephone lines or private lines" and thereby facilitates numerous functions including:

> "direct two-way communications between many types of business machines . . .
>
> ". . . .
>
> ". . . direct computer-to-computer operation . . .
>
> ". . . .
>
> ". . . rapid, direct, low-cost data communications between separate business locations.
>
> "Makes possible centralized data processing operations--
>
> ". . . .
>
> "increases the efficiency of existing business machine operations. . . ." (DX 6893, pp. 2-3.)

By the early 1960s Bell had announced the development of "#1 Electronic Switching System (#1 ESS) . . . a stored program control system which has been developed to handle a variety of switching jobs". (DX 10448, p. 18.) No. 1 ESS was a "real-time" electronic system and introduced to the telephone switching field "the control philosophy, which utilizes a stored program". (DX 6884, p. 2; DX 6886, p. 1.)

> "A system employing a stored program is one which consists of memories for storing both instructions and data, and a logic unit which monitors and controls peripheral equipment by performing a set of operations dictated by a sequence of program instructions. The stored program philosophy permitted the designers [of ESS] to use centralized logic circuitry and large-capacity memory units as a means of attaining flexibility and over-all economy in the system." (DX 6886, p. 1.)

As described by AT&T, No. 1 ESS had "primary inputs from [telephone] lines and trunks via scanners, and outputs to the network and signal distributor, with teletypewriters as administrative input-output devices and with a magnetic tape for automatic message accounting . . . output". The memory units in the No. 1 ESS could be expanded over a wide range to accommodate the largest office. (DX 6886, p. 2.) "[T]he central processor contains two types of memory: a semipermanent memory system (program store) for storing programs and a high-speed readable and writable memory (call store) for storing [telephone] call progress data". (<u>Id.</u>) As discussed below, the first No. 1 ESS was installed in 1965. (DX 14210. p. 7.)

AT&T's U. S. EDP revenues rose from $770,000 in 1952 to more than $97 million in 1963. (DX 8224, p. 133.) Those revenues can be further broken down, by beginning and ending years for the period 1950-1963, as reported in DX 5945, as follows:

(a) Sales by Western Electric to the Bell System Operating Companies of stored program electronic digital central data processors and related equipment and software--

1962 $263,000

1963 $407,000 (DX 5945, Dunnaville, pp. 7-8);

(b) Sales by Western Electric of data sets--

1961 $1,159,000

1963 $3,579,000 (*id.*, pp. 9-10);

(c) Sales by Teletype Corporation of EDP products--

1952 $770,000

1963 $61,444,000 (*id.*, pp. 10-11, as amended by Letter, Dunnaville to Deutsch, February 27, 1975, included as a part of DX 5945);

(d) Sales of computer systems manufactured by AT&T or its subsidiaries to the United States Government--

1952-1954 $263,000

1963 $31,963,000 (*id.*, pp. 11-12).

24. Raytheon/Honeywell. Raytheon rose to prominence during World War II primarily as a manufacturer of radar and other electronic equipment for the military. Raytheon was involved in developing and producing computers as early as 1947 when it began work on the Raytheon Digital Automatic Computer (RAYDAC) under the sponsorship of the Bureau of Standards and later the Office of Naval Research. (R. Bloch, Tr. 7570, 7575; see Hurd, Tr. 86326.) The RAYDAC was first delivered in approximately 1951. (R. Bloch, Tr. 7570; DX 13684-A, p. 8.) In the late 1940s and early 1950s Raytheon also developed certain other computers "under code names that went to top security agencies". (R. Bloch, Tr. 7570; see also Hurd, Tr. 87661-63.) In the early 1950s, Raytheon also manufactured various electronic components, including transistors, triodes, rectifiers, and Klystron tubes. (E.g., DX 13684-A, p. 27.)*

Raytheon during this time period funded its computer operations entirely by government contracts and marketed its computers exclusively to U.S. government agencies. (R. Bloch, Tr. 7567-70, 7572-73.)

Richard Bloch, who joined Raytheon in 1947 as head of its Analytical Department and later became General

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* For its fiscal year ending May 31, 1952, Raytheon had total revenues of $111,287,000. (DX 13684-A, p. 3.)

Manager of its Computer Division, described Raytheon in the early 1950s as "one of the prime centers of technological development at that time, and probably [a] leader roughly parallel with the Univac operation in terms of scope of competence". (R. Bloch, Tr. 7570, 7736.)* Indeed, in 1952 Raytheon was one of several companies (including RCA, Remington Rand and IBM) with which M.I.T.'s Lincoln Labs conducted detailed discussions concerning proposals for designing the SAGE computer system. (Crago, Tr. 85962; Hurd, Tr. 86463-64.)

By 1953 or 1954, Raytheon had begun development of a computer known as the RAYCOM, a "general purpose commercially oriented . . . digital computer, which was a takeoff of work [Raytheon] had done on the RAYDAC". (R. Bloch, Tr. 7570, 7739.) Raytheon, however, ultimately decided not to pursue a commercially-oriented computer:

> "The primary reason was that Raytheon at that time was primarily a Government-funded corporation, very heavily so; they did not attack commercial activities in other fields very effectively, [**] and had no

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* For reasons summarized previously in this text, Bloch testified that technical leadership in computer development passed to IBM "in the area of 1953 or '54, and certainly by 1955". (Tr. 7742.)

** In 1956, Raytheon totally withdrew from a different "commercial activity"--the manufacture and sale of television and radio sets--by selling that business to the Admiral Corporation. (DX 13686, p. 5.) Raytheon at that time told its stockholders it could not "compete profitably" in that business. (Id.)

desire to make a move into this commercial field. Furthermore, and probably most importantly, they did not have the funds that would be required. They were accustomed to being funded by Government contract, and this required funding from the [corporate] exchequer." (R. Bloch, Tr. 7573, 7575.)

Nevertheless, Raytheon had "in existence an extremely capable group" working in computers. (R. Bloch, Tr. 7571-72.) Rather than disperse them, Raytheon, in 1955, entered into a joint venture, called the Datamatic Corporation, with the Minneapolis-Honeywell Regulator Company (hereafter Honeywell) to "design, develop and produce large scale computer systems" for business data processing, based on Raytheon's work on the RAYCOM. (Binger, Tr. 4502-03; R. Bloch, Tr. 7571; PX 318, p. 33.) At the time of the joint venture, Honeywell was one of the United States' largest manufacturers of automatic control equipment for home, commercial, military, and industrial applications. (DX 13670, pp. 5, 7-11.)

Raytheon, with a 40 percent interest in the Datamatic joint venture, contributed essentially all of the "computer know-how". (Binger, Tr. 4502; R. Bloch, Tr. 7573, 7739-40.) Indeed, Bloch testified that the group he headed at Raytheon, which had designed the RAYDAC and worked on the RAYCOM, was subsequently responsible for developing the Datamatic-1000 (based on the RAYCOM), as well as the later Honeywell 800 and 400 computer systems, and "had an important role to play" in developing the 200 computer system. (Tr. 7741-42.) Honeywell's "major contribution was money and management". (R. Bloch, Tr. 7740.)

Bloch testified he believed it was a mistake for Raytheon not to pursue the RAYCOM development. (Tr. 7746.) He thought that if his group at Raytheon had pursued the development of the RAYCOM it would have been successful:

> "Some of this I must say is a question of an immodest belief that we would marshal the necessary forces to do the job, but remembering that we had a strong technical group, I feel that we would have developed, with time, the necessary marketing force, and so on.
>
> "This was an early time in the field. The most important thing at this time, certainly, was technical competence in terms of being able to develop any product that made sense. And that we had." (Tr. 7748-49.)

From Honeywell's point of view, the purpose of the Datamatic joint venture was "to bring them into, overnight as it were, an important position, certainly technologically, in the then infant computer field". (R. Bloch, Tr. 7571-72.) According to James Binger, Honeywell's chairman, Honeywell "looked upon the move as a very natural extension of [its] existing automation business". Indeed Binger stated in 1973: "[Honeywell] never regarded [the computer business] as a separate business, and we are more convinced today of its synergism with our control systems than we were in 1955." (DX 130, p. 12.)

In 1955, when the Datamatic joint venture began, Honeywell had sales of $244 million, net income before taxes of $40 million and total assets of $164 million (DX 13670, pp. 5, 16); Raytheon had sales of $182 million (fiscal year ending May 31, 1955), net earnings before taxes of $9 million, and total assets exceeding $82 million. (DX 13685, pp. 4, 18.)

Datamatic's first product was the D-1000, a large-scale, first generation, vacuum tube computer system first shipped in late 1957 at a price of approximately $2 million. (Binger, Tr. 4502; DX 13671, p. 16; DX 13888, p. 37; DX 10552, pp. 7-8; PX 318, p. 34.) Honeywell manufactured the D-1000's CPU and tape drives but obtained other peripheral products from several suppliers, including printers from Analex, card readers and various kinds of tabulating equipment from IBM, and large magnetic rotary files from a machine tool business located in New England. (Binger, Tr. 4512-13, 4549-50.)

Honeywell had "approximately 8 or 10" customers for its D-1000, including the Michigan Hospital Service (Blue Cross-Blue Shield), the First National Bank of Boston, the B&O Railroad, the U.S. Treasury (Savings Bond Division), the Bureau of Public Debt, and the County of Los Angeles. (Binger, Tr. 4503-04; DX 13672, p. 40.) The D-1000 was used primarily for processing business data, "largely of an accounting nature". (Binger, Tr. 4504.)

In 1957 Honeywell acquired Raytheon's 40 percent share of Datamatic for about $4 million. (Binger, Tr. 4504-05; R. Bloch, Tr. 7574.) Raytheon reported that

> "substantial additional investments will be required to develop Datamatic's full potential. In view of Raytheon's growing cash requirements, it was decided to dispose of our interest in Datamatic and to concentrate all available funds on our own business."* (DX 13855, p. 7.)

At that time, Raytheon's other businesses were expanding rapidly. Its revenues rose to nearly $260 million for calendar year 1957, and rose again to $375 million for calendar year 1958. (DX 13855, p. 7; DX 13688, p. 6.)

Prior to selling its Datamatic equity to Honeywell, Raytheon had approached Lockheed. According to Norman Ream, Corporate Director of Systems Planning at Lockheed from 1953 to 1965, Lockheed was initially interested because "in the 1956-57 era . . . the aerospace companies were branching out into electronics and . . . [Lockheed] looked upon this as a possibility of getting some advanced electronic techniques--or

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* Raytheon currently offers "intelligent terminals, minicomputers and telecommunications systems" (DX 7961; see also Hangen, Tr. 6424-25; McCollister, Tr. 11159-61; O'Neill, Tr. 75729-31) and is in the business of maintaining IBM computer products and IBM plug-compatible computer products. (Vaughan, Tr. 21397, 21414-16, 21887.)

technical knowledge." (DX 9070, Ream, p. 37.) Ream testified that in 1957, Datamatic had delivered about nine DATAMATIC 1000s and was "estimating the sale of a very large number of their DATAMATIC 1000 Systems". (Id., p. 36.) Ream, after studying Datamatic, "did not believe that [estimate]"; his own study indicated that Datamatic would not "sell another machine [1000]--and they did not"--because Datamatic "had not advanced the state of the art". Lockheed, accordingly, decided not to acquire Raytheon's interest in Datamatic. (Id.)*

At year-end 1958 Honeywell announced the transistorized Honeywell 800, which it described as its first "medium-scale computer", for delivery in the third quarter of 1960. It described the Honeywell 800 as a fully transistorized, small in size, but "extremely high speed" and efficient computer that could "be expanded in small economical increments to meet a growing data processing requirement--business and scientific". (DX 13672, pp. 8-9; see Binger, Tr. 4550.)

In 1959 Honeywell's Datamatic Division announced another new product, the H-290, a digital computer developed "for use in the public utility field and to control continuous processes in the chemical, petroleum and other industries". (DX 13673, pp. 27-28, 43.)

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* Shortly thereafter Lockheed purchased another organization that became the basis for its Electronics Division. (DX 9070, Ream, pp. 37-38.)

In December 1960 Honeywell actually delivered the first of its 800 systems to the Associated Hospitals of New York and the American Mutual Liability Insurance Company of Boston. (DX 13674, pp. 45-46.) It also announced the Honeywell 400--a computer system fully compatible with the Honeywell 800--priced at about half the price of the 800 and delivered in the latter part of 1961. Taken together, these two systems covered "a sizeable range in solid-state electronic data processing systems", with prices ranging "from approximately $400,000 to several million dollars". (Binger, Tr. 4550; DX 13674, pp.10-11;DX 13675, pp. 35-36.) Honeywell described the 400 as a "full-scale data processing system" that included magnetic tape and "diverse input/output capabilities", that could be used independently or in conjunction with the 800. (DX 13675, p. 36.)

Honeywell also, throughout 1961, operated a service bureau using a Honeywell 800. (DX 13675, p. 35.)

In 1961 Honeywell introduced a "FACT" compiler for use on its 800 computer systems. (Spangle, Tr. 5092-93; DX 13675, p. 37.) Like IBM's COMTRAN, FACT (which had been developed for Honeywell by Computer Sciences Corporation (Spangle, Tr. 5092-93)) was "a programming language based on English", and a "compiler to develop machine programs from programs written in that language". (Withington, Tr. 56516.) Honeywell described FACT as perhaps "the most complete and powerful program for compiling business applications". (DX 13675, p. 37.) Although Honeywell claimed that its FACT programming language was superior to both COMTRAN and COBOL, Honeywell ultimately abandoned FACT in favor of COBOL, "thereby losing its investment" just as IBM had been forced to abandon COMTRAN. (Withington, Tr. 56512-16.)

In 1962 Honeywell announced the Honeywell 1800, describing it as "an extremely powerful computer capable of handling both business and scientific applications". (DX 13676, p. 29.) Honeywell also concluded an agreement with the Nippon Electric Company under which Nippon, on a royalty basis, would "produce and market, in the Far East, computers incorporating Honeywell designs and features". (DX 13676, p. 31.)

In 1963 Honeywell announced the 1400 as "a ready means of expansion to Honeywell 400 customers who desire to move to a larger system without reprogramming" and as having "unique real time capability in the field of computer-communication systems". (DX 198, p. 25.) Honeywell also announced its 200 system in December 1963. (DX 167.) The 200 was intended to be a "powerful, low-priced magnetic tape system designed for the smaller user, and thus is directed toward that part of the EDP market that represents the largest dollar volume". (DX 167; DX 198, p. 26.) The 200 contained an "automatic program conversion package, called 'Liberator'". (DX 198, p. 26.) Liberator was designed to automatically convert "instruction programs written for three competitive systems, thus eliminating major reprogramming costs". (Id.)

Honeywell's U.S. EDP revenues grew from $1 million in 1958 to $27 million in 1963. (DX 8631, pp. 31, 37; DX 14484, p. R1.) In 1963, Honeywell's total corporate revenues were $648 million. (DX 198, p. 4.)

25. RCA. Radio Corporation of America, with 1952 revenues of nearly $694 million, was another large, technically sophisticated company well situated to enter the computer business during the early 1950s.* McCollister testified he believed that throughout the 1950s, RCA's revenues exceeded those of IBM. (Tr. 9553.)

a. RCA's Early Computer-Related Activities. Before and during the early 1950s, RCA gained experience in computer-related activities in three areas: Computing devices, vacuum tubes and transistors, and core memories.

Scientists at RCA Laboratories "began a study of electronic computing devices as far back as 1935" (PX 344A, p. 1) and in the early 1940s, RCA "'pioneer[ed] in electronic data processing'" with its "'systems for anti-aircraft fire control'". (PX 343, p. 3.) RCA produced its first computer in 1947 at the request of the U.S. Navy. (PX 344A, p. 1.) This computer, the Typhoon, "was a very large analog computer, one of the most sophisticated for its time, and it was used primarily for simulation studies". (Beard, Tr. 8652.)

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* At that time RCA operated in five divisions. Nearly three quarters of its total revenue, or $507 million, came from the manufacture and distribution of RCA Victor products --phonographs, records, radios, televisions, etc.--and from RCA Laboratories; the National Broadcasting Company had revenues of $162.5 million; RCA Communications had revenues of $17.5 million, and RCA's Radiomarine Corporation had revenues of $11.9 million. (DX 658, p. 6.)

By 1950 RCA had undertaken an "exploratory investigation of a digital computer for commercial applications". (Beard, Tr. 8651.)

By 1952 RCA reported that a "substantial part of [its] Laboratories Division activity . . . was devoted to research on classified Government projects in such fields as electronic computers". (DX 658, p. 17.) MIT selected RCA as one of the finalists in the competition to produce SAGE computer systems. (Crago, Tr. 85962; Hurd, Tr. 86463.)*

By the early 1950s, as a result of its involvement in the manufacture of radios and televisions, RCA was one of the nation's major manufacturers of vacuum tubes. (DX 658, pp. 19-23.) The designers of the ENIAC consulted RCA's engineers in an effort to develop "ultra reliable" tubes for the ENIAC computer. (Eckert, Tr. 768.) Following the invention of the transistor, RCA began research on possible transistor applications, recognizing as early as 1952 that "substitution of transistors" for vacuum tubes would permit the construction of computers "of greater versatility and utility, as well as reducing their size and power consumption." (DX 658, p. 13.)

RCA also pursued the development of core memory during the early 1950s. In 1953 RCA employees wrote: "[r]ecently ferrite materials have been developed which are suitable for use

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* RCA continued to work on classified military projects to develop electronic computers during the 1950s. (E.g., DX 659, p. 20; DX 661, pp. 34-35.)

as memory elements for large-scale electronic computers. A memory unit capable of storing ten thousand bits of information has been developed by RCA." (DX 659, p. 16.)*

Against that background it is plain, as Mr. Beard acknowledged, that "in the early 1950's . . . RCA had the financial and technical capabilities successfully to develop, manufacture and market computers for commercial application". (Beard, Tr. 8652.)

b. RCA Computer Developments 1956-1959. RCA did not deliver a digital computer until 1956. (PX 344A, pp. 1-2.) In that year, it delivered the BIZMAC, which was "a data-processing giant" (PX 343, p. 3) with a purchase price of $4 million. (DX 661, p. 21.) It had a small amount of core memory: approximately 28,000 cores. (Hurd, Tr. 88213.)

RCA developed BIZMAC for the Army and intended it to be used for business-type applications: "stock control of replacement parts for military combat and transport vehicles". (DX 661, p. 21.) It was intended to "provide speedy and accurate information on inventories, to determine in minutes the current supply of any item at any Ordnance depot in the nation, and to compute forecasts of future requirements." (Id.; see Beard, Tr. 8449-50.)

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* In 1953 Dr. Rajchman of RCA realized that, having made a 10,000 core memory, the next important step would be a core memory comprising "millions" of cores. To accomplish that goal would "require great innovations in construction techniques and still further improvements in magnetic switching." (PX 6091, p. 16.)

The BIZMAC took RCA "a lot of time and money to develop." (McCollister, Tr. 9254-55.)

RCA shipped approximately six BIZMACs during the 1950s.* (Beard, Tr. 8710-11.) Withington testified that the BIZMAC worked "relatively poorly" and classified the product as a "failure". (Tr. 56507-08.)

Because of its size, the BIZMAC program kept RCA "pretty well occupied up through the middle fifties and maybe 1956, 1957". (McCollister, Tr. 9255.) In 1958 RCA began work on the 501. (Id.)

The 501 was, according to RCA's management, "the first completely transistorized, general purpose electronic data processing system". (PX 343, p. 1.) It was announced in December 1958** (id.), and first delivered in mid- to late 1959.≠ (PX 114, p. 18.) It was Mr. Beard's understanding that only three 501s were delivered to customers outside of RCA during the 1950s.

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* Customers included: Travelers' Insurance, New York Life, Higbee Department Stores and The Army Tank and Automotive Command. (Beard, Tr. 8658; McCollister, Tr. 9254; DX 662, p. 20; DX 664, p. 18.)

** "The 501 is the fifth of six new products which Mr. Burns [RCA's President] said last May would be announced by RCA in 1958. The first four were a tape cartridge to provide stereophonic music in the home, a line of stereo tape and record players, the 'Wireless Wizard' remote control for black-and-white and color television receivers, and a two-way belt radio which transforms the wearer into a 'walking radio station.'" (PX 343, p. 2.)

≠RCA received orders for the 501 prior to its announcement. (PX 343, p. 2.)

(Tr. 8711.)

While McCollister believed the 501 was a "competitive system" and that it was "well designed by the standards of the time" (Tr. 9542), RCA experienced difficulties with some peripherals. The card reader and card punch equipment were "slow" and "unreliable", and the line printer "required a lot of maintenance"; its "print quality wasn't particularly good". (McCollister, Tr. 9542-43.)*

As of December 1959 RCA reported "commitments for 41" of its 501 systems. (PX 114, p. 5.) Nevertheless, because the computer division had "optimistically scheduled production in excess of what they were able to sell", more 501s were built than were marketed. (McCollister, Tr. 9541-42.)

In the late 1950s, RCA was chosen as program manager for the BMEWS project, a computer system commissioned by the North American Air Defense Command to provide early warning of any ballistic missile attack. (Beard, Tr. 8450-51, 8676.) Among RCA's BMEWS subcontractors were IBM (which provided the main CPUs--IBM 7090s), General Electric and Sylvania. (Beard, Tr. 8676.) RCA also developed computers of its own for the BMEWS system, and RCA's subsequent commercial products made use of the

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* The Social Security Administration was not satisifed with the 501, and transferred its workload to an IBM 7080. (DX 5793, p. 9; DX 7539, pp. 31-32.)

advances introduced in the BMEWS.*

During the late 1950s, RCA announced its third computer, the 110 Industrial Control Computer. (Beard, Tr. 8660; PX 114, p. 37.) RCA's Electronic Data Processing Division performed the development work on the 110. (Beard, Tr. 9027-28.) According to Beard the 110 differed from RCA's other computers in that it was supplied with less software and was designed to operate in a "more severe environment". (Tr. 8565-66.) The 110 was offered as a "standard unit" that could be "modified readily" to accomplish different functions and could be "supplied with a wide variety of optional functions". (PX 114, p. 37.)**

Despite its substantial technological capabilities at the beginning of the 1950s, RCA, by the end of the 1950s, had not succeeded in establishing a substantial presence in the computer industry. As late as December 1959, in a business review of RCA's Electronic Data Processing Division, the company stated that it was just "beginning to overcome the major obstacle which

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* For example, the RCA 3301 computers used an improved version of the electronic circuitry developed and designed for BMEWS; it used some of the electrical packaging features of the BMEWS computers. Also, the RCA 4100 used similar packaging and a somewhat improved circuitry over that which had been used in BMEWS; the 4100 was used by United Airlines to provide communications functions as part of an airlines reservations system. (Beard, Tr. 8684-86, 8983-84.)

** Modified RCA 110s (called 110As) were used by NASA as part of the Saturn Missile Launch Computer Complex at the Kennedy Space Center. (DX 5255, pp. 11-12.)

plagued us previously; namely, doubts as to RCA's seriousness in the EDP business". (PX 114, p. 5.)

About this time RCA's management was "faced with a decision as to what they should do about being in the computer business". (McCollister, Tr. 9255.) Expressing one point of view was RCA President John Burns, who felt that "in view of RCA's technical capabilities and what appeared to be great growth opportunities in the computer field, . . . this was a business . . . RCA should be in". (Id.) Pushing in the other direction was RCA's desire to develop and commercialize color television. The resulting battle for investment money within RCA began during the 1950s and continued through the 1960s, to the detriment of RCA's computer related activities. As Beard testified concerning the allocation of RCA's total corporate resources throughout the 1950s, there was a "greater total effort in television from the engineering point of view than there was in the computer". (Tr. 8717.)

Production of peripheral products was limited in this time frame. Thus, RCA's computer division decided to curtail the development of peripherals in the late 1950s or early 1960s in order

> "[t]o concentrate RCA's investments in areas where they felt they would get the most return and where it would be possible to procure such things as printers, card readers,

and punchers from other manufacturers who were making them available directly to other manufacturers". (Beard, Tr. 8998-99.)

c. <u>RCA's Computer Developments 1960-1963</u>. On April 13, 1960, RCA announced two new computer systems, the 601 and the 301. (PX 344A, p. 1.) RCA described the 601 as "an ultra-high speed, general purpose EDP system . . . equally efficient for massive business data processing <u>and</u> complex scientific computation" (DX 562, p. 2; see Beard, Tr. 8958); the 301 was a "small to medium size" computer. (Beard, Tr. 8454.)

McCollister described the 601 as a "disaster" (Tr. 9622):

(1) The manufacturing cost for the 601 turned out to be "very, very substantially higher than the original cost estimates upon which the pricing had been predicated". If RCA had raised the price of the 601 to cover its costs, the product would have been "uncompetitive". (McCollister, Tr. 9543; Beard, Tr. 8458.)

(2) RCA had difficulty in providing "some of the functional capabilities that had been originally announced and specified in that system". For example, RCA intended the 601 to be an "on line" and "multiprogramming type of system". RCA's attempt to make the system operate that way was "economically just a totally impractical thing to do" and also "there was a big slowdown in being able to accomplish these functions in a technical sense". (McCollister,

Tr. 9544.)

(3) RCA used coaxial cable to improve the performance of the CPU. However, so many cables were used that:

> "it was virtually a physical impossibility to interconnect all of the points on the back side of the machine that had to be interconnected". (McCollister, Tr. 9544.)

John L. Jones, then employed at the Air Force Logistics Command, observed the same problem:

> "it required a large amount of special wiring and the wiring got so thick on the back board, the back plane of the machine, that they could no longer get down to the pins to attach more wires through this layer of wiring and there was still a large number of wire connections that needed to be placed, and at that point they gave up on delivering the RCA 601 on its original schedule and, of course, that impacted the decision as far as the [Air Force] Logistics Command was concerned. And, in fact, what they had to do was to go back and redesign a new type of very thin coaxial cable in order to again come forward with the RCA 601." (Tr. 79347-48.)

Thus, after marketing the 601 for a short time, RCA realized that:

> "there were severe technical problems, both in a functional and in a manufacturing sense, and there were also severe financial problems, so much so that the company began to look for a way out of the program." (McCollister, Tr. 9544.)

In 1962, RCA stopped marketing the 601. At that time it decided to honor the "present commitments that were made to customers but not to sell any more". (Beard, Tr. 8457-58.) McCollister believes that RCA manufactured only five 601s and delivered only four. (McCollister, Tr. 9545.)

The aborted 601 program hurt RCA's computer business in several respects. McCollister testified:

"[The 601] cost [RCA] money, from which we received no worthwhile return, both from the manufacture and the development expense, which was quite substantial, and it also lost us time of engineering people because, while they were working on that product, trying to salvage it within the limits that had been established, they were unable to put their efforts into the design of products that might have had a more important business future." (Tr. 9624.)

The failure of the 601 "embarrassed" RCA. (Beard, Tr. 8723-24.)

"[I]t hurt [RCA's] reputation very badly, because we had placed great public emphasis upon the 601 as a product and its capabilities, and it hurt us with several important customers." (McCollister, Tr. 9623.)

The failure of the 601 hurt RCA's ability to market its other products because RCA "had counted on the 601 to fill the upper end of the computer systems market." (Beard, Tr. 8724.) The absence of the 601 "left a void for the 301 customers who were looking to move into larger systems." (Beard, Tr. 8983.)*

The failure of the 601 cost RCA about "three or four years" in development of its computer business. (McCollister, Tr. 9362-63.)

RCA intended the 301 for "regular data processing type work loads". (Beard, Tr. 8955.) It offered an enhancement to the 301 processor, for about a 10% extra charge, that was intended to assist the system in performing scientific applications. Beard considered this "a plus factor" because:

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* In September 1963 RCA announced an interim product, the 3301, which was a relatively large computer designed to substitute for the withdrawn 601. (Beard, Tr. 8455, 8983; McCollister, Tr. 9629.)

"the machine as used by the customers at that time had to be looked at for both their data processing needs, which generally were the primary needs, and the secondary needs of engineering and scientific calculations". (Beard, Tr. 8955.)

RCA experienced some success with the 301. According to McCollister:

"[T]he 301 system was a successful product program and . . . a strong product program, as the sales results of the following years indicated." (Tr. 9622.)

The 301 System had some problems, particularly with some of the peripheral products purchased from other companies.* For example, RCA used a Bryant disk file on the 301. When it failed, "it took a long time to get the necessary parts in to get the equipment back on the air, as much as six hours or twelve hours". (Beard, Tr. 9009-10.) Withington regarded the RCA 361 disk, used on the 301, as a "major product failure" because of reliability problems. (Tr. 56508-09.) Another example is the printer RCA obtained from Anelex, which, "for certain applications . . . had insufficient . . . print quality". (Beard, Tr. 10323.)

RCA "effectively stopped selling" the 301 "somewhere in 1964, '65." (Beard, Tr. 8457.)

By the end of 1961, RCA's EDP division "was in considerable trouble. It had grown rapidly and it was incurring

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* The peripheral products RCA purchased from other suppliers included IBM card readers and punches, Anelex printers, Farrington optical scanners and Bryant disk files. (McCollister, Tr. 9599-600.)

a substantial operating loss and, worst of all, it was in severe technical difficulties." (McCollister, Tr. 9245-46.)

In 1962 RCA decided to resume developing and manufacturing its own peripherals. According to Beard this was done for two reasons:

> "The first was that our experience with some of our suppliers had not been entirely satisfactory. Secondly, it was felt that resources were available to expand the product development to include more work in the peripheral area and that as a consequence of this we would have control over the product characteristics, such things as reliability, and certainly would be able to enjoy a greater contributed value in the product, and our manufacturing costs we expected to be less than the purchase price we were paying to other people". (Tr. 9003-04; see Tr. 8451.)

Stopping and then restarting its development of peripheral products hurt RCA's product line:

> "It certainly had an effect on how far forward RCA was able to move in the development of peripheral products. . . .
>
> "But when RCA decided to redevelop its products, it had lost the continuity of the engineering effort that had been going on in such things as printers and essentially had to reestablish its engineering skills and manufacturing skills in those areas. So in that sense time was lost by the early decision to abandon these peripheral developments". (Beard, Tr. 9004.)

By the end of 1963 RCA's computer business had not made up for its slow development in the late 1950s. As McCollister testified, IBM made "greater strides" than RCA during the 1950s "in the sense of a wider range of products and a larger quantity of products delivered to customers". (Tr. 9552-53.)

26. General Electric. During the early 1950s, General Electric was a large, diversified manufacturer of industrial and consumer products, including electrical generating and transmission equipment, turbines, transformers, jet engines, nuclear power apparatus, process control systems, televisions, radios, and home appliances. (Weil, Tr. 7174-75; DX 14192.) In 1952, GE was "substantially larger than IBM" (R. Bloch, Tr. 7744-45), with corporate revenues approximating $2.6 billion. (DX 14192, p. 30.)*

General Electric's first computers were "rather specialized" systems directed to ordnance and military applications (Weil, Tr. 7012), including the OARAC ("Office of Air Research Automatic Computer") installed in 1953 at the Air Force's Wright-Patterson Air Base. The Air Force described OARAC, a one-of-a-kind computer, as "quite slow, limited in input/output capability, and very unreliable." (DX 4993, p. 4.)

ERMA ("Electronic Recording Method of Accounting"), announced in 1956, was GE's first commercially available computer. (Weil, Tr. 7012; Withington, Tr. 55979; PX 318, p. 34.) ERMA was developed "somewhat on an opportunistic basis" under a large contract with the Bank of America which called for GE to produce "a system basically for reading checks and for doing the accounting

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* GE's revenues rose to $4.1 billion in 1956 and to $4.9 billion in 1963. (PX 325, pp. 34-35.)

within the bank associated with those checks". (Weil, Tr. 7012-13, 7155-56; PX 320, p. 4.) Valued at $60 million, ERMA was the largest non-governmental computer contract to that time. GE produced 30 ERMA systems under the contract for installation, beginning in 1958, at 13 Bank of America branches in California. (PX 318, p. 34.)

ERMA gave General Electric "a head start in the application of electronic data processing technology to the banking industry", but GE failed to capitalize on that head start. (Weil, Tr. 7157-59; PX 353, p. 43.) According to Weil, within General Electric it "was generally regarded and often voiced that [ERMA] was an opportunity that had not been capitalized on, and that was voiced with some regret." (Tr. 7158-59.) His own experience in the computer division was consistent with that conclusion:

> "I can only speak to what I saw when I joined the computer business in 1963 [from another part of GE]. What happened prior to that I really don't know.
>
> "But as of that time General Electric had become more interested in those markets which were normal to it, the kinds of businesses which were typical of General Electric and in which General Electric had user's experience.
>
> "So it was interested in serving the business and technical computations of a kind that were more familiar than banking was. GE is not in the banking business". (Tr. 7157-58, 7004.)

In 1970, in its "Advanced Product Line Master Plan", GE's Advanced Systems Division concluded that ERMA had contributed to GE's image of "fail[ing] to follow through" in EDP:

> "An enviable image in the banking industry was built through the success of the ERMA project and GE's leadership in development of Magnetic Ink Character Recognition

standards. This image was subsequently lost due to neglect." (PX 353, p. 43.)*

While building ERMA, GE also began to manufacture under contract to NCR a processor NCR had designed. NCR in turn marketed that processor to end users as part of the NCR 304 computer system. (Weil, Tr. 7173; DX 387, p. 12; DX 9097, pp. 14-15.) Weil described the 304 as "a minor offering [for GE] . . . intended primarily for use in business data processing, in commercial applications." (Weil, Tr. 7006.) Only 29 NCR 304s were installed by customers; four other 304s were used internally by GE. (DX 401, p. 1.)

In the late 1950s GE also developed the GE 312, which Weil described as a computer intended to perform process control applications. (Weil, Tr. 7166-67.) Using the 312 as the "starting point", GE delivered, in 1961, the GE 225, which was based on the design features of the 312, including circuit components, word length, a similar input/output structure, and a similar instruction repertory. (Weil, Tr. 7167-68; see PX 320, p. 4.)**

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* In the late 1950s, GE did announce the 210, a product "derivative of the ERMA machines" and "aimed at and sold exclusively to banking institutions." (Weil, Tr. 7005-06; PX 320, p. 4.) However, the GE 210 was reported to have achieved only 79 installations at its peak. (PX 3448, p. 19.)

** GE initially had one organization responsible for developing computers used for a variety of applications, including process control. (Weil, Tr. 7166.) However, by 1963, a separate group had been established to focus on process control applications. (Weil, Tr. 7046-47, 7166-67.)

According to Weil, in the early 1960s, there was "in the industry",

"a common belief that specialization of the internal

Weil said that the 225 was "originally intended as a small scientifically oriented machine, although in the end it was not sold that way"; instead, it was sold "increasingly for non-scientific commercial and business applications". (Weil, Tr. 7006-07, 7106.)

> "Some of the [225's] characteristics, and particularly . . . the software that was offered on it [including the GECOM business compiler, a "precursor to COBOL"], made it attractive to such users [for business applications] and I am not sure that it was ever in fact really sold strongly to the scientific market that was its original intention". (Tr. 7016, see Tr. 7170-71, 7262.)

GE advertised the 225 for both business and scientific applications:

> "For the accountant, the GE 225 is a fast, flexible decimal computer; for the engineer, it is a fast, powerful binary machine". (DX 486; see Weil, Tr. 7170-71.)

In the first half of 1963 GE introduced the 215 and 235. (PX 2 (DX 14501).) The 215 was smaller, slower, and cheaper than the 225. Compared with the 225, the 235 employed "more advanced

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portions of a computer could make the computer better adapted for certain kinds of applications, and there was a format of computer which people would look at at that time and say that is a process control computer.

"I might comment that that distinction has since died, but at least at that time in the early sixties, that was a relevant distinction". (Weil, Tr. 7046.)

electronic circuits, and, as such, was designed to be a higher performance, more cost effective later version of the same computing system". (Weil, Tr. 7171.) Weil testified that

> "The 235 . . . was addressed to the same market as the 225, which by then was largely a commercial market, although the additional speed and capability of the 235 did make it more attractive to organizations that had scientific computations. So it probably got somewhat heavier engineering and scientific use, although in those days it was not regarded really as a primary scientific computer". (Tr. 7016-17.)

According to Weil, the features of the GE 235 made it suitable for both scientific and business applications:

> "[F]irst of all, since it was an upward compatible machine with the GE 225 . . . it did all the things that the 225 would do. In addition, it had a special high performance floating point . . . particularly suited for scientific applications. I believe the only way in which the 235 would be more appealing to business data processing than the 225 may have been in the additional peripheral capability that comes from the additional speed of the circuits, and the Dual Controller Selector". (Tr. 7171-72.)

In 1963, GE also announced the DATANET-30 computer, which Richard Bloch described as "a superb machine meant for [a] communication environment"; IBM, he said, had nothing comparable. (Tr. 8033; PX 353, p. 43.) GE believed it "assumed a leadership position in the area of communication systems and communications control concepts" with the announcement of the DATANET-30. (PX 353, p. 43.)

GE also offered data processing services to customers as early as 1963, using GE-manufactured computer equipment. (Weil, Tr. 7159-60.)

> "[GE] provided installations of computers to which people could bring their problems physically for the computer to provide batch processing servicing for their particular problems. It was of the nature of a computer service bureau." (Tr. 7159.)

Through 1963, GE purchased from outside suppliers "quite a substantial share" of the equipment offered as part of GE computer systems, because GE did not develop in-house electromechanical input/output equipment. (PX 320, p. 4.)

In the late 1950s and early 1960s, GE did not "make the allocation of resources to the [EDP] business that were warranted", in the view of Reginald Jones, GE's Chief Executive Officer since 1972. (R. Jones, Tr. 8752, 8874.) According to Jones,

> "I can only say that as early as the 1950's, if we had increased substantially the technical manpower assigned to the business, if we had increased at that time the financial resources required for the business, they would have been much smaller in terms of absolute numbers than they would have been, let's say, some fifteen years later." (Tr. 8875.)

Ralph Cordiner, GE's chief executive from the mid-1950s through 1963, shared that view. Jones testified that Cordiner was once asked to identify the most important mistakes GE had made in managing its computer systems business, and Cordiner was quoted publicly as having said that:

> "General Electric's mistake was that it failed [in the 1950s and early 1960s] to realize the opportunity and therefore made an inadequate allocation of resources, both human and physical, to the business." (Tr. 8869, 8875-76.)

As early as 1964 Mr. Van Aken, General Manager of GE's Computer Department, reported to GE's "executive office":

"As a result [of GE's] late start and limited product coverage, General Electric did not participate to any great extent in the expansion period of 1960-1964". (PX 320, p. 04; Weil, Tr. 7084-85.)

Weil reported at that meeting that GE, through 1963, had not begun "to bring its corporate strength behind its entry into the information business". (PX 320, p. 18.)*

Weil contrasted GE's commitment to success in the atomic power business with its relative lack of commitment to the computer business in the early 1960s:

"General Electric was then . . . a very strong supplier of major equipment to the power generating industry, turbines and generators and the like.

"Nuclear power, which was a set of equipment that went to the same customers and into the same plant, was regarded as, first of all, an adjunct to that core of business of the company and, second of all, that if someone should get in the business of supplying central station nuclear power on a turnkey basis, that perhaps GE would lose some of the business it enjoyed in turbines and generators, so that was regarded as a threat to a strong existing business.

"It was clear that the mission of the nuclear power business was: We don't know whether there is a business, but if there will be a nuclear power business, you will be one of the leading competitors.

"That was the charge as I interpreted it to the Atomic Power Equipment Department.

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* Richard Bloch, who was in charge of computer divisions at Raytheon and Honeywell in the 1950s and early 1960s (Bloch, Tr. 7566, 7575-76)(and who was "unimpressed" with GE when he was asked to and did in fact join GE in 1968 (Bloch, Tr. 7616)), testified that in the 50s and early 60s it had been his feeling that GE's commitment to the EDP business was "tainted with some tentativeness or speculativeness . . . as a long-term commitment to the field. My feeling was that if it turned out to be a great success, the company would be delighted; if it turned out not to be a great success, the company could extinguish parts or all of its activity in the field without necessarily any great remorse". (Tr. 7623-24; see Tr. 7616.)

"The computer business I don't believe was ever viewed as a threat in any strong sense to other businesses that General Electric was in. And the equivalent charge might be: We are sure there will be a computer business, now you must demonstrate that you can compete." (Weil, Tr. 7174-76.)*

Even though GE failed to commit adequate resources to EDP during Cordiner's years as its chief executive, Weil testified that in the 1963 time frame, GE "had several major advantages which could make it a factor, a serious factor, in the computer business". (Tr. 7009-10.)

"It had a very broad technical basis in the many different businesses in which General Electric participated at that time. Many of these technologies would be applicable to the computer business.

"Second of all, General Electric used computers very broadly. They were in fact one of the pioneering users in the commercial world of computers and as such probably understood how to use the then existing computer technology as well as anyone.

"Thirdly, because of the capital resources of General Electric, it could devote, if it wished, enough effort to put all this together and become a significant competitor." (Tr. 7009-10.)

Weil added that from a technical standpoint in the early 1960s, GE had "[m]ixed" competence for developing its computer business:

"Very strong in basic technology and background and experience in using computers; relatively naive when it came to the discipline of manufacturing large electronic systems or designing them or bringing them to market." (Tr. 7010.)

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* By 1963, GE had 35 distinct product and service groups consisting of approximately 100 departments. Only two of these departments were dedicated to the computer industry. (PX 325, p. 15; DX 485; see also Weil, Tr. 7153-54.)

In 1963, revenues of GE's Computer Department were less than 1% of GE's total corporate revenues. (PX 325, p. 2; DX 8631, p. 31.) Its United States EDP revenues totalled only $38.6 million in 1963. (DX 8224, p. 6; DX 8631, pp. 33, 37; DX 14484, p. R1.)

27. Electrodata. Electrodata began as a division of Consolidated Engineering Corporation (CEC), "a company in the technical data recording and acquisition field" which made mass spectrometers and "a line of scientific instruments [transducers]" used "to sense physical phenomena and data and to record them in one form or another during the testing of physical devices such as aircraft". (McCollister, Tr. 10995-96, 10998-99; see DX 12674.)*

McCollister (who left IBM's employ in 1954 to become head of marketing at Electrodata (Tr. 9161)) testified that in the early 1950s CEC viewed computers "as a new business opportunity" and "a logical addition to their product line": "If you could sense data and record data, the final link in the chain was to process data. So, with the aid of a consultant or two, CEC undertook the development of a digital data processor, the CEC . . . Model 202 or 203 . . . and this is what became the Electrodata Corporation Datatron 203/204".** CEC spun off Electrodata in the early part of 1954: "[F]or reasons, in large part, of financing [CEC] decided to set it up as a separate corporation and to sell stock publicly". (McCollister, Tr. 10995-96.) Electrodata's initial capitalization

* CEC reported revenues in its 1952 Annual Report of approximately $8 million. (DX 14329, p. 3.)

** McCollister testified that in the mid-1950s there were several model numbers of Datatron computer systems, the 203, 204 and 205; however, "the central computer in all these cases was identical". (Tr. 9164.)

was between $1 and $2 million. (McCollister, Tr. 11001, 11006-07; see DX 698, p. 6.) McCollister estimated that Electrodata's first computer system, the Datatron, cost in the neighborhood of $300,000 to $500,000 to develop. (Tr. 11001; see DX 700, p. 9.)

The first Datatron (with a "basic cost of approximately $120,000") was shipped in June 1954 to the Jet Propulsion Laboratory in Pasadena; six additional Datatrons were installed that year by the U.S. Naval Ordnance Laboratory, Socony-Vacuum Oil Company, Purdue University, Allstate Insurance Company, the Arma Division of American Bosch Arma Corp., and Land-Air, Inc. (located at Wright-Patterson Air Force Base). (DX 698, pp. 4-5; see McCollister, Tr. 11000-01.) Electrodata's revenues were just under $1 million in 1954. (DX 698, p. 7.)

McCollister testified that the Datatron

> "[i]nitially . . . was sold largely to the engineering scientific marketplace. Subsequently it was offered to the commercial marketplace due in part to the fact that the All State Insurance Company became a major customer and this led to our going into the commercial marketplace or so-called data processing marketplace as well as the scientific.
>
> ". . . .
>
> "We were a small company. The potential business with AllState Insurance was so important to us that we really couldn't ignore it.
>
> "We needed the business. We had to get it wherever we could. This led to our seeking opportunities in the commercial marketplace as well as in the scientific, engineering marketplace." (Tr. 9164-65.)

In its 1954 Annual Report, Electrodata stated that the "[d]evelopment of a general-purpose computer opened up a broader potential market than was originally anticipated". (DX 698, p. 4; see McCollister, Tr. 11016-17.)* McCollister testified that the Datatron, "within the limits of its capabilities, its technical capabilities, . . could solve any of a wide range of problems or perform tasks both in the field of engineering computation, technical computation and in business accounting, record keeping and statistical work"--"the list of ways in which it would be used is almost infinite". (Tr. 11017-18.) For example, in its 1955 Annual Report, Electrodata depicted Datatron computer equipment used by Allstate to keep "up-to-the-minute records on three million policyholders", as well as Datatron equipment at the Southern California Cooperative Wind Tunnel, used to process "in seconds thousands of test data on aircraft undergoing supersonic shock" (an application described by Electrodata as "high-speed data reduction"). (DX 700, p. 7.) Withington, who was initially employed in Electrodata's home office marketing support group and became District Manager of Technical

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* Electrodata reported in 1954 that "[a]s a result of the operating success of the installed DATATRON systems and the apparent potentialities for future sales, we have more than doubled our personnel, begun work on a new plant with twice our present production capacity, and undertaken development of auxiliary and accessory products to broaden our potential market". (DX 698, p. 3.)

Services from 1957-59 (Tr. 55498, 55500), similarly testified that the Datatron 205 "was a medium-priced general-purpose computer as defined at that time, capable of both business and scientific applications and with what was for those days a wide range of peripheral equipment". (Tr. 55499.) He testified that Datatron 205 customers included Atlantic Mutual Insurance, Michigan Bell Telephone, the U.S. Geologic Survey, and Navy and Air Force installations. (Withington, Tr. 55503-04.)

McCollister testified that the initial competition for the Datatron 203, 204 and 205

> "in the scientific marketplace . . . was almost entirely IBM [the 650].
>
> "In the commercial marketplace we encountered IBM [the 650 and "in a few cases" the larger IBM 705] and very, very occasionally the Univac file computer." (Tr. 9165-66.)

Withington testified that he had considered the IBM 650 to be the "primary competitor to the Datatron 205". (Tr. 55506.)

By March 1956, Electrodata had installed 24 Datatron computing systems (some purchased and some leased), with "unfilled orders for 19 additional systems". (DX 700, pp. 3-4.)*

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* In 1956 two new peripheral products were introduced, the "Cardatron" and "Datafile", for use with Datatron computers. (DX 10257, p. 5; see DX 700, p. 6.) The Cardatron used "individual magnetic storage drums as buffers", and controlled the operation of "as many as seven card readers as inputs and punches or printers as output". With the Cardatron, all of

Electrodata was also operating a "contract data processing center" in Pasadena, which it described as the oldest and largest such facility in the West. (DX 700, p. 3.) With assets exceeding $3 million, Electrodata's 1955 revenues were $1,845,327. (<u>Id.</u>, pp. 3-4, 8.) According to its 1955 Annual Report, Electrodata entered 1956:

> "equipped with the essential elements to assure profitable growth. Its long-range plans include manyfold increases in staff and facilities, and continued vigorous development of new products to take advantage of a dynamic market." (DX 700, p. 6.)*

Electrodata was acquired by the Burroughs Corporation on June 29, 1956, in return for 475,465 shares of Burroughs stock valued at $20,504,000. (Stipulation of the Parties, Tr. 11036; see DX 700, p. 6.)

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that input/output equipment could "operate simultaneously at maximum speed", enabling "the computer to do its work of computation continuously".

The Datafile was an auxiliary storage, random access device, described by Electrodata as using "short, 250-foot, disconnected lengths of magnetic tape housed in static-free metal bins, rather than conventional tape reels, [which] substantially shortens the time required to locate any record". (DX 10257, p. 5.) Withington described the Datafile as a "major product failure" because it was "insufficiently reliable, or, put another way, they never worked for very long". (Tr. 56470.)

* In 1955-56, Electrodata again, in response to "market demand for Datatron systems", expanded its production facilities with financing provided by its largest customer, Allstate Insurance. (DX 700, p. 5.)

28. Burroughs. Kenneth Tiffany, a Burroughs Vice President, in a speech delivered in 1959, described Burroughs at the outset of World War II as a manufacturer of adding machines, accounting and bookkeeping machines and cash registers. During the War, Burroughs "placed its facilities and know-how in precision fabrication at the disposal of government" and produced, among other things, the Norden Bombsight on a large-scale basis. According to Tiffany, virtually all of Burroughs' war-time business was for the military. (DX 10282, p. 2; see also DX 10283, p. 1.)

At the end of the war, Burroughs mounted a substantial effort to return to its more traditional businesses; however, as Burroughs president Ray Eppert described in a 1959 speech:

> "World War II propelled Burroughs into other fields which ended our preoccupation with purely mechanical equipment. Experience with military contracts, and management awareness of the new era which technology had ushered in, caused the company to move into electronics and thence into automation and data processing." (DX 10283, p. 1.)

In 1947, Burroughs decided to begin its own electronics research. According to Ray Macdonald, who joined Burroughs in 1935 and who became President in 1966 and President and Chief Executive Officer in 1967:

> "The decision to begin electronics research, which may have been the most important decision to Burroughs in the past 30 years, was made by John Coleman, who was then our President. He determined that our company should develop its own scientific capability

> and development program in close association with the great technical universities.
>
> "That decision represented courage and foresight, because in the 1946/1948 period, our revenue averaged less than $100 million a year and our net profit was as low as $1.9 million, in 1946. Yet Coleman began the electronic research and development program in excess of $1 million per year, rapidly expanding to $3 million, because he recognized the importance of electronics and of establishing our own capability. A significant portion of our R and D budget was allocated to the critical area of applied research.
>
> "The early research performed under Coleman's direction, and continued and expanded by his successor, Ray Eppert--who increased the R and D budget to four percent of revenues in spite of modest profit--produced substantial invention and design. By the early 1960s, we already had introduced significant early data processing systems." (DX 427, p. 4.)

According to Macdonald, the post-war years also marked the end of the "era of traditional management by the founders of Burroughs" with the selection of Coleman ("a university-trained manager and career manager in Burroughs") as President. (DX 427, p. 2.) In Macdonald's view:

> "Professional management of our company was given strong impetus during Coleman's administration, with the introduction of a program to attract young university-trained people from many of the country's leading schools of engineering, science, and business administration. Many of these new people, entering our company in the late 1940's and in the 1950's, reached the early levels of management and intermediate levels by the late 1950's. By the early 1960's, they had matured in responsibility and some had reached the level of senior management.
>
> "Our company was fortunate in developing this professional management, because we were required [in the 1960s] to bring about a major transformation of our business." (DX 427, p. 2.)

In 1953, Burroughs reported that its Philadelphia Research Center had "completed a static magnetic memory to be used with the United States Army's ENIAC, first of the electronic digital computers," and that this memory "increase[d] ENIAC's memory six-fold." (DX 10254, p. 12; see also DX 10255, p. 8.) However, in the same report Burroughs downplayed the immediate significance of computers to its office equipment business:

> "[D]espite extraordinary advances in new fields of technology, the automatic office cannot be expected in the near future.
>
> "<u>New Techniques Not Yet Practical</u>
>
> "While a few electronic devices have been applied to highly specialized office problems, the majority of electronic computers now in operation were designed for scientific use. In this field the input and output problem is relatively simple. The core of the job is rather the complex and vast work of computation. But in business the arithmetic is usually not difficult. It is the feeding of the business machine, item by item, and the printing of the result which is both time consuming and costly. It would be no advantage to speed up the rate of figuring, if input, output and other peripheral operations did not keep pace.
>
> "<u>Other Difficulties</u>
>
> "There are other difficulties, too, which will delay the practical application of electronics to the office, not the least of which is the major obstacle of cost. The outlook for electronics in business, then, must be summed up in the words 'not yet.'" (DX 10254, p. 15.)

In the early 1950s, Burroughs built two models of an experimental computer, called the UDEC (Unitized Digital Electronic Computer) one of which was installed at Wayne

University in Detroit as part of its Computation Laboratory.* (DX 10255, p. 8.) Burroughs reported in 1955 that it was using a redesigned and reassembled UDEC (called UDEC II) to solve "complex problems in such fields as design analysis, production scheduling, cost analysis, inventory control and market forecasts." (DX 10256, p. 8.)

In 1954, Burroughs introduced its first commercial computer, the E-101, which it described as "the first of a series of low-cost electronic digital computers for scientific and business use . . . designed for the large volume of computations between the problems adaptable to mechanical devices and the highly complex problems requiring large-scale electronic computers." (DX 10256, p. 8.) The E-101 was "desk size" and "employed a modified accounting machine for input from the keyboard and output to the printer, and its program was provided through an external plug board." (Withington, Tr. 56499; DX 5652, Bruns, pp. 5-6.) Withington testified that the E-101 was "perhaps the very first of the small scientific computers," though he also testified that it was intended for use both by "actuaries and other business

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* Burroughs stated that the "[p]rimary purpose of UDEC in Wayne's educational program is to help train urgently needed personnel for the operation of the country's growing number of electronic computers and to seek new developments in the field of automatic data processing equipment." (DX 10720, p. 2.)

mathematicians, and also by scientists having problems small enough to be able to fit within the limitations of this external plug board." (Tr. 56498-99.)* Burroughs shipped the first E-101s in 1955. (DX 10713, p. 11; see Withington, Tr. 56499.) According to Withington, the E-101 was a major product failure:

> "The business market for it never developed, perhaps because the things it could do were too limited, and the scientific market proved to be of limited size for the same reason. The basic reason for its failure, then, was that the external plug board program provided insufficient versatility to handle the problems of users." (Tr. 56499.)

In 1954, Burroughs reported that it was also developing computers for the military and had integrated that defense work with its commercial research, development and production activities:

> "Because of its strong position in electronics, electro-mechanics and magnetics, Burroughs has been

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* In a 1956 speech to security analysts, Kenneth C. Tiffany, Burroughs' Vice President of Finance, noted that:

> "[M]ost of the well-publicized large-scale computers, or 'giant brains' as they are popularly called, require a sizeable investment. The mere price of these so-called 'giants' has greatly restricted their use. Only the larger corporations have been able to afford them.
>
> "We feel that the E101 and its successors will make a profound change in this situation. Its cost--about $35,000--is low enough to make it a practical tool. Moreover, we expect to lease many of them. . . . [B]ecause of its low cost, small size, and versatility, we expect it to bring electronic computing techniques within the reach of a much wider range of users." (DX 10281, pp. 22-23.)

> given responsibility for highly specialized work for the armed forces, both in research and production. Several extensive long-range projects are being carried on, including the development of general-purpose and special-purpose computers for data-handling systems. Involving as it does techniques closely associated with the Corporation's work in new type equipment for business and industry, the defense program has been integrated with Burroughs' commercial research, development and production activities". (DX 10256, p. 4.)

Burroughs used its defense work to bolster its efforts to market computer equipment to commercial customers. Kenneth C. Tiffany, Financial Vice President of Burroughs, said that Burroughs "began to seek out defense contracts for which its facilities and capabilities were best suited and which had the greatest potential for commercial systems development." (DX 10282, p. 2.) He continued:

> "We did not, however, break into electronics with a San Juan charge . . . rather, we insinuated ourselves into a field that was still unknown and unpredictable, testing every step of the way. A major stimulus was our receipt of government contracts involving precision computational and data processing equipment in the area of fire control, navigation, anti-aircraft battery evaluation, and ultimately, the guidance computer for the Atlas ballistic missile and the data processing systems for the SAGE intercontinental air defense network." (DX 10282, pp. 5-6.)

During 1955, Burroughs received contracts to build equipment for use in the Air Force's SAGE system-- namely, hard-wired computers to process data collected by radar units for transmission over phone lines to SAGE direction center computers. (DX 10713, p. 9; DX 10714, p. 8; see Crago, Tr. 85964-65.) Deliveries of these large-scale computers began in 1956. (DX 10257, p. 5.) Burroughs also received a contract from the Air Force to build computers for the ground guidance system of the ATLAS ballistic missiles. In its 1957 Annual Report Burroughs reported that it had "complete responsibility for the concept, design and production" of those computers, which it described as "large-scale" and"general purpose". (DX 10714, p. 8; DX 10281, p. 28; see also DX 10288, pp. 10-15.)

In its 1957 Annual Report, Burroughs disclosed that its SAGE orders to that point were nearly $40 million, and its ATLAS contracts totaled $37 million. (DX 10714, p. 8.)

Referring to the SAGE and ATLAS projects, as well as other defense work, Burroughs Vice President Kenneth C. Tiffany stated in a speech to security analysts in 1956:

> "The knowledge gained from our research, the development of original concepts and design ideas, and the experience in high precision volume production are also invaluable in the design and production of our commercial line.
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> "[T]his reasoning--that our defense experience will help to accelerate the Company's plans for automatic business systems of the future--lies behind most of our defense work . . . ." (DX 10281, p. 28; see DX 10713, p. 9.)*

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* According to Burroughs another example of Burroughs' defense work was the NADAC, an airborne digital computer developed as a result of a 1956 "Burroughs-sponsored study." Burroughs described the NADAC as a "high-performance, high-capacity, solid-state, general-purpose, airborne, digital computer" which could "perform, in real-time, essentially any computation problem required by modern combat aircraft",

As already noted, Burroughs acquired Electrodata in 1956, which contributed to "greatly strengthen[ing] the corporation's competitive position in the growing field of electronics". (DX 10257, p. 4.) Indeed, Ray Eppert, Burroughs' President, said the acquisition "made Burroughs one of the world's three major producers of electronic data processing systems". (DX 10283, p. 2.) McCollister testified that in the 1956 to 1960 period, Burroughs' Electrodata Division was "still in the scientific marketplace but increasingly in the commercial marketplace because this was the one that Burroughs as a company tended to have more exposure than in the scientific marketplace". (Tr. 9194, see also Tr. 9189.) McCollister said the Datatrons (including the Datatron 220 (described below)) in that time period met IBM in the scientific and commercial marketplace, and the Honeywell 800, the RCA 501, and the Univac II (at least on one occasion) "in the commercial market". (Tr. 9182.)

According to a 1957 Burroughs news release its Electrodata Division began production of the Datatron 220 computer systems for delivery in December 1958. (DX 10272,

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and whose capacity was "equivalent to that of ground-based computers many times larger and heavier" at that time. Burroughs reported that the NADAC prototype was accepted by the Navy in June 1959. (DX 10288, pp. 10, 17.)

p. 1; see also DX 10288, p. 30.)* The 220 however, was a vacuum tube machine; it soon faced competition from transistorized computers such as the IBM 7070 and 1401 (described by Withington as the 220's "primary competitor[s]") 56500):

> "[The Datatron 220 was] the last vacuum tube computer ever announced. It was superseded within two years by [the] IBM 7070, which was both a second-generation machine of much better price/performance, but also offered the beginnings of improved programming tools, and the Datatron line came to a sudden and permanent end." (Tr. 55918.)

According to Withington, because the 220 was "wrong in establishing a set of standards and ways of designing a machine, the company effectively left the [computer] business and re-entered only later". (Tr. 55918-19.)

In 1958-59, Burroughs was nevertheless working on developing new computers. Eppert described Burroughs' research and development at that time as follows:

> "Our research expenditures have been very large and they were deliberately made in the belief that this action was essential in an exploding technology. We

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* When the 220 was announced, Burroughs' Electrodata Division had reportedly installed approximately 200 Datatron 205 and E-101 computer systems. (DX 10272, p. 1.) According to Burroughs:

> "[T]he satellite input-output capabilities of the 220 give it its greatest power. One adjunct to the system, as important as the entire computer, is the new high speed printer system announced last year." (DX 10282, p. 7.)

chose to defer profit-taking and divert revenues into intensive product development as long-range insurance for our competitive position. This action resulted in reduced earnings during recent years. (DX 10283, p. 3.)

Eppert noted that defense contracts continued to play an important role in those research efforts:

"There is another important factor in our research program--namely, the powerful stimulus provided by military development contracts. As you know, the electronics technology got its initial thrust from the wartime demand for advanced weapons and data reduction systems. Since then, our defense needs have paralleled the mounting pitch of international tension. The result has been a continuing high level of military awards to industry.

"This team effort in researching for new break-throughs in technology has had the effect of developing scientific and engineering know-how in a fraction of the time such new developments would otherwise have consumed. No one private company could afford the basic research required for many of the new techniques if it had to depend entirely on its results in the marketplace to repay its efforts. But the knowledge gained by organizations involved in research for new military techniques is helping to strengthen total competency on commercial products.

"Burroughs has shared in these government-under-written programs. Among our achievements has been the guidance computer for the Atlas intercontinental missile and data processing systems of the SAGE warning network for continental defense.[*]

"The Atlas computer project led to several major design breakthroughs in miniaturization, solid-state

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* Burroughs reported that it had a continuing substantial involvement with SAGE throughout the 1950s; for instance, in late 1959, it was awarded system management of the SAGE ALRI program to build an airborne version of the AN/FST-2 Data Processor. (DX 10288, p. 11.) It was reported that by 1959 Burroughs contracts in connection with SAGE and ATLAS exceeded $220 million. (DX 10282, p. 4.)

electronics and human engineering.

". . . .

"This cross fertilization between our military and commercial development activities has important implications for the future." (DX 10283, pp. 6-7; see also Withington, Tr. 55976-77.)

By the early 1960s, Burroughs introduced several new data processing systems, including "the D 825 computers which were designed for government communications management, and the B 5000 and the B 200 general-purpose systems, both of which were designed for general commercial use." (DX 427, pp. 4-5.)

According to Withington, the D-825 "was the progenitor" of the B-5000 (Tr. 58527), which according to Burroughs was first delivered in 1963. (DX 10419; DX 10420.) The B-5000 was "an entirely different product with an entirely new type of machine architecture" as compared to the 220. "[I]t was in fact military work which provided the origin of the B-5000 commercial computer, which in turn was the foundation of Burroughs' subsequent successful product line." (Withington, Tr. 55918-19, 55976-77.)

Despite these new product introductions in the early 1960s, Burroughs still had not, in the view of Ray Macdonald, made the "major transformation"--from electro-mechanical office equipment to electronic computer technology--

it would have to make to survive.* (DX 427, pp. 4-5.) In Macdonald's words,

> "The survival of Burroughs required that we supplement the precision mechanical technology of the earlier office machine industry--at which we excelled--and establish ourselves as a major force within the new, electronic, data processing industry, which embraced an entirely new technology. These two technologies--and the new and the old 'breeds' of people who represented them--had to be reconciled and coordinated, and an entirely new range of products had to be developed which would make use of the best of both technologies.
>
> "The roster of companies which have failed when a dramatic invention made their traditional products obsolete is long and sad. New inventions and new technologies have added significantly to the productivity of our industrial society, and they have made possible a standard of living beyond the imagination of only a few generations ago. But they also have left many a proud enterprise in shambles, outdated and unable to continue in a competitive environment." (DX 427, p. 4.)

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* Burroughs' total revenues rose from $151,326,854 in 1952 to $390,773,545 in 1963. Its U.S. EDP revenues for 1963 were $42,145,000. (DX 10254, p. 17; DX 10260, p.28; DX 8224, p. 1.)

29. <u>National Cash Register.</u> According to John J. Hangen, NCR's Vice President of Finance (Hangen, Tr. 6233-6241), "[f]rom the 1880's until the early 1920's NCR was a single product company--the cash register. In the 1920's the company entered the accounting machine market, and in 1943 NCR purchased the Allen-Wales Adding Machine Company." (DX 372, p. 1; see Oelman, Tr. 6117-18; DX 7635, Anderson, pp. 12-13.)

In the late 1930s, NCR began "to experiment with electronics" and "formed a very small electronic engineering group of only two men who . . . did build a device which through vacuum tubes performed all the normal arithmetic functions." (Oelman, Tr. 6120; DX 337, p. 24.) During World War II, NCR suspended its commercial electronics research, but did "some secret work for the government" in its electronics division. (DX 9097, Oelman, p. 9.)* From the end of the war until 1952 NCR resumed research in electronics on a small scale. (Oelman, Tr. 6120-21; DX 9097, Oelman, p. 9.) During that period NCR produced an electro-mechanical Bombing Navigational computer described by NCR as "in effect, a giant brain which calculated at such speed that its answers are practically continuous". (DX 360, p. 10.)

In 1953, when NCR's total revenues approximated $260 million (DX 481, p. 20), it acquired the Computer Research Corporation, "a small spin-off of the Northrop Aircraft Corporation" (Oelman, Tr. 6121; Hangen, Tr. 6262), "to expand

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* We understand that the Court has not yet ruled on the admissibility in evidence of DX 9097. We nevertheless rely on it because it is the sworn testimony of NCR's chief executive officer.

substantially [NCR's] efforts in electronic research and development". (DX 360, p. 12.)* CRC "was one of the earliest manufacturers of medium-priced general purpose systems". (Withington, Tr. 55983.) A 1952 CRC ad listed three digital computers (the CRC 107, 105 and 102-A) available, for either sale or lease, to perform "engineering, science and business" applications. (DX 12655.)** NCR paid approximately $1 million to acquire CRC and, within two or three years, had invested an additional $4-5 million in the company. (Oelman, Tr. 6121-22.) Oelman described NCR's reasons for acquiring CRC as follows:

> "Well, at that time it was becoming quite clear I think that the mechanical state of the art, that's the state of the art of mechanical engineering, had just about reached its zenith, just about reached its peak, and we could see that through electronic technology, you would have a product, the computer, which could be sold for general business purposes, and we could also see that our traditional products, the cash register, the accounting machine, that you could apply electronic principles to those products and achieve results, hope-

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* CRC was "a Hawthorne, California, based organization founded in 1950 by five talented missile-guidance systems electronic engineers from Northrop Aircraft". (DX 372, p. 1; DX 9097, Oelman, p. 10.) "They had set themselves up . . . as a small producer, mainly of computers for the military." (DX 9097, Oelman, p. 10.)

** Oelman, NCR's Executive Vice President in 1963 and subsequently Chairman and Chief Executive Officer, took a narrower view of CRC's business; CRC, he said, "was engaged in the business of building a very few scientific computers, which they sold some to the military branches of the government and some to air frame companies" to solve, for example, "very complicated differential equations" or to "determine the location of an airplane in flight". (Tr. 6121, 6123; see also DX 9097, Oelman, p. 10.)

fully, far better than we were able to get through mechanical methods and at considerably lower costs.

"Also, I think another thing is probably true, that at that period of time there were -- there was a movement throughout the business equipment industry of some of the major companies acquiring smaller electronic companies. I recall at that time Burroughs Adding Machine Company acquired one, Underwood did, Marchant did, and NCR did, so it was kind of a general movement of recognition of what the state of the art could do for business equipment." (Oelman, Tr. 6122-23; see DX 9097, Oelman, pp. 11-12.)

Shortly after the CRC acquisition, NCR introduced the CRC 102D computer for what Oelman described as business as well as some scientific applications. (Tr. 6124; DX 9097, Oelman, p. 13.) However, NCR did not pursue the production of CRC's existing line of what Oelman described as "scientific" computers. (Oelman, Tr. 6121, 6124; see DX 337, p. 24.) Instead, NCR stated in its 1953 Annual Report:

"We have always been associated with recordkeeping in the average business up and down Main Street: the retail store, the bank, the department store and many others. In this field lies our greatest experience with the problems involved and our first responsibility for the development of new methods. We have, therefore, devoted our efforts to applying the advantages of electronics to the fields we have always served." (DX 337, p. 24.)

In 1954-55, NCR worked on the development of a computer system called the 303. However, the 303 was never produced, manufactured or delivered. (Hangen, Tr. 6292.) Development was discontinued around 1955-56 because, as Hangen testified: "it used an earlier technology [vacuum tubes] and . . . in our judgment it would not meet the marketplace in an early enough time frame to make it a viable system". (Tr. 6292-93.) NCR redirected its efforts towards designing a transistorized computer system called the 304. (Hangen, Tr. 6292-93; DX 9097, Oelman, p. 14.)

NCR's U.S. EDP revenues rose from approximately $317,000 in 1953 to $3,102,000 in 1954. In 1955, EDP revenues fell to $211,000 and rose only to $308,000 in 1958--a year in which NCR's total corporate revenues were $394 million, apparently reflecting NCR's sluggish EDP product development during that period. (DX 8224, p. 3; DX 400, p. 1.)

In 1957, NCR finally announced its new solid state computer, the 304, designed by its Hawthorne Electronics Division and scheduled for delivery in late 1959.* (DX 387, p. 12; DX 400, p. 14; DX 9097, Oelman, p. 14; see also Hangen, Tr. 6293.) It cost "between five to 10 million" dollars to develop, and was priced between $750,000 and $1,250,000 depending on the peripherals selected. (Hangen, Tr. 6294; DX 482, p. 14.) The 304 CPU was designed by NCR, but was production engineered and manufactured by General Electric for NCR, using transistorized computer circuits GE had developed. (DX 387, p. 12; DX 9097, Oelman, pp. 14-15; see

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* Hangen claimed the 304 was the "industry's first all-solid-state system". (DX 372, p. 2.)

Weil, Tr. 7006, 7172-73.) NCR also obtained certain peripherals from GE. (DX 400, p. 14; DX 9097, Oelman, p. 15.) NCR "thought that General Electric was more experienced in the art at that time than NCR was, and that a joint relationship would be helpful and profitable to NCR". (DX 9097, Oelman, p. 15.)

Although Oelman and Hangen described the 304 as NCR's "major entry into general purpose computing systems,"* NCR's "[m]arketing strategy was to sell [the 304] to selected customers only since this product was considered as an experimental entry into the EDP marketplace". (Oelman, Tr. 6127; Hangen, Tr. 6293-94; see also DX 401, p. 1.) NCR's original plan projected installation of 25 systems; actual installations totaled 33 of which four were used by GE for internal purposes. (DX 401, p. 1.) The 304 performed order processing, customer billing, inventory control, actuarial studies, and personnel records applications. (DX 400, p. 15.)

In 1960, NCR began marketing the small 310 computer manufactured by CDC. (Oelman, Tr. 6158; DX 401, p. 1.) Though marketed as the 310 by NCR, the basic computer hardware was

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* Oelman, in using the term "general purpose computer system" said that "[g]eneral purpose is simply described as the function of the computer system". It is "an adjective describing the type of system". (Tr. 6132-33.) Hangen used the term "general purpose computer system" to refer to the "type" of computer that "would normally be used on business applications". (Tr. 6293.)

the CDC 160 which NCR did not modify. (Oelman, Tr. 6158; Hangen, Tr. 6321-22; DX 331, p. 4-5.) NCR had "an exclusive right to sell this CDC equipment in the financial and retail markets of the United States." (DX 330, p. 2; DX 331, p. 4-5.) The 310, which NCR viewed as "a rather minor computer line" (Oelman, Tr. 6158), was sold by NCR's accounting machine salesmen rather than by its EDP salesmen. (DX 401, p. 1.) Withington classified it as a major product failure in part because it was one of the last vacuum tube machines. (Tr. 56510-11.)

NCR began operating computer data centers in 1960, using first the 310, and later the NCR 315. According to Oelman, the data centers performed a "variety of types of work. For example, we sell the service to many small retailers who furnish us information on their sales breakdown and then we take that information and come up with merchandise reports, inventory control reports, that type of work". (Oelman, Tr. 6163.) NCR continued to expand its data processing centers in 1962. The firm's Dayton center processed "several million items monthly" at that time. (DX 403, p. 11.)

In 1960, NCR introduced the 390, a computer developed in Dayton (i.e., not by CRC) to offer "moderate-cost" data processing "[f]or the small business firm." (Oelman, Tr. 6130; DX 382, pp. 3, 12.)

In 1960, NCR also announced the 315 computer system first shipped in early 1962.* (DX 382, pp. 3, 10.) When NCR priced the 315 "in late 1960, it was estimated [NCR] could secure 200 orders for delivery over three to four years at the rate of five systems per month". (DX 746, p. 1; see Hangen, Tr. 10767.) NCR in fact obtained orders for 135 such systems by 1962, and by the end of the program had delivered approximately 700 of its 315 systems. (Hangen, Tr. 10762, 10764.)

In connection with the 315, NCR developed its Card Random Access Memory Unit ("CRAM"). NCR described CRAM as a "revolutionary electronic filing unit". (DX 402, p. 12.) Hangen testified that the

> "CRAM unit was a magnetic storage device which operated on the basis of 256 magnetic cards that were available from memory for the recovery of information stored on those cards and rewriting of fresh information. It provided a capability of being able to access the information at a faster speed than that which would be available under your normal magnetic tape device, since you could randomly select the cards, but on a magnetic storage device, you had to sequentially search for the information." (Tr. 6311.)

Withington classified NCR's CRAM as a major product failure because "it too required replacement by disk drives". (Tr. 56469-70, 56511.)

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* Asked whether the 315 was designed as a replacement for the 304, Oelman stated that "[a]ll these successive families of computers, they are designed for replacement, but also hopefully to accomplish a great deal more at less cost." (DX 9097, Oelman, p. 16.)

NCR's "315 system was developed as a family of products giving NCR a range of computer systems" renting from approximately $5,000 per month to $12,000 per month. (Hangen, Tr. 6314.) The 315 had both COBOL and FORTRAN compilers. (DX 342, at 7.) NCR advertised the 315 with CRAM as a "general-purpose computer to handle both your business and scientific problems". (DX 350B; see also DX 383B.) "Typical" NCR 315 installations included "those of a large aircraft company for part scheduling and control and a motor manufacturing company for production control, inventory control, and design". (DX 403, p. 8.)

NCR's strategy was "to sell our traditional customers and our traditional equipment in conjunction with the delivery of 315 computers in order to satisfy the customer's total systems requirements." (Hangen, Tr. 6319.) Thus, NCR "developed cash registers which would produce as a by-product of the clerk's recording of the transaction, either a punch paper tape or sales journal . . . . which then could be used to provide input to the computer system". (Id.)

Oelman testified that from the mid-1950s through the early 1960s NCR's main competitors in the manufacture and marketing of computer systems for business purposes included Burroughs, IBM, Univac, RCA, GE, Honeywell, and CDC ("in some cases"). (Tr. 6125, 6129.)

NCR's U. S. EDP revenues rose from approximately

$308,000 in 1958 to $30,718,000 in 1963. (DX 8224, p. 3.) NCR's total revenues in 1963 exceeded $592 million. (DX 344, p. B.)

30. Philco. With 1952 revenues of $366 million, Philco manufactured industrial, military and consumer electronics products. (DX 14196, pp. 1-2.)

In approximately 1955, based on its work to develop a "surface barrier transistor", Philco won a competitive award to develop an airborne computer for the U. S. Air Force. (DX 7512, p. 190.) In 1955-56, Philco developed three one-of-a-kind transistorized computers, the C-1000 (described by Philco as an "airborne real-time, general purpose parallel . . . computer using surface barrier transistors"), the C-1100 (a "general purpose, stored program digital computer" occupying only five cubic feet) and the C-1102 (an "advanced version" of the C-1100).* (Id.)

During 1955-56, Philco also began developing what it described as "the world's first all-transistorized computer" for the National Security Agency. (DX 7512, p. 190.) That work then led to the Philco TRANSAC S-2000, introduced commercially in 1958. Philco advertised the S-2000 as the "first large-scale transistorized EDP system". (DX 7512, p. 20; see DX 5421, Davis, pp. 14, 19; DX 5642, Hintze, p. 7.)

The initial TRANSAC S-2000 was the model 210; follow-on

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* Philco's 1957 Annual Report noted that "Philco's airborne computer, TRANSAC C-1102, is now being utilized by a large mid-west manufacturing company, which became the first industrial firm to use this computer. Until now, all airborne computers produced by the [Industrial] Division were for the Armed Forces." (DX 13683, p. 12.)

models were developed in 1960 (the 211) and 1961 (the 212). (DX 7512, pp. 190-96.)* Philco advertised that TRANSAC could be "selected for commercial, scientific, real-time, and military applications". (DX 7512, p. 25.) Customers included the Atomic Energy Commission, GE,** the California Department of Motor Vehicles, United Aircraft, Chrysler, System Development Corporation, Ampex, the Government of Israel, the University of Wyoming and the Defense Communications Agency. (Fernbach, Tr. 513; Weil, Tr. 7072; DX 7512, pp. 191-92.)

Philco obtained core memory for the 2000 from Ampex (PX 3624, p. 2) and contracted with ADR for software, including such things as sort programs and a "simulator" that permitted programs written for an IBM 705 to be run on the 2000. (Goetz, Tr. 17454-55, 17792-93.)†

Philco's computers were among the most powerful computers of their time, in some ways comparable to LARC and STRETCH. (See, e.g., Fernbach, Tr. 512-13; DX 5642, Hintze, pp. 7-8; DX 5374.) Philco was one of only four manufac-

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* The 212 was approximately five times as fast as the 211 (and approximately 400 times as fast as the UNIVAC I). (DX 4938.)

** GE's Atomic Power Equipment Department leased TRANSAC 2000s in 1961-62 and converted applications from an IBM 704 and 7090. (Weil, Tr. 7072.)

† ADR also worked with Philco on a proposal for the NSA in the early 1960s. Philco paid ADR to prepare detailed designs for software to be used in proposed Philco computer systems, and Philco then incorporated these designs in its proposal. (Goetz, Tr. 17849, 17854-55.)

turers (the others were IBM, Burroughs and CDC) in 1962 to bid a large computer of their own manufacture for installation by NASA at the Johnson Space Center for use in the GEMINI Program. (DX 7581.) Even GE and RCA bid third party equipment (CDC 3600s and IBM 7044s/7094s, respectively). (DX 7581, pp. 8, 28.)

Ford Motor Co. acquired Philco in December 1961. Arjay Miller, then Vice President of Ford, testified that Ford's interest in acquiring Philco "was to get into the space and defense business". (Tr. 85182-83, 85188.)

> "[I]n the 1960s we were generating excess cash, we wanted to get into space and defense. We had a small space and defense business of our own that was not growing fast enough. We saw in the purchase of Philco an opportunity to grow in that particular area. It had a significant position. It was producing other products, and we decided to get out of the other products of which the computer business was one." (Tr. 85191-92.)
>
> "It was a phase process that as soon as we could, we moved the resources, the computer resources we had, into space and defense." (Tr. 85186.)

Philco's U.S. EDP revenues were $19.8 million in 1955 and $73.9 million in 1963. (DX 8387, pp. 1, 6.)

31. <u>Control Data Corporation (CDC).</u> Control Data Corporation was formed in mid-1957 by William Norris along with two former colleagues who had left Sperry Rand and a Minneapolis attorney. (Norris, Tr. 5604, 5606-07, 5713; DX 271, p. 7.) CDC's initial capitalization was approximately $600,000, of which Norris himself contributed $70,000 in return for slightly more than 10 percent of the total equity. (Norris, Tr. 5604-05; DX 271, p. 7.) Norris stated that Control Data initially contemplated doing "[p]rimarily consulting business and research and development work, principally for the Government, the plan being that out of the research and development work, and possibly the consulting work for business, would come ideas for products which we could later put on the market." (Tr. 5606.)

Shortly after its formation CDC hired other employees who had previously worked for Sperry Rand, including Seymour Cray and Henry S. Forrest. (Norris, Tr. 5713-15; DX 280, pp. 4, 6.) Led by Cray, CDC (with only 12 employees) started working in a Minneapolis warehouse to design what became the 1604 computer system. (Norris, Tr. 5607-08, 5742-43; DX 271, p. 7.) A "1/10-scale prototype" was in operation by April 1958 when the 1604 was announced. (Norris, Tr. 5738; DX 271, p. 7.) According to Norris, the 1604 was "the first solid-state, large-scale computer announced". (Tr. 5611.)* In early 1958, CDC also began producing missile and aircraft components for the military and developing a special air traffic control inquiry-keyboard-display unit for the Civil Aeronautics Authority. (DX 271, p. 7.) In May 1958, CDC received $500,000 in military orders, including its first computer research and development contract. (Id.) CDC obtained additional financing the following month from the Navy for developing and manufacturing the 1604. (Norris, Tr. 5608; DX 271, p. 7.)

When first delivered in January 1960, the 1604 computer system sold for slightly less than $1 million. (Norris, Tr. 5608.) CDC did not initially manufacture the peripheral products; instead, it obtained magnetic tape units from Ampex, printers from Anelex and IBM, card readers from IBM, and paper tape readers from Ferranti, an English firm. (Norris, Tr. 5609; PX 6066, p. 1.)

CDC marketed the 1604 primarily to government laboratories and agencies "doing a large amount of scientific work", and to "large companies, corporations, doing military[,] space and nuclear work". (Norris, Tr. 5609.) Subsequently in 1962, CDC offered the 1604-A computer with COBOL capabilities "[b]ecause there were customers who wanted to use the machine also for some BDP processing"--that is, there were cases "where the customer had some

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* According to Lacey, Cray very early "had become convinced about the possibilities of a solid state, transistorized (instead of vacuum tube) computer which could be built from complex printed circuit cards. With these as the starting point, a computer of almost any size could be made." (DX 280, p. 7.)

business data processing requirements that fitted with his total business aspect and he wanted to get those done on the same computer". (Schmidt, Tr. 27236, 27521; PX 355, pp. 33-34.)

In Norris' view, at the time CDC began marketing the 1604, it competed with Philco, Univac and IBM. (Tr. 5611, 5733-37.) The 1604 was initially "very successful". (Norris, Tr. 5611.) Norris agreed that he expected someone to offer a product competitive with the 1604, either a better product at a lower price or the same product at a lower price or a better product at a higher price (Norris, Tr. 5925), and subsequently the 1604 did come under very "severe competition" from IBM computers, including the IBM 7090 (announced after the 1604 but delivered one month before the 1604),* the 7044 and 7040 and, somewhat later, the 7094. (Norris, Tr. 5613, 5615, 5923-25.)

CDC announced its second computer, the 160, in December 1959. (PX 355, p. 33.) The 160 was delivered in May 1960. (Id.) Norris testified that the 160 was a "small" computer which CDC marketed "primarily for engineering work". (Tr. 5614-15.) CDC also sold 160 computers "on an OEM basis to NCR". (Norris, Tr. 5979.) Norris described that arrangement, which began in 1960, as follows:

> "The sales of the 160 through our own marketing organization are augmented through an arrangement we negotiated

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* Norris believes the 7090 was the first large-scale solid-state computer delivered. (Tr. 5737.)

> with the National Cash Register Company. The arrangement between Control Data and NCR provides that . . . [NCR] has exclusive marketing rights to the Model 160 Computer within the United States for the banking and retail trade areas, and can sell it world-wide on a non-exclusive basis in all other fields." (DX 331, pp. 4-5; see also Tr. 5984.)

CDC said that the 160s could "be used as input-output data processors for the 1604 Computer"; they could also be used in a "satellite system" with a 1604, communicating "directly with the 1604's magnetic core memory . . . and all of the 1604's peripheral equipment". (DX 13666, p. 7; see DX 5421, Davis, pp. 26-31.) In 1961 CDC announced a follow-on computer, the 160A, with twice the memory capacity of the 160, that sold for approximately $90,000. (PX 355, p. 33.) CDC sold more than 275 of its 160As. (_Id._)

Norris described CDC's "initial strategy" as being

> "to build large, scientific computers with a lot more bang for the buck.
>
> "This was achieved primarily by very high performance hardware with a relatively small amount of software with the customer doing most of his own software. Our business took off like a rocket to the moon as our large computers made rapid and significant penetration in the education, aerospace and large government laboratories markets. . . . With the success of the initial strategy there was also early recognition in Control Data that we would need to broaden our product line and markets to sustain growth.
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> "Our first product diversification was in peripheral equipment, back in 1960 -- a magnetic tape handler. Shortly after that we started to offer data services." (DX 284, p. 3.)*

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* Norris testified that CDC was "very successful initially" because "we picked out a particular niche in the market", namely what he described as the "scientific and engineering part of the market", and "met the needs of the particular part very proficiently and much more so than any computer then available". (Tr. 5611.)

CDC began almost immediately to expand by acquisitions. (DX 296.) CDC's intent in making acquisitions was not to broaden its "base as . . . a conglomerate, but rather to buy new computer products and services and markets to spread development costs and gain economies of scale as rapidly as possible". (DX 284, p. 7.)* This was the case with CDC's first acquisition, of Cedar Engineering (for $428,200) (DX 296), just four months after CDC was founded. (PX 355, p. 3; DX 280, p. 6.) At the time of the acquisition Cedar Engineering did not manufacture computer-related products but had the "basic skills and facilities to manufacture high performance peripheral products at very competitive costs". (DX 284, p. 7; Norris, Tr. 5794.)**

CDC opened its first data center in 1960. (DX 284, p. 3.) That facility used the third 1604 CDC had manufactured. (Id.) CDC believed "there would develop an important market consisting of organizations that could benefit from the power of a large computer to solve large scale problems", but that lacked "either capital or technical resources to afford such a system". (DX 284, pp. 3-4.) In 1960, CDC sold time "on a 'service bureau' basis to universities, scientific and business organizations"; CDC also used its data center

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* According to Norris, "Our high P/E ratio stock, or Chinese money . . . . was used to acquire companies with complementary technology, products, services and markets". (DX 284, p. 7.)

** Cedar Engineering, "organized in 1952, had become a $2 million business, producing a variety of instrument and control devices. It operated from a 33,000 square foot plant in suburban Minneapolis." (DX 280, p. 6.)

facilities to perform in-house engineering design and accounting applications. (DX 13666, p. 7.) CDC "proceeded to install data centers in most principal cities in the United States"; by 1965, CDC had seven data centers. (DX 284, p. 4.) Many years later Norris said: "It was a big commitment with high risk for a little company to embark on such an ambitious data center program back in 1960." (DX 284, p. 4.)

In 1960, CDC also "delivered to the Defense Department a very large-scale special purpose solid state digital computer several times larger than the 1604", which "in fact, use[d] a 1604 for input/output purposes". (DX 13666, p. 8; see also DX 331, p. 5.) That year CDC also acquired the Control Corporation for $2,274,814 of CDC stock. (Norris, Tr. 5789; PX 355, p. 3; DX 296.) This acquisition allowed CDC "to implement a decision to enter the industrial market area of computers for automatic control purposes . . . for electric utilities and gas and oil pipeline companies". (DX 331, p. 5.)

In 1961, Norris delivered an address to the Twin City Security Analysts. He described CDC's products as being

> "at the forefront of computer technology. Through aggressive research and engineering we intend to have our products in front tomorrow. Control Data is the smallest company in the industry today selling complete computer systems; however, mere numbers don't precisely determine the effectiveness of research and engineering. Significant technical innovation still springs from the flash of genius and again it's -- 'Not how many, it's who.' Millions of dollars and massive engineering effort without those sparks produce only mediocre results. Unfortunately, the number of creative engineers in the computer industry is woefully small.

"Thus, if a small company has creative talent and since it has access to the general store of scientific knowledge, it can spark computer technology. The hugh [sic] government expenditures for research and development is the equalizer between large and small companies. Approximately 70% of all basic research done in the United States is financed by the government. This means that most of the new additions to scientific knowledge are just as available to the little company as to the large company. Furthermore there is no company today with resources sufficiently large that it alone can significantly alter the state of the computer art." (DX 331, p. 9.)

In the same speech, Norris also described CDC's efforts to design a computer "many times more powerful depending on the problem being solved" than either CDC's 1604 or IBM's 7090. (DX 331, p. 5.) Indeed, prior to the time of Norris' speech, CDC was discussing this new computer under development in CDC with MITRE Corporation and the Lawrence Radiation Lab (Norris, Tr. 5934, 5938; DX 308; DX 309; DX 310), as well as many other users or potential users of this new, unannounced computer. (DX 13526, Forrest, pp. 191-97, 205-06, 225-30, 232-42, 245, 504-08, 570-74, 580-81.) In July 1962, CDC announced this new large-scale computer, the 6600 (JX 10, p. 2), and announced that the Lawrence Livermore Lab had ordered the first one, which was delivered in September 1964 (id.) "at a sales price of approximately $7 million". (PX 355, pp. 34-35.) Norris agreed that CDC had far more difficulty designing and building its 6600 system than it had anticipated when it began marketing that system. (Tr. 5854.) Those problems took substantial periods of time to solve, caused delays in delivery schedules and caused additional expenditures of funds and efforts by CDC employees. (Norris, Tr. 5853-54.)

In June 1958 Control Data employed about 250 people, of which approximately 40 were scientists and engineers. Sales for the preceding nine months were approximately $600,000. By March 1961 CDC employed more than 1,000 people, and sales as of the middle of the fiscal year were $8 million. As of 1961 CDC had reported a profit for every year except the year it incorporated. (DX 331, p. 1.)

CDC announced the first of its 3000 Series computers, the Model 3600, in May 1962. (PX 355, p. 34.) The first 3600 was delivered to Livermore in 1963, "as an interim system to [Livermore's] acquisition of the first CDC 6600 system". (Plaintiff's Admissions, Set IV, ¶ 82.0(f); see PX 355, p. 34.) The 3600 was more powerful than the 1604 but less powerful than the 6600. (Norris, Tr. 5615-16.) Norris testified that CDC developed the 3600 because "[w]e were under severe competition -- competitive pressure from IBM computers" -- the 7044, the 7040, and the 7094. (Tr. 5615.)

In 1962, CDC also began a joint venture with the Holley Carburetor Company "to develop and manufacture medium-speed printers". (Norris, Tr. 5793; PX 355, p. 3.)*

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* CDC acquired 100% ownership of this joint venture in 1964. (Norris, Tr. 5793; PX 355, p. 5.)

In 1963, CDC made seven acquisitions, principally in exchange for CDC common stock. (norris, Tr. 5792-93; PX 355, pp. 3-4; DX 296.) In Withington's view the most significant of these was the acquisition of Bendix's computer business.* (Tr. 55984.) CDC also acquired MEISCON, a company developing techniques for employing computers to automate industrial and highway design procedures; Beck's, a designer and manufacturer of unique imbedded printed circuits; Electrofact, a manufacturer and vendor of a "broad line of measuring, recording and control devices" as well as systems for use in industrial processes; the Digigraphic system business of Itek, a researcher and developer of a cathode ray tube/photoelectric pen system for

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* In 1952, Bendix was a diversified, high technology firm producing aviation, automotive, marine, radio and television, and other products, many of which were incorporated in military systems. Revenues exceeded $508 million. (DX 13538, pp. 3, 15-21.) In that year, Bendix announced it was applying its "years of Electronic Leadership" to the development of digital computers:

> "Bendix Aviation Corporation, a world leader in electronics, has established the Bendix Computer Division for the development of specialized electronic digital computing instruments.
>
> "The latest engineering knowledge in electronics is now being incorporated in a new digital computer." (DX 12664.)

Bendix built two commercially available general purpose computer systems, the G-15 and G-20, in the 1950s and early 1960s (Perlis, Tr. 1331; Binger, Tr. 4514; Spangle, Tr. 4938; Norris, Tr. 5790-91; Schmidt, Tr. 27218), and was also involved in the SAGE project. (Crago, Tr. 85964.) EDP revenues grew from less than $1 million in 1958 to nearly $13 million in 1963 (DX 6086, p. 13; DX 8224, p. 137), a year in which Bendix's total revenues exceeded $813 million. (DX 13549, p. 1.)

conversion of graphic documents stored in a digital computer; the Control Systems Division of Daystrom, a "pioneer and leader in the development and installation of advanced electronic digital computers for use in power, chemical, petroleum and oil industries"; and Bridge, a designer and manufacturer of "card punch and reader systems and other computer peripheral devices". (PX 355, pp. 3-4; DX 296.)

Norris, who believed there is a relationship between a company "determining to focus all of its resources and concentration on the computer business as such, or a substantial part of its resources on the computer business as such, and success in that business" (Tr. 6010), said that being "willing to take risks" was one of the "key factors" in CDC's record of business success (DX 284, pp. 2, 4; see Norris, Tr. 5846-47):

> "Our willingness to take risks was in reality probably the safest course for a small company with limited resources competing in the high and fast-moving technology of computers. Now not every risk can pay off -- nor did they all. To have played if [sic] safe would have meant one of two things: 1) being too late in the marketplace with a new product; or 2) having a good marketable new product but being unable to capitalize on the demand before our giant competitors' moved in with a similar product. Therefore, Control Data, while still in the conceptual stage of designing a large computer made commitments on production for inventory, before the development and testing was completed. In those early years this is what is correctly called 'total commitment' -- i.e., failure of the product for some reason meant bankruptcy for the company. Some of our people called it a 'you bet your company strategy.' Control Data made a total commitment three times, once for the 1604, then the 3600 computer and the third time the 6600 computer. Fortunately all were very successful -- particularly the 6600." (DX 284, pp. 4-5.)

CDC's EDP revenues rose from $2,607,000 in 1958 to $84,610,000 in 1963. (DX 298.) Its total assets grew from $1,223,311 in 1958 (its first full year of business) to $71,338,765 as of June 1963. (DX 302.) Between 1958 and 1963 CDC raised more than $40 million through equity and long-term debt financings. (DX 300.)

32. Technological Progress. The computer industry experienced rapid technological progress through the early 1960s:

(a) Withington testified that "the computer industry during the period 1956 through 1964 [was] . . . in a state of technological ferment":

> "new technologies and new methods, new types of components, such as magnetic cores, transistors, new devices such as magnetic disks, the first significant software products, including compilers for the FORTRAN language and input/output control systems, were being invented and employed at a rapid rate, and . . . computer systems were being superseded by new models of computer systems, both from the present manufacturers and from new competitors, at a rapid rate, and . . . the new ones were achieving a relatively rapid success in the marketplace". (Tr. 56459-60.)

Withington believed that the rate of technological change in the computer industry had proceeded as rapidly as users could absorb. (Tr. 56637-38.)*

(b) Harold Seidman, Assistant Director for Management and Organization, Bureau of the Budget, testified before a House Subcommittee on Census and Statistics in 1966 that:

> "The technological progress achieved by the computer industry in the brief 15 years of its

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* On June 9, 1980, Withington testified that the rate of technological innovation in the general purpose computer business is "at least as rapid today as at any period in the past and more rapid than at some periods". (Tr. 112946.)

existence has been nothing short of remarkable. Internal speeds, initially measured in thousandths of a second, then millionths, are now measured in billionths of a second. Improved packing techniques have increased the number of characters which can be stored on an inch of magnetic tape from 200 to 1,500. Internal high-speed memory capacity has, through miniaturization and improved production techniques, increased from 12,000 characters to over a million, while auxiliary addressable memory which did not exist before 1957 is now virtually unlimited in capacity." (DX 13451, p. 7.)

(c) The General Accounting Office (GAO) surveyed the use of computers within the Federal Government in 1957, 1960 and 1963 and reported the results to Congress (Plaintiff's Admissions, Set IV, ¶¶ 189.0, 201.0, 212.0):

(i) In 1957 "the size and complexity of Government data processing systems had increased rapidly due to advances in technology". (Plaintiff's Admissions, Set IV, ¶ 198.0.)

(ii) In 1960 the GAO reported that:

"[a]s of 1960 new equipment being developed had the capability of processing data at speeds hundreds of times faster than the installed machines and some of the newer machines were able to perform several jobs at the same time" (Plaintiff's Admissions, Set IV, ¶ 210.0), and that "progress achieved in the development and application of automation and automatic information processing systems have borne out earlier predictions of a second industrial revolution." (Plaintiff's Admissions, Set IV, ¶ 205.0.)

(iii) By 1963 "developments of new equipment had been so rapid that much electronic equipment had been technologically surpassed by more advanced models by the time it was installed." (Plaintiff's Admissions, Set IV, ¶ 212.1.)

(d) Edward Mahoney of the GAO testified that as of 1962 the EDP industry was "a rapidly expanding and dynamic field in which new equipment, new methods, and even new concepts" were constantly being introduced. (DX 7528, Mahoney, p. 17.)

(e) Donald Turner, Assistant Attorney General for Antitrust, wrote in 1966 that "in the rapidly changing computer field, obsolescence is frequently measured in months." (DX 9110, p. 2.)

(f) McCollister said that the technological progress in the development and manufacture of EDP equipment since the 1950s had "been outstanding both in an absolute sense and in comparison with the rate of progress that [took] place in most other industries. There has been dramatic progress in the electronic data processing field . . . almost throughout its entire history." (Tr. 9813.) He added, "one of the things that no one envisaged [in the early 1950s] is how rapidly the computer technology would improve and evolve and become increasingly . . . much more cost effective, which, of course, gave it a broader market". (Tr. 11019.) Among the advances McCollister identified were "[i]mproved capabilities and lower costs of components and improvement in capability of the overall system through improved engineering design and a greater range of peripheral devices available". (Tr. 11019.)

(g) Welke testified that "[t]aking the first generation as one, the second generation was ten times as fast or 1/10 the cost". (Tr. 17305.)

(h) In a 1959 speech Burroughs' President Ray Eppert described office automation as "the most dynamic market of our time." (DX 10283, p. 8.)

The General Accounting Office summarized the advancements with respect to the computers the Federal Government began to receive in the early 1960s:

> "[These] solid state systems were more compact, required less reinforced flooring and floor space, required less special power and air conditioning facilities, were more easily maintained, and operated at faster speeds and with greater versatility than their predecessors." (Plaintiff's Admissions, Set IV, ¶¶ 213.0, 213.1.)

Those improvements, in turn, led to substantially greater price/performance. In addition, because of their greater functionality, reliability, and ease of use, new computers could be used more efficiently than their predecessors and to perform qualitatively different applications. (Fernbach, Tr. 470; Perlis, Tr. 1829; Hindle, Tr. 7384-85; McCollister, Tr. 11019, 11072; Welke, Tr. 17304-05; Butters, Tr. 46449-50; Withington, Tr. 56578; Hart, Tr. 80189, 80215-16, 80221-24; PX 289; DX 3553B, DX 3554D; DX 3617; DX 13451.)

This technological progress was one of the most important factors explaining the rapid growth of the computer business during the 1950s and early 1960s.

33. <u>Reasons for IBM's EDP Success through the early 1960s.</u> IBM's EDP success in the 1950s and early 1960s can be directly traced to its excellent management, which led it to take the risk of making an early, large, effective and sustained commitment to EDP unmatched by any of its competitors:

(a) Unlike many of its competitors, IBM did not obtain its EDP expertise by acquisition.* In the early 1950s, computer products were so unique and the technical, manufacturing, and marketing uncertainty so pervasive that it was especially vital for a firm's EDP operations to be well integrated into the corporate chain of command reporting to top management. Because EDP was so different from IBM's traditional unit record business, IBM's decision to develop its first computer systems aroused considerable corporate opposition. Nevertheless, because IBM chose to rely on inside resources to develop its computer business and because of Thomas J. Watson, Jr.'s personal involvement in that business, EDP never became isolated either from the rest of the corporation or from top management. Remington Rand's problems in integrating Eckert-Mauchly and ERA into its mainstream businesses, NCR's delay in introducing successors

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* By contrast, as discussed elsewhere, Remington Rand acquired Eckert-Mauchly and ERA, NCR acquired CRC, and Burroughs acquired Electrodata.

to the CRC product line, and Burroughs' failure to introduce a successor to Electrodata's Datatron 220 contrast unfavorably with IBM's accomplishments.

(b) In the first years of the computer business there was enormous uncertainty as to whether it was either technically or economically feasible to manufacture and market a computer system that would be of value to a range of customers. As Dunwell put it, there was "no evidence that a machine of such complexity could be made to work reliably or could be maintained in working condition". (Dunwell, Tr. 85522-23.) Yet IBM chose to commit far more of its corporate resources to this risky business venture than any other firm.

Richard Bloch, the head of Raytheon's computer division through 1955, summarized the reasons IBM acquired "technical leadership" of the EDP business from Remington Rand between 1953 and 1955:

> "[IBM made] a sustained effort to be a paramount element in the business equipment field, and they showed at that time strong determination to do so, allocated the necessary resources to begin to exert their power--or attempt to exert their power in the field and did a very fine job of it in the beginning in that era. (R. Bloch, Tr. 7742-3.)

When asked to explain, Bloch continued:

> "The dedication of the company was, to my view, greater than the dedication of [Sperry Rand or General Electric]. And I would say that the organization of the resources, aside from the size of the resources, which at one time were no greater than these others, if not smaller--the organization power of the resources

was what I felt was a forte of IBM management". (R. Bloch, Tr. 7743.)

IBM's senior management consistently demonstrated a willingness to commit substantial resources on uncertain, risky investments. As Rooney testified, IBM "had excellent and aggressive management willing to take risks at the right time". (Tr. 12385.) Most of these investments proved successful and, as a result, IBM reaped economic profits. Indeed, Thomas J. Watson, Jr.'s foresight in deciding to risk investing resources to develop the 701 and the 650 must be recognized as one of the most important decisions in the history of American business.

(c) At approximately the time of Thomas J. Watson, Jr.'s appointment as chief executive officer in the mid-1950s, IBM became the first large, established firm to conclude that its principal business should be EDP. Because of IBM's early commitment, EDP accounted for a much larger fraction of IBM's total business than it did for competitors such as GE, Sperry Rand, Burroughs, NCR, RCA, and Honeywell. Since the EDP business subsequently grew much more rapidly than other businesses, this meant that even if IBM's EDP business only expanded at the same rate as the total EDP business, IBM's total revenues and profits would grow disproportionately (as compared to the listed firms) from EDP's subsequent, unexpected, rapid growth.*

(d) IBM management recognized that to grow the EDP market rapidly, it was essential both to increase the range of applications worldwide that could be performed cost effectively on a computer system and to reduce customer uncertainty. IBM achieved these results by offering its equipment on short-term leases, working closely with customers, educating them and providing them with programming aids (such as FORTRAN), and by introducing a steady stream of more versatile, reliable, and maintainable products offering substantial improvements in price/performance and spanning a large size and price range.

As Withington testified:

> "I think one of the major factors [that led to the current size of IBM's installed base] was IBM's rate of innovation during the first decade. The series of machines 701, 704, 709, 7090, 7094, appeared within a ten-year period for a significant part of the market, and with these as leaders, IBM innovated almost as rapidly in its larger volume business machines. No other vendor was willing or perhaps able to obsolete its own products and innovate at that rate in those days." (Tr. 55974; see also McCollister, Tr. 9553.)

It is evident that such a strong commitment to innovation was essential for any firm to have a sustained record of success in a market as technically dynamic as EDP. However, in EDP's early years IBM's managers faced a

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* Later entrants like SDS, CDC and DEC also considered EDP their principal business; like IBM, they benefitted disproportionately from EDP's rapid growth. (DX 8224, pp. 4, 5, 142.)

nearly overwhelming temptation to stick with the proven technology already embodied in its successful unit record and EDP products. McDowell testified that "The large majority of our people were not knowledgable in the field of large computers" and that to get that know-how meant spending considerably more money. He observed that the decision to do so was "not an easy decision to make. There were not unlimited funds within the IBM Company." (DX 7594, McDowell, pp. 187-88.) The fact that IBM, like "no other vendor", resisted the temptation to maximize short-term profits and instead constantly introduced new product lines obsoleting its still profitable product lines contributed greatly to IBM's becoming the world's largest EDP company.

More quickly than any of its competitors, IBM recognized that EDP customers were not really interested in acquiring computer hardware but rather were interested in acquiring data processing capabilities. (Rodgers, Tr. 16842; Spain, Tr. 88790; Akers, Tr. 97352; Cary, Tr. 101618.) To perform data processing efficiently requires access to a well-balanced computer system--not just a high-performance CPU. From the beginning of its involvement in EDP, IBM consistently responded to customers' data processing needs by emphasizing generalized, highly functional software (Perlis, Tr. 1887; O'Neill, Tr. 76225; Hurd, Tr. 86726) and high quality peripherals. (Beard, Tr. 9048, 10272; O'Neill, Tr. 76224-28.)

In the 1950s and 1960s many IBM-manufactured peripherals were so well regarded that several IBM competitors sold them as part of their computer systems. (Binger, Tr. 4512-13 (Honeywell); Spangle, Tr. 5102 (Honeywell); Norris, Tr. 5608-09 (CDC); Beard, Tr. 8999-9000, 10207-08, 10322 (RCA); Currie, Tr. 15064 (Xerox), 15506-07 (SDS); Withington, Tr. 56510 (Burroughs, Univac).)

(e) IBM was the first company to reap sizeable production economies and reliability gains from producing its computers in high volume and on a production line rather than individually. Throughout its involvement with EDP, IBM management pushed efforts to mechanize production and cut costs. (Hurd, Tr. 86345, 86360; E. Bloch, Tr. 91530; Dunlop, Tr. 94377-81.) Years later the Boston Consulting Group formulated a concept called the "experience curve"* to explain why those firms reaping the highest unit sales of electronic products will have substantially lower unit costs. Long before the concept had been popularized, IBM became the first EDP firm to reap "experience curve" economies when it began high volume production of the 650.

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* This is sometimes mistakenly referred to as the "learning curve", a concept limited to direct labor.

(f) The ultimate orientation of IBM's EDP business has always been towards the marketplace.* As IBM's chairman, Cary described it, the "orientation of always keeping the customer in mind, as I call it, '[t]he customer is king', kind of idea . . . has been a very, very important element in the success of the IBM Company. It's something that the founder of the company drilled into everybody and I think we have stayed with it all through these years". (Tr. 101716-17.) General Electric's chief executive officer, Reginald Jones, also recognized the importance of satisfying customers if a firm were to achieve success in EDP. Thus, when asked his "opinion as to the reasons for IBM's success in the business computer systems business", Jones testified:

> "[I]t is my experience that in business you succeed when you satisfy a customer and when you do it in terms of giving values that are highly satisfactory from the standpoint of the customer. And I use 'value' in the sense of conveying reasonable price, quality of product, features of product and performance, overall performance of product." (Tr. 8868; see also Rooney, Tr. 12385.)

John Jones, who has been involved with EDP since 1951,**

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* The fact that Thomas J. Watson, Sr. was a salesman and that all of his successors as IBM's chief executive officer had a sales background is consistent with the firm's marketplace orientation. (Hurd, Tr. 86333, 88177; DX 8058.)

** Jones, as an Air Force corporal, was trained to maintain and operate the first Univac I's at the Eckert-Mauchly/ Remington Rand facility in Philadelphia in 1951-1952, and thereafter was involved with operating the Univac I at the Pentagon in 1952 and from 1954-1957. From 1952-1954 he attended graduate school at MIT, where he studied computing, and used the Whirlwind. In testified:

> "[F]irst of all, a vendor must have product, whether . . . hardware . . . or . . . software, or a combination of the two, which is responsive to what is needed by a user." (Tr. 79335-36.)

Then, after describing important elements of manufacturer responsiveness (e.g., product reliability, service, maintainability, balanced systems, and meeting schedules), Jones added that IBM's success in manufacturing and marketing EDP products was due to its ability to provide those elements:

> "Certainly, in my experience the delivery of the equipment, the performance of the equipment in terms of its reliability, the service of that equipment and the support from [IBM] have been in every case extremely good. (Tr. 79337; see also O'Neill, Tr. 76224-28.)

Jacqueline Johnson, Chief Executive Officer of Computer Generation and an employee of Sperry Rand and GE in the 1950s and 1960s testified that "IBM has achieved its position of leadership" in the EDP industry:

> "through the excellence of its management and marketing. IBM marketing is the best in the world. With respect to IBM management decisions, IBM supported what they sold. They enhanced their product lines. They introduced new products. They kept the state of the art and advanced technology well ahead of all vendors. They poured large amounts of money into research and development, and they developed a marketing arm that supported what they manufactured." (DX 3979, Johnson, p. 16.)

1957-1959, he was in charge of technical computing at Chrysler, and in 1959-1963, he was in charge of evaluation of and selection of computers at the Air Force Logistics Command, one of the largest users of computers at that time, with an EDP budget of $26 million. (J. Jones, Tr. 78699-786; DX 3715; DX 3722; DX 3723; DX 3721.)

(g) Since at least the mid-1950s, IBM management has practiced the contention system of dispute resolution. (Liptak, Tr. 84619-21, 84644-46; Miller, Tr. 85046, 85105-06; McCarter, Tr. 88433-35; Spain, Tr. 89645-47; Cary, Tr. 101328-29, 101503-04, 101608-13, 101718-19, 101953-54.) Whenever two parties or organizations within IBM disagreed on an issue, it was escalated for resolution to the next highest level. IBM management strove to resolve conflicts speedily rather than allowing them to fester and breed disharmony. Even though speedy resolution of conflicts is an obvious principal of good management, the record establishes that IBM's principal competitor during the early and mid-1950s, Sperry Rand, was unable to resolve the managerial disagreements between the two warring camps based in Philadelphia and Minneapolis/ St. Paul and with corporate management. (Eckert, Tr. 1016-17; Norris, Tr. 5707-09; DX 10; DX 272; DX 280; DX 7584, Mauchly, p. 21.)

Knaplund described how IBM's contention system worked in the late 1950s:

> "It was the responsibility of the product divisions to respond to marketing requests wherever it was practical and economic to do so, but to resist those requests and provide acceptable alternatives where necessary in order to assure profitable results. . . . It is my understanding that IBM top management, that is, Mr. Watson, Jr., and Mr. Williams, deliberately established the responsibilities of the product and marketing divisions which I have described to insert conflict in the

IBM organization structure between the product divisions, on the one hand, and the marketing division, on the other, so as to ensure that the IBM Corporation would maintain its vitality and responsiveness to the competitive requirements of the marketplace. . . . [T]his conflict in the IBM organization structure was sometimes referred to by me and others as the 'contention system'." (Knaplund, Tr. 90468-69.)

(h) IBM had a reputation for attracting "capable people". (Rooney, Tr. 12385-86; DX 7597, pp. 11, 13.) IBM's treatment of its employees undoubtedly played a significant role in its success. In addition to its full employment practice with the emphasis on retraining and re-education of employees (Liptak, Tr. 84618; Miller, Tr. 85058-59) and its "open-door" policy assuring every IBM employee access to IBM's highest management to resolve grievances (Liptak, Tr. 84618-19; DX 8886, p. 120; Miller, Tr. 85046, 85092, 85097, 85105-06), IBM encouraged its employees to strive for excellence. (McCarter, Tr. 88402-03; DX 8886, pp. 149-51.)

In IBM's October 29, 1959 Management Briefing, Mr. Watson, Jr. gave the following advice to IBM managers:

> "The man most likely to succeed in a corporation is not the conformist--the organization man--but the man of initiative who crashes through to get things done in spite of risks and obstacles." (DX 8886, p. 26.)

Welke eloquently described how this philosophy filtered down to the lower rungs of the corporation. He said that IBM's salesmen and field technical representatives "always took pride in the amount of commitment, dedication and involvement that we had. . . . It certainly wasn't an eight-hour-a-day, 40-hour-a-week type approach to life that we had. It was work as long or as hard or wherever was necessary to accomplish a job and make the project successful.

". . . .

"The reasons for the commitment probably stemmed in part from the adventure, or . . . the technical challenge that we were undertaking . . . . It was the interest and the fun of cutting new ground, doing things that other people hadn't done before, probably coupled also by the fact that we had a sense at least of being awfully good at what we were doing.

"We knew that we were supported by the company, we were trained well, we could see that in our daily activity. It's all of the things that cause a winning team to be a winning team. . . ." (Welke, Tr. 17356-58; see also Hughes, Tr. 34015-16.)

Welke described the influence of Watson, Sr.:

"I can see where his philosophies, his way of doing business, his commitment in effect pervaded the entire organization, and I don't mean, you know, the business decisions that he was making because we weren't part or party of that down at our level, but the total commitment to the job, the demands that he made for excellence and perfection, his requirement for a 100-percent performance; his entire approach to conducting business, I think, was exercised down at that level of all of the field people that I worked with, salesmen, field tech reps, as well. It became a very personalized thing." (Welke, Tr. 17358-59.)

In conclusion, throughout the 1950s and early 1960s, IBM chose to invest far greater resources than any comparably situated firm in a market that would become the most important new market of the post-World War II period and organized those resources more effectively than any of its competitors.

As Ray Macdonald testified, IBM

> "has been an extremely well managed company and not only has it been extremely well managed but this has been over a very long period of time in a rather continuous experience which someone remarked doesn't allow much room for error on the part of their competitors." (Tr. 6904.)

As Richard Bloch testified, IBM has been "a splendidly managed company" since 1952 with a management far superior to most of its competitors. (Tr. 7746; see also Liptak, Tr. 84604; Miller, Tr. 85014-15; J. Pfeiffer, Tr. 85337; Hurd, Tr. 86720-21; Peterman, Tr. 99911; DX 7578; DX 7581, p. 4; DX 9322 (showing an article published in Metal Working Economics); DX 5929, Benscoter, p. 26.)