PART II

THE HEIGHTS (1979–1999)

From Digital Equipment and
Franklin Computer to Intel.

5. THE RISE OF PCS

By 1979, I had spent ten years specializing in the use of computers in real-time applications in cardiology (coronary care unit monitoring, catheterization lab). Thinking about my future and about leaving Israel, I felt that I was overly specialized and needed to focus on either medical science or computer design. If I chose medical science, we would return to Holland. I was well-known there, and it was Arianne's home and the place where my sons were born. I spoke fluent Dutch, so our family's language issues would disappear as soon as the kids learned to speak that language. If I wanted to work in the computer industry, however, we needed to move to the United States. Forced to make a choice, I realized I could never give up computers. While I enjoyed medical science, I was really at heart an engineer and wanted to be deeply involved with the design of computers.

At that point in my career, I made a critical decision, and in many regards, a very risky one, to leave the medical field and join the computer industry. What I did not know, of course, was the computer industry itself was about to go through a major transition in just a few years, driven by the rise of the personal computer, a transition that would have a profound impact on the world and would dramatically affect my future.

Although I contributed in only a limited way to the early development of the personal computer (PC) industry, I do have a unique perspective resulting from my decades in the industry. Thus, before

continuing on with my story, I want to pause here and recap the story of the IBM PC.

IBM ACCIDENTALLY TURNS THE COMPUTER INDUSTRY ON ITS SIDE

In 1964, when IBM introduced the System/360 line of mainframe computers, it was primarily a tabulation and typewriter company. This "bet-the-company decision" sure paid off. In just a few years, IBM became the leading computer company in the world, capturing more than 70 percent of computer-industry revenues. Strangely, a company that made its fortune by developing a line of compatible computers at different price points, all running the same software, would end up damaged by that very same phenomenon of software compatibility. This pattern of not recognizing discontinuities—even by companies that had previously created them—would be repeated over and over.

— listen to the market

The story of the IBM PC is not primarily about hardware. It is a story about software, as well as unintended consequences, hubris, and greed. Nobody at IBM imagined that their own actions would transform the computer industry in such a way as to significantly diminish their leadership role and even put the company's existence in peril. Likewise, nobody at IBM foresaw that many small companies would form, each taking a bite out of IBM, let alone that among these thousands of piranhas would be the likes of Bill Gates and Andy Grove.

Sometime in 1980, the top management of IBM, watching Apple Computer's growth, concluded that IBM should enter the nascent PC market. Apple had transitioned from serving a hobby market into building a productivity tool, driven by business applications like VisiCalc, the first spreadsheet application. If the PC were to create a new market, IBM management wanted to dominate it. Atari, then the leader in

computer gaming and a subsidiary of Warner Communications, had contacted John Opel, IBM's president, with an offer to develop a PC for IBM to serve the business market. Frank Cary, IBM's CEO, asked Bill Lowe, the general manager of its Entry-Level Systems Division in Boca Raton, to evaluate this possibility. A few months later, Lowe presented his review to the IBM management committee. He recommended that IBM acquire Atari from Warner and use a repackaged version of the Atari 800 computer as a starting point for IBM's entry to the PC market. He even demonstrated to the committee a modified Atari 800, which had been brought to market a year earlier and was doing well.

My close friend Steve Mayer, one of the founders of Atari, had been the lead developer of the 800. This computer was designed for entertainment and games, so why Lowe thought it could serve IBM's needs is a mystery to me. Perhaps he thought IBM could never develop a competitive PC in time to enter the market and so at least wanted to take the available opportunity. Or perhaps he cleverly manipulated the committee to give him the authority to move forward outside of the normal IBM processes.

The IBM executives wisely rejected Lowe's Atari proposal. However, they understood the challenges of creating new products within the IBM culture. Developing a new computer at IBM could take five years or more, as IBM's cultural focus on quality impacted both design and manufacturing. Indeed, Lowe's team had already spent almost four years developing the IBM Datamaster, a precursor to the PC.

IBM had numerous committees and procedures. Anyone could say no, and no one person could say yes. To counter this, Cary had already begun to encourage the creation of small autonomous units—"independent business units (IBUs)"—to counter IBM's sluggishness. He asked Lowe to form an IBU to develop a PC. Lowe returned to the Management Committee on August 8, 1980, with a plan to set up a small team to develop the IBM PC. Don Estridge, who had been the assistant general manager of Entry-Level Systems, became the head of the newly formed PC team, which also included marketing and sales. Lowe committed to bringing the IBM PC to market in an astounding one year. Therefore, he explained that his team would have to go outside of IBM for most of the critical components, including the microprocessor

and the operating system. The Management Committee approved this plan.

One year later, on August 12, 1981, the IBM model 5150—the IBM PC—was launched during a splashy press conference at the Waldorf Astoria in New York City. Its price tag was $1,565 (about $4,400 today). No one at IBM or anywhere else understood that the computer industry had just been turned on its side. IBM had launched a near-fatal blow to its own business, creating a "virus" that would almost kill IBM and that would prove a mortal blow to most of the other existing computer companies.

In order to meet the one-year product shipping deadline, the IBM PC team used existing hardware components from other companies. Importantly, this included the microprocessor: the Intel 8088. IBM also licensed the computer's operating system from Microsoft. The decision to go outside IBM for most of the PC's hardware and software was probably the most consequential decision taken to date concerning the development of the computer industry. But the decision's impact was not understood by anyone at the time, certainly not by IBM, and certainly not by Apple, at the time the leading PC company. On the day of the IBM announcement, Apple ran a full-page ad in the *Wall Street Journal* headlined, "Welcome, IBM. Seriously," with the touch of arrogance only Steve Jobs could supply. At this time, Apple had about 20 percent of the PC market. Their share would drop below 4 percent just a few years later. They mistakenly thought they would be competing only with IBM.

PROJECT CHESS

The PC unit's code name was Project Chess, and the first computer was called Acorn.

Strangely, Bill Lowe was promoted right in the middle of the PC's development, and Don Estridge, his number two, was now placed entirely in charge of the effort.

— small teams can outperform big ones

The team was just thirteen individuals, and that included marketing, licensing, and software people. But the power of small teams should not be underestimated. Yes, they used off-the-shelf components and subsystems, but there were many, and they required integration. They also had to develop an overall architecture, create a third-party software business, and set up distribution, among other things. Robert X. Cringely, in his excellent book *Accidental Empires*, explained their speed as a head start; they reused much of the work already done in developing the IBM Datamaster, a word- and data-processing system aimed at small businesses. The Datamaster, released a month before the IBM PC, used the Intel 8085, which had a compatible bus architecture with the 8088. Still, I scratch my head. None of the people I met who worked on the team really impressed me, with the exception of Don Estridge.

BRING IN THE CLONES

Many think that Microsoft and Intel created the PC revolution, but Compaq actually set the course. When the IBM PC was introduced, neither Intel nor Microsoft recognized the opportunity. Intel was worried that its x86 architecture was uncompetitive and would soon lose out to the various RISC processors being developed by competitors like Motorola and National Semiconductor. And so, Intel embarked on its ambitious plan to develop the 32-bit 432. Microsoft, meanwhile, was working on an operating system, Xenix, which was based on Unix.

Compaq was founded in 1982 by three engineers working at Texas Instruments: Rod Canion, Jim Harris, and Bill Murto. Canion documented the story of Compaq in a 2013 book, *Open: How Compaq Ended IBM's PC Domination and Helped Invent Modern Computing*. Wanting to leave Texas Instruments and start their own company, Canion, Harris, and Murto explored several ideas, including developing an add-on hard disk for the IBM PC. Eventually, on January 8, 1982,

they decided to create a portable version of the IBM PC. A nascent venture capital fund, Sevin Rosen, put together Compaq's first financing of $1.5 million, alongside the well-known venture firm Kleiner Perkins. Sevin Rosen had also, importantly, backed the start-up Lotus Software, which developed Lotus 1-2-3, the most critical application (a spreadsheet) for the IBM PC. A little over a year later, in 1983, Compaq began shipping their portable computer. They ended that year with an astonishing $111 million in sales.

Two initial strategic decisions set Compaq on a course for success. First, and most importantly, their computer was 100 percent compatible with the IBM PC. That meant that all software developed to run on the IBM PC would run on the Compaq computer, too. The second was to offer a portable computer, which was a product that IBM did not have.

To make their computer compatible, Compaq had to consider the BIOS (basic input/output system). A small sliver of software, the BIOS acted as the interface between the operating system and the computer hardware. It was often called firmware, because it did not change and was stored in read-only memory (ROM). Application software was supposed to access hardware through the operating system, not the BIOS directly. Still, application software developers would sometimes reach down into the BIOS to get higher performance from their applications. The *Apple v. Franklin* ruling in August 1983 (more about this in the next chapter) made clear that a BIOS could be copyrighted. Once IBM released its PC, many companies began to offer IBM-compatible PCs by just copying IBM's BIOS in the same way as Franklin had copied the Apple II BIOS. They therefore infringed on the IBM copyright in the same way as Franklin Computer had infringed on Apple's. Starting in late 1983, then, after the *Apple v. Franklin* ruling, IBM used the courts to put these other companies out of business. It was not pretty.

Compaq, by contrast, understood that they had to develop a fully compatible BIOS that did not infringe on IBM's. Compaq did so successfully, no easy task. Compaq also had to reengineer Microsoft's operating system, MS-DOS, so that it was compatible with IBM's PC DOS. Eventually, Compaq licensed its changes to MS-DOS back to Microsoft, as Microsoft had incorrectly assumed that application software for other personal computers would use its application

programming interfaces (APIs) without reaching into the underlying hardware. The BIOS, Microsoft thought, would be unique for every computer manufacturer. As it turned out, that was not what happened. Clone manufacturers would routinely bypass the operating system to improve performance or reduce programs' size.

Compaq's second critical strategic decision was to offer a portable as their initial product. Since IBM had no portable computer, Compaq's portable provided customers permission and an opportunity, especially at larger corporations, to buy a non-IBM computer that was nevertheless software compatible with the IBM PC. By the time Compaq was formed, the market had some portable (luggable) computers, like the Osborne 1 and the Kaypro II, and these were doing well. Compaq believed that the combination of portability and compatibility would be a killer proposition on the market. It was!

CAN'T PUT THE GENIE BACK INTO THE BOTTLE

Compaq was the first to throw a sword into the body of IBM by designing a fully compatible computer. It was followed by tens of other companies. IBM never imagined that other companies could develop a compatible PC without infringing on their BIOS copyright, nor could they believe that such companies could succeed even with a non-infringing BIOS. In 1984, Lance Hansche, a senior executive at Phoenix Computers, discovered a failed clone company in Texas that had successfully developed a non-infringing BIOS. Phoenix acquired the BIOS and also made changes to MS-DOS, like Compaq did, offering full IBM PC compatibility to the many companies that wanted to offer clones without going through the expense and time needed to develop a legal BIOS. Phoenix's many customers included Hewlett-Packard, AT&T, Tandy, Gateway, and Dell. Now that any company could develop a computer that was fully IBM PC compatible, many did. By 1986, clone manufacturers had more sales of IBM-compatible PCs than IBM.

In 1984, IBM launched the IBM AT. This was perhaps the most consequential event in creating the PC industry. The AT utilized the Intel 286 processor, which was backward compatible with the 8088

that IBM used in its original PC. This solidified the importance of software compatibility, and unknowingly, IBM handed the keys to the PC kingdom to Intel and Microsoft.

IBM, soon enough realizing that it could not compete with the clone manufacturers that had a much lower cost structure, decided to develop a proprietary system, called the PS/2, with a proprietary operating system, called OS/2, and a new bus structure, called Micro Channel. They also used their proprietary networking technology, Token Ring. The PS/2 finally launched in 1987, and IBM paid Microsoft to help develop it. As silly as it may sound now, IBM paid Microsoft per line of code. So, of course, OS/2 was bloated, although it was probably technically rather strong.

IBM thought it could put the genie back in the bottle. PS/2 would be a success, and clone manufacturers would have to license technology from IBM. The resulting licensing fees would increase prices and provide IBM with the margins they needed to be profitable in the PC business.

At the same time, Microsoft was developing Windows. Gates tried to convince IBM to use Windows and abandon the development of OS/2. IBM refused and so found itself dependent on what would soon be its competitor in the operating system business: Microsoft.

IBM wanted to move from Intel microprocessors and use the PowerPC microprocessor, which they were developing together with Motorola and Apple. However, only Apple would use it in a personal computer. Compatibility forced IBM to continue to use Intel microprocessors. IBM based the PS/2 on the Intel 286 chip. Meanwhile, Intel was counting on the 386 to be a big success and tried to convince IBM to use it.

IBM strongly resisted using the Intel 386, the first 32-bit microprocessor that was compatible with the earlier x86 processors. They had concerns that a more powerful 32-bit PC could compete with their minicomputers, and they were exploring the development of their own 32-bit microprocessor with the PowerPC. In an interview with *PC Magazine* from March 25, 1997, Bill Gates stated that IBM was concerned that Intel was not capable of getting the 386 done. I doubt that was really IBM's view; most likely, it was just the excuse they gave Bill.

I'm still amazed that IBM thought they could succeed with this strategy. Perhaps if the PS/2 was vastly superior to the PC clone products, it might have had a chance. But it wasn't. It would have been much better for IBM to exit the PC business sooner—as it eventually did—to specialize in integrating PCs into the corporate world. After Asian PC companies entered the market, they drove prices down to the point that IBM had no choice but to exit the PC market altogether in 2004, wisely selling their PC business to Lenovo, a Chinese company.

Not having IBM's support for the 386 put Intel in a quandary. Intel decided to do everything it could to get Compaq to bring out a desktop PC using the 386, leapfrogging IBM. At one meeting at Intel I attended, someone said Compaq would be the rabbit that the dog (IBM) would chase. Once Compaq came out with a 386-based PC in 1987, the rest of the clone industry followed. The next year, Dick Boucher, an Intel vice president and my officemate, discussed the IBM situation with me. IBM had a license to manufacture a certain percentage of the 286 chips they were using. As Dick was the senior executive dealing with IBM, IBM had asked Dick if Intel would agree to let IBM manufacture more units, since they had unused capacity at their factory. IBM had negotiated rights to manufacture a portion of all future processors in the x86 family, including the 386. I suggested to Dick that Intel agree to let IBM build more 286 chips if they gave up the rights to the 386 and future x86 processors. IBM agreed.

IBM found itself in a difficult spot. The clone manufacturers did not move to IBM's proprietary technologies. IBM could not compete with the clone manufacturers, nor could they get the industry to move to any of their proprietary technology. IBM never brought the PowerPC to the desktop market successfully, though Apple did use the microprocessor for its Macintosh computers starting in 1994. The PC market that looked so good to IBM in the early 1980s was now a rock tied around their necks in a sea of clones, and IBM was drowning.

The American clone companies were not immune to the pressures of Asian competitors, either. Intel was very active in developing low-cost PC manufacturers in Asia that were willing to accept low margins. It served both Intel and Microsoft well to have many PC manufacturers, none with any market power. Effectively, the PC manufacturers became distributors for Intel and Microsoft products. Microsoft,

in fact, could sell its products directly to end users, bypassing the PC manufacturers entirely, and even began to sell hardware peripherals like mice and keyboards, as well as application software like Microsoft Office. Access to end users was a very important advantage for Microsoft, one that Intel did not have. Intel's lack of such access is probably one of the reasons that Microsoft is worth so much more than Intel today.

Many years after the introduction of the IBM PC, Andy Grove described the change from a vertical to a horizontal computer industry in his 1995 book, *Only the Paranoid Survive*. He reflected on this change in the context of what he termed "a strategic inflection point":

> A strategic inflection point is a time in the life of a business when its fundamentals are about to change. That change can mean an opportunity to rise to new heights. But it may just as likely signal the beginning of the end.

The structural change in the computer industry from vertical to horizontal integration would take more than a decade; throughout the 1980s, the computer industry remained dominated by mainframes and minicomputers. The transition would only become clear to everyone much later. I think Andy thought the change would be permanent, but it did not hold through the ascendance of mobile computing devices, such as the iPhone.

6. GOING DIGITAL

Back in 1979, the impact the PC would have on the computer industry's future was still unknown. Having achieved recognition as an expert in the use of computer technology in cardiovascular medicine, I was going to give all that up to become a designer of computers. It was a scary decision. But at least I knew what company I wanted to work for. I had worked with Digital Equipment Corporation's computers for more than a dozen years, so that company was my first choice.

I got interviews with Digital Equipment Corporation through contacts I had developed over my long-standing relationship as their customer. Digital, at that time the second-largest computer company in the world, comprised many business units, called product lines, as well as some core services (manufacturing, engineering, sales, and finance). I interviewed with a number of the product lines and with a group run by Dick Clayton, whom I knew through Mort Ruderman. It was Clayton who organized and paid for my trip to Digital's headquarters in Maynard, Massachusetts.

A key person within Clayton's organization was Roy Moffa, and we hit it off. I wanted to work in his department. Within the dominion of the Digital Equipment Corporation, the engineer was king. To be successful there, I would have to prove that I was a great engineer, especially since I had no formal engineering training. I spent a few days meeting with Roy and other members of his team. Arianne, who had come to Massachusetts with me for this week of interviews, and I

had dinner at Roy's house and met his wife. The week went by quickly, and Friday afternoon arrived before I knew it. Roy and I met for drinks at a restaurant near the Mill, Digital's headquarters, to wrap things up.

I fully expected Roy to offer me a job, and I was excited to accept it. Instead, he told me he could not offer me a position. While he thought that I could make a significant contribution to his group and the company, he felt strongly that the other managers in his group should agree. One of them did not, as it turned out. It was quite a blow. I was counting on getting this position at Digital; I didn't have a backup plan and had to take action. I emphatically told Roy that this was the wrong decision for Digital, for him, and for me. I asked him if I could speak with the manager who was not in favor of my joining the team, and I asked him to reconsider his position. The manager backed down, as I was pretty sure he would if confronted. Roy then hired me on the spot. I don't know what would have happened had he said no.

We flew back to Israel the next day. It took us about three months to arrange to leave Israel and move to the United States, which involved many complications, including how to get my share of the house sold. Fortunately, Moshe agreed to buy it for $100,000 in cash—and I mean bills. How he had so much in hard, printed US dollars was a mystery to me. Getting the money out of Israel, which had currency restrictions at the time, was a real challenge. I went to different banks with about $5,000 in cash, the maximum that could be transferred under the restrictions, and asked them to wire the money to my bank in the United States. Though terrified that the authorities would realize I was avoiding the currency restrictions, I was desperate to get my money out of Israel.

Arianne, who had both Dutch and Israeli citizenship, had to get permanent residence (a green card) to live in the United States. We also had to find a place to rent. I wrote to the synagogue in Sudbury, close to Digital's Maynard headquarters, and they found us a lovely home to rent for a year. It was exhausting, but we were there by July 1979. I remember the sense of relief we felt as we flew out of Israel. Now, some forty years later, I have a sense of relief when I arrive back in Israel, now my home once again.

Digital Equipment's headquarters, the Mill

Computer development within Digital's Central Engineering was organized into four quadrants: high-end and low-end hardware and high-end and low-end software. I became responsible for developing product strategy for low-end computer hardware. Then, just three months after I started, Roy moved to a new position, launching Digital's semiconductor capability in Hudson, Massachusetts. My new boss, Herb Shanzer, reorganized the group. I was now in charge of hardware development, product support, and strategy for low-end computers, which included all PDP-11s utilizing the Q-bus. It was a big job with more than a hundred engineers and technicians reporting to me. For the first time in my career, I did not know the names of all the people working for me.

In my new position, the manager who objected to hiring me ended up working for me. I fired him soon after, not out of any sort of revenge but because I thought that his opposition to my hiring wouldn't be the last time, as he put his insecurities above the well-being of the corporation. He quickly found another position at Digital.

While I did not work with Roy long, we stayed friends, and I will always be grateful for the opportunity he gave me. Roy died young,

sadly. Many years later, ironically, Intel purchased the Hudson semiconductor facility he had started.

Promoted twice within my first year at Digital, I must have been doing something right. I was in heaven, spending my time working with my team on product design and computer architecture. I had first discovered computers just twelve years earlier. Now I was running hardware engineering for low-end computers at a major computer company. Who could have imagined?

Herb and I got along well. We often ate Philly cheesesteaks at a cafe in Maynard and talked about the world. He was more friend and mentor than boss. My group was much larger than those I had managed in the past. Fortunately, Digital had internal courses and formal management processes, so I was able to develop some critical skills.

Ken Olsen, the legendary founder and CEO of Digital, was very focused on the mechanical packaging of computer systems. While he did not really grasp software, he had a strong interest in the physical design of computers, an attribute he would share with Steve Jobs. Ken had a poster printed and put it up all over the Mill with a photograph of the back of the company's DECmate word processor. Cables ran everywhere. At this point, I had just been promoted to be responsible for DECmate hardware, among other computer systems. While I thought that Ken's poster made a good point, I couldn't help myself. I scrawled on a number of the posters, "Can you imagine what software would look like if you could see it?" But I did agree that DECmate was a mess.

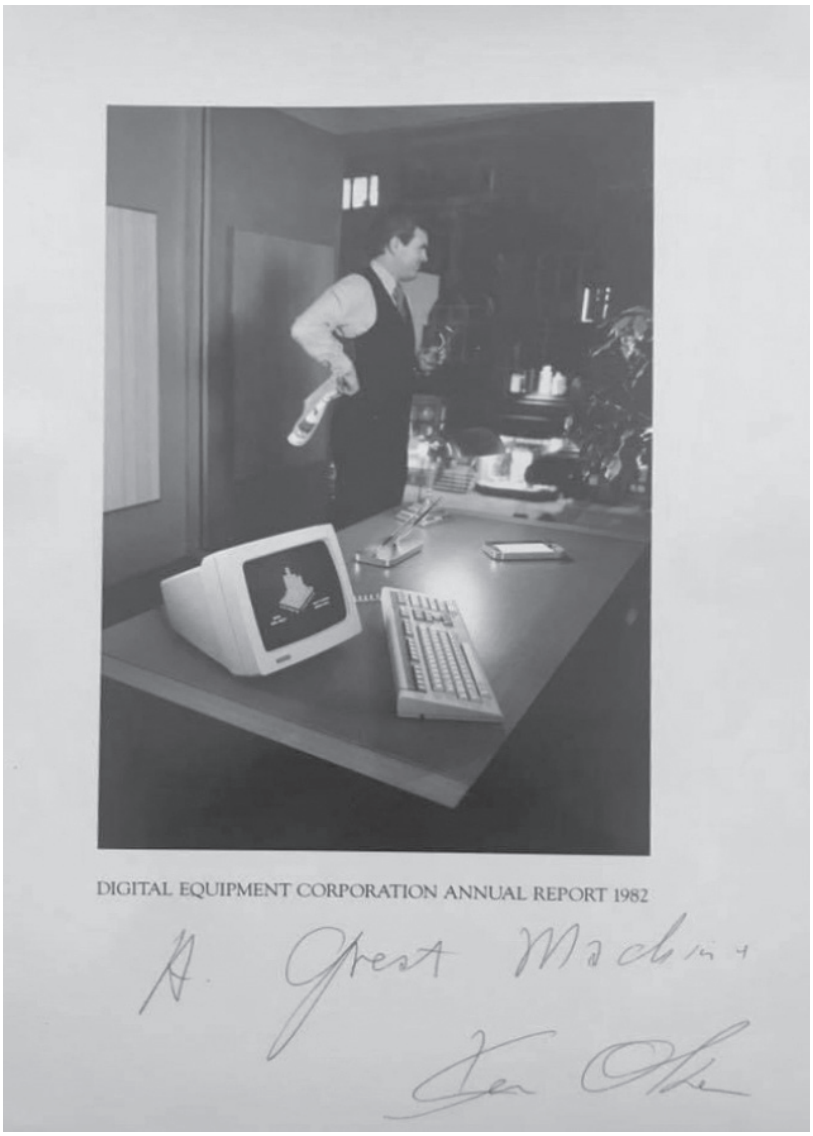
A COMPUTER FOR CLERKS AND CLERICS

Soon after, I received an invitation to attend the annual off-site meeting of about a hundred senior engineering staff. Outside speakers were invited. I most clearly recall a presentation by Al Shugart, the key person behind the Winchester disk technology still used in many personal computers. Al had led IBM's storage efforts, and he had just started a company, Shugart Associates. At that time, hard disks were large and very expensive. Al, realizing that the then nascent personal computers would become essential products of the computer industry, decided to

make a small form factor consistent with their size, the same 5 ¼–inch size as the floppy disk units already shipping with personal computers. His initial product held five megabytes, just large enough to store one uncompressed photo taken by today's typical smartphone.

A few days later, Gordon Bell asked me to attend a small meeting at the home of Stan Olsen, Ken Olsen's brother. Gordon Bell was and is still a very respected computer scientist/architect. He was the driving force behind most of Digital's computers and, most importantly, the VAX. Along with Stan and Gordon, two other members of the engineering organization, was Ken Olsen.

The meeting's primary purpose was to discuss the possibility of developing a small, single-user computer. But later, it became clear to me that it was really a job interview. In addition to engineering for low-end PDP-11s, my group was also responsible for the company's DECmate word processor and a small computer system offered by the commercial product line. I had already started designing a small computer system. Gordon had reviewed this work with me, so it made sense that I was invited to this meeting. At that time, a number of personal computers, like the Apple II and the TRS-80, had already hit the market, but Digital considered these products to be designed for hobbyists and unsuitable for business use.



Ken Olsen gives me a copy of the annual report.

We never used the term "personal computer." I remember Ken saying that it should be so simple to use that even his minister and his secretary could use it. I jokingly referred to it later as a computer designed for clerks and clerics. Ken never considered that he might use a computer himself. Once when I asked him about that possibility, he told me his fingers were too big for the keyboard. But I knew that was not the reason. If he had really wanted to use a keyboard, he would have had one built with bigger keys.

Stan, Ken's brother, suggested that the computer monitor be tilted upward so that someone with bifocals could quickly look at the screen. It was a pretty good idea, one which we eventually implemented. I don't remember having a conversation about software during the meeting. Much of the decision that day had to do with the packaging of the computer.

After hours and hours discussing the features of this computer that did not exist, it became clear to me that no one in the room had any idea how to make such a product happen. I looked right at Ken and asked: "Do you really want this to happen?" He said he did. "Then I'll make it happen," I said. I was thirty-four years old. Ken was fifty-two years old, the same age as my mother. I thought then of Ken as close to retirement age, which is funny because now that seems so young to me. I do wonder where I found my apparently bottomless self-confidence at that age.

Ken questioned, during that meeting, whether it was actually possible to make such a computer at Digital. He even half joked that he and I should think about leaving Digital and starting a new company together. In retrospect, it is possible that everyone would have been better off if we had. I did not realize it at the time, and I guess Ken did not as well, but the company had grown too large for him to manage. Spending that day with Ken was a powerful experience for me. It would be the first time I spent time with someone of Ken's stature but far from the last.

For many years prior, Ken had not taken personal computers seriously. It is easy to understand. At the time of the meeting, the most successful personal computer was the Apple II, which had just a forty-character display. However, it did run VisiCalc, the first spreadsheet program, which was perhaps the catalyst for the PC revolution. Ironically, it had been developed on a Digital product—the PDT-11 Intelligent Terminal System.

Ken was very intuitive. It was that very intuition that led to the creation of Digital in the first place. Back in 1957, Ken had realized there was an opportunity to offer computers in what was then the low end of the computer market, computers that did not require air-conditioned rooms with specialized staff to operate them. He came to understand the potential of personal computers to create a new market but could

not seem to get anyone in the company interested. At that time, the company's focus was VAX, the world's most successful minicomputer. The most talented engineers in the company under the leadership of Gordon Bell wanted to develop ever more powerful computers. I would observe a similar phenomenon later at Intel.

Ken was looking for someone to take charge and lead the company's efforts to create a personal computer. Gordon was looking for someone to get Ken off his back. This was to be me.

PROJECT KO

I told Ken that if he wanted this computer to happen, he had to give me the authority to do it. I asked him to invite me to the Operations Committee meeting (his staff meeting) scheduled a few days later. I explained that I would present a plan to the executives and would ask various groups to provide me with the resources I needed. I asked Gordon to write up our discussions and send out a memo to the members of the Operations Committee in advance, making it clear that Ken stood behind this project. I called the project KO, which I said stood for "knockout." Everyone knew it referred to Ken Olsen. We later renamed the program CT, for Communicating Terminal. I no longer remember why we took that name.

Gordon never had his heart in this project, focused as he was on the development of the VAX and VMS, Digital's 32-bit architecture. Meanwhile, we planned to use the 16-bit PDP-11 architecture. Gordon was glad that Ken had found something to keep him busy and away from VAX and VMS. Ken and Gordon clearly had some issues, to put it mildly.

The presentation to the Operations Committee went very well; even though I had never made a presentation to a group of senior executives before, I felt very comfortable doing so. The outcome was never in doubt because of strong support from Ken Olsen, Stan Olsen, and Gordon Bell. I asked each of the functional managers to provide me with someone to represent their organization, matrixed to me. I described my role as program manager for the KO project.

I no longer reported to Herb Shanzer. Elevated one level (promoted again), I reported directly to Dick Clayton, vice president of all low-end engineering. Dick was supposed to make sure that I got all the resources I needed, but he was pretty passive in reality. He also did not want to get in between Ken and me, so I met directly with Gordon and Ken to get things done. I must have complained to Ken about Dick's lack of interest, and as a result of this and several other issues, he was given a new role. Bill Avery replaced him. While Bill did provide the resources I needed, he did little else to help me but neither did he get in my way. I kept direct lines to both Ken and Gordon, frequently meeting with both individually and sometimes together.

The first person recruited to join my team was Vahram Erdekian, an engineering manager in the manufacturing organization. He was outstanding and made significant contributions to our effort. Ron Ham joined us as the head of software development. Art Williams was responsible for hardware development. Mike Weinstein joined the team to run our marketing, and Bob Sanfacon ran operations. For a while, I even made Ken Olsen the packaging and power supply engineer, and eventually put him in charge of all mechanical engineering for a time. The actual engineering was done by Dick Gonzales, the senior mechanical engineer at Digital and a man who was very close to Ken. But Ken did sign off on Dick's designs. I knew this area interested him the most, and it kept him engaged and committed to the program. It also gave me a reason to meet frequently with him alone. I realized that even though he was the CEO of a major corporation, he missed being a design engineer.

The team, except for Ken, met every day both to define our product offering and to figure out how to get everything done. It was exhilarating, and I was very happy. I could not believe my good fortune. The next two and a half years would be the most intense of my career, and I learned so much about leadership. I had found my voice.

Ken wanted a computer that was beautiful to see and simple to use. His limited experience using computers was word processing, and his assistant did that for him. I doubt that he ever touched a keyboard himself. His vision was a computer that was powerful, easy to use, beautiful, and at a low enough price point that every professional and small business could afford one. In many ways, Steve Jobs would

later remind me of Ken. Ken saw this as a new market, as larger enterprises and institutions were already served by time-sharing computers accessed via terminals. In 1980, Digital's core business comprised the VAX and PDP-10, many of which operated as time-sharing systems. Indeed, it was on a PDP-10 time-share computer where a young Bill Gates would learn to program. Enterprises, even the personal computer companies such as Apple itself, did not use personal computers to run their businesses. More than a decade would elapse before that began to happen.

We defined a system called the CT325 to meet Ken's design requirements. My heart was not in that product. It was very limited, with small memory (128 kilobytes), and only a floppy disk for external storage. It was undoubtedly beautiful, however. We designed a much more robust system, the CT350, meant as a workstation for professionals. This is where we directed much of our effort and budget. Later, we changed the name from CT to the Professional to reflect our focus. The DEC Professional 350 was elegant, powerful, and, ultimately, a total failure. I still love it.

Ron Ham developed our software architecture. Digital was slowly moving to a single computer architecture under Gordon Bell's technology leadership. The hardware was VAX, the software was VMS, and the network was DECnet running on top of Ethernet, which had just been designed. Digital was already making significant investments in semiconductor capability through the facility in Hudson run by Roy Moffa (and Steve Thiecher). Their target was VAX on a chip, but that would be many years in the future. We wanted to make the Pro 350 compatible with VMS, the VAX's OS, at the application layer. That way customers could migrate to the VAX architecture when we eventually had a VAX/VMS version of the Pro.

To accomplish that, Ron advocated that we use an operating system called RSX-11, an exceptional multitasking and real-time operating system developed for the PDP-11. It would be a decade before Microsoft would be able to offer such capabilities. Applications were written for VMS in the BLISS programming language, which was created at Carnegie Mellon University. As the primary programming language used for VMS application development, Ron figured out how we could recompile those applications on RSX-11 to offer a great many

applications that were also offered on VAX/VMS systems. The Pro 325 ran a low-end operating system, RT-11, and was not software compatible with the rest of the Pro family. Had the IBM PC never launched, resulting in an eventual restructuring of the computer industry, this strategy might have been very successful. When it was proposed, we had no knowledge that the IBM PC was in development, which was kept very secret by IBM.

My group had about three hundred people directly, alongside probably more than one thousand people in other groups including manufacturing, service, marketing, and sales. Our initial budget was $20 million. There were only thirteen people within IBM's Boca Raton Entry Systems Group developing what became the IBM PC.

Gordon had no interest in low-end computers and kept himself busy developing ever more powerful VAX systems. He did have a passing interest in workstations, and we visited Sun Microsystems together around 1982. We briefly discussed trying to acquire Sun, but Gordon was not interested. Digital really should have owned the workstation business that Sun and later Silicon Graphics dominated. It would have been a natural fit for Digital, but I didn't press the issue; my heart was really in developing systems for professionals (knowledge workers).

THE WORLD'S MOST POWERFUL PERSONAL COMPUTER

Several critical design decisions defined the Pro. We decided to develop a unique dual-sided, five-inch floppy disk drive. Floppy disks at that time were single-sided, so we doubled the amount of storage while keeping the same size enclosure. This was an example of an engineering-driven decision that resulted in our floppy disks not being compatible with any other computer system. The display was bitmapped, and it used the same memory space as the programs and data, which was a very advanced concept for its time. Wim Englse, whom I brought over from Rotterdam, and I developed this over the objections of the Pro engineering team, who thought that it would slow down performance too much and did not appreciate the power it could provide. Wim and I had a lot of experience with bitmap graphics from

our work much earlier at the Thoraxcenter. Using a bitmapped, directly addressable display enabled powerful formatting on the screen, including advanced fonts. In 1981, the Xerox Star was the first commercial system to offer bitmapped graphics on an eighty-character display, but it was priced about five times higher than the Pro. Wim and I won an award for our design of the graphics unit. I was and still am very proud of it.

Personal computers (PCs) at the time were desktop devices. Since we did not want to take up valuable desktop space with the computer enclosure, we designed the Pro so it could not only lie flat but also be rotated ninety degrees to stand vertically on its side. This way, the monitor and keyboard took the bulk of the valuable desktop space. Later, other manufacturers would adopt this design, and it would become the dominant way of orienting desktop computers.

Professional 350

Working as a consortium, Xerox, Intel, and Digital agreed to develop and launch Ethernet, which was a way to connect computers together if they were located physically close to each other. The first specification was published in 1980, so Gordon asked me to incorporate Ethernet into the Pro. We added a board from 3Com, the company founded by Bob Metcalfe, who had developed the original concept of Ethernet while at Xerox. The initial design of Ethernet used a coaxial cable, similar to the ones used for television. For some reason, it was yellow. If you wanted to connect the Ethernet, you used a clamp that not only gripped the cable but also penetrated it, creating a physical connection. One day, when I was in Gordon's office in the Mill, Ken walked in with a yellow cable in one hand and a bunch of phone cables in the other. Ken said to Gordon, "Maybe your university friends want these yellow cables, but my friends want telephone wire." Gordon, angrily, snapped back, "Why don't you go work at Data General and do an Ethernet with phone wire. I hear they are looking for engineers." Ken was right; telephone wiring ended up as the standard. Interestingly, neither Xerox, Digital, nor Intel directly benefited from their work defining Ethernet. New companies, like 3Com, and later Broadcom, would take advantage of the opportunity they had created instead.

The key to our system was a five-megabyte, 5 ½-inch Winchester hard disk that I had seen at the Central Engineering retreat. Finis Conner was head of sales of Al Shugart's company, which was now named Seagate, the only supplier at that time to offer a hard drive in this small form factor. Finis asked me to give him a $1 million purchase order in advance of the Seagate IPO. I did, which I'm sure was beneficial for them. Had I been more sophisticated at the time, I might have asked for some warrants so that Digital would have made some money on the increase in their value as a result of our order. I almost certainly did not even know what a warrant was at that time. We had a lot of problems with their first shipments. I used to joke that Al Shugart taught me that you could sell, manufacture, and then design a product in that order.

Digital never became a large customer for Seagate, because we were unsuccessful in the personal computer market. Their primary customer became IBM, with the IBM PC XT. Meanwhile, the disk

engineering group at Digital, run by Grant Saviers, was actually in the process of developing a five-megabyte Winchester disk themselves. Before I could order any Winchester disks from a competitor, I had to convince the disk engineering group to approve this plan. Expecting delays, I didn't want to depend on an internal engineering group for critical parts. I suggested to Grant that his group develop a ten-megabyte hard drive so they could leap ahead of Seagate. I told them I was confident they could launch such a large drive soon after Seagate brought their smaller five-megabyte drive to market and promised to switch to the Digital drive as soon as it was available. When Seagate launched a ten-megabyte drive before the internal group could, I had to convince them once again, this time to develop a twenty-megabyte hard drive. I don't know if they ever got that done, either, because I was gone from Digital before it was supposed to happen.

The keyboard, as it turned out, was one of the most challenging components to develop. The technical challenges were modest at best, but the critical business units couldn't agree on the labeling of the keys. We set up a keyboard committee that comprised the various interested parties, which met every week and never came to an agreement. The keyboard was named the LK200. Finally, fed up, I went to the committee meeting and told them how proud I was of their work and dedication. I explained they could take as much time as they needed. In the meantime, I said, we should start working on the successor keyboard, to be called the LK300. Since they were all so busy with the LK200, I suggested, I would find other people to work on the LK300. That week, the committee finished their work. All the members then volunteered for the LK300 committee, which I never formed. I was so glad to be rid of them.

In 1980, the telephone and handwritten or typed letters either mailed or faxed were the primary forms of personal communication. Voice-mail systems from companies like ROLM, Octel, and AT&T were just being introduced. I decided that we should integrate telephony capabilities into the Pro. We called it the Telephone Management System (TMS). The idea was to provide a professional voice-mail option in a small, remote office as if it were a central office. The user could select from a contact list to dial and record voice messages. There was a built-in 300-baud modem, the maximum speed

for a modem without a direct connection to the phone line. With a direct connection, one could go as fast as 1,200 baud. By comparison, connections to our homes using cable modems today achieve speeds between a thousand and ten thousand times faster.

We worked together with VisiCorp, distributors of the hugely successful spreadsheet, VisiCalc, developed by Software Arts. VisiCorp distributed several other applications in addition to VisiCalc, with only the "Vis" at the beginning of their names shared in common. The company decided to create a product, Visi On, that integrated all of these applications, modeled after the Xerox Star. The Pro 350 was their target platform, as it was the only personal computer with a hard-drive operating system and enough memory and power to support this ambitious software project. VisiCorp was larger than Microsoft when Bill Gates saw Visi On demonstrated at the 1982 Comdex trade show in Las Vegas on a Pro 350. The documentary *DEC: Personal Challenge, 25th Anniversary Video*, produced by Marc Porat, focused on the development of the Professional. It shows Ron Ham, Mike Weinstein, and me walking around the 1982 National Computer Conference in Houston, clearly thinking that we had just won the PC war. The CEO of VisiCorp, Terry Opdendyk, and Bill Gates had serious discussions about the two companies merging, but these talks collapsed. Seeing the Visi On demo probably influenced Gates's decision to build Windows.

We wanted to develop an independent application ecosystem, so we devised the idea of "digital authorized software" with three levels: platinum, gold, and silver. Platinum software was marketed, distributed, and supported by Digital. Gold software was certified by Digital, meaning that we tested the software in our labs. Silver software was self-certified based on a testing process we had developed. We signed up a lot of software companies, particularly in vertical areas like finance, health care, and education, and those companies paid Digital for certification. The product lines drove the development of the application business.

Periodically, I gave updates on the project to the Operations Committee. I was also asked to update Digital Equipment's board of directors, which was pretty heady stuff for me. The board at that time included Georges Doriot, father of the modern venture capital

industry; Philip Caldwell, the CEO of Ford Motor Company; and, of course, Ken Olsen, who later joined Ford's board.

The Operations Committee asked me to rehearse my presentation with them before I gave it to the board. This was a problem; unlike the Operations Committee, the board was not very technical, so the same presentation would not really go over well for both. I carried a bag of cables and power supplies into the Operations Committee, set them down on the table, and said, "You can really help me if you can do a bit of role-playing and act like the people on the board instead of executives of a computer company. But, if you would rather do the latter, I brought some hardware with me." Somehow, this stunt worked. The presentation to the board went well, although the board had no clue what I was saying. I think they were just trying to figure out if I knew what I was doing, a test I apparently passed. As I told the Digital board, the Professional represented Digital's initial attempt to address the PC market by offering a proprietary system that was compatible with Digital's PDP-11 line of computers.

Coincidently, around the same time I was laying out my plans for the Professional Series PC to the Management Committee of Digital Equipment, Bill Lowe was presenting to the IBM Management Committee in August 1980. While IBM had just thirteen people working on its PC and would ship it twelve months after the start of the project, I had hundreds of people working on the Professional at Digital and spent three years developing an unsuccessful product. The Professional would not ship until mid-1983, by which time IBM and manufacturers of IBM-compatible computers would be well entrenched in the market. The IBM team traded off functionality and quality in favor of time; the one-year deadline was held absolutely constant. At Digital, we instead favored functionality and quality. We failed to understand what Adam Osborne, the founder of Osborne Computer Company, meant when he spoke of being "adequate." While the IBM PC Group primarily bought off-the-shelf components, Digital designed almost everything from scratch.

HENRY FORD'S OFFICE

Digital created a system of executive sponsors, executives who were assigned to look out for different companies. As an executive sponsor, one had to make sure the customer was happy and give them someone to call if there were serious issues. Ken asked me to be the executive sponsor for Ford Motor Company. I considered this a great honor, since Ford CEO Caldwell was on the board of Digital and Ken was on the board of Ford.

Toward the end of 1980, Ken asked me to go to Ford's headquarters in Dearborn, Michigan, to give Caldwell's assistant a DECmate computer. The Digital salesperson responsible for the Ford account picked me up from my hotel in Dearborn the morning after I arrived. He drove a Ford and explained that all people who dealt with Ford had to drive Ford cars. We got into the parking area, and indeed, I saw only Ford cars. I asked him if Caldwell drove a Ford. He said of course he did, but he did not drive it himself, and the vehicle was serviced every day.

We took an elevator dedicated solely to the ten or so senior executives on the floor where Caldwell had his office. The boardroom was one floor higher. This part of Ford headquarters had rooms where board members could actually stay overnight. The walls were marble. Each executive had an executive suite with a waiting room, an office, and a place for their assistant, back then called a secretary. I was introduced to Caldwell's assistant. She first showed me Caldwell's office, which had been the office of the founder, Henry Ford. It was filled with millions of dollars' worth of art.

We then went into the assistant's office. I explained to her how the DECmate word processor worked. She looked at me, confused. Eventually, she asked, "Why would I use this?" I replied it would help her with her typing. She laughed. "I do not type anything. If something needs to be typed," she said, "I send it down there." She pointed at the floor. "What's down there?" I asked. "The typing pool," she explained, perhaps a bit irritated. I told Ken she loved the gift, hoping he would never find out that she would never use it.

AND THE COMPETITION WAS . . . US

In August of 1981, IBM released its model 5150. I got my hands on the IBM PC soon after its release. I took the IBM PC into my lab at the Mill, and invited CEO Ken Olsen to join me there. Ken had a background in power supplies and mechanical engineering. He asked me for a screwdriver, and we began to take the IBM PC apart. I don't think we ever actually turned it on. Ken was disgusted at its construction. He looked me right in the eyes and said that if I ever built anything like this, I would no longer be welcome at Digital. He never asked a single question about the PC's software, which was not so surprising. Ken famously said that if you build great hardware, the software will come from heaven.

I agreed with Ken; the IBM PC was not impressive. I could not figure out why anyone would buy it. About a year later, Digital decided to develop an IBM PC–like computer, the Rainbow. It was not fully compatible with the IBM PC; the requirement that application programs be modified is one of the main reasons it failed in the market. Of course, as we now know, it was a start-up, Compaq, that understood the need to be 100 percent compatible. They introduced their first product in 1983 and ended that year with an astonishing $111 million in sales.

But back in the summer of 1981, I had been working hard on the development of the Professional for more than a year. I visited Digital's European headquarters in Geneva to engage that management team to help develop the European rollout for the Professional. Before that meeting, I took a few days' vacation and went to the Algarve in Portugal. There, I got a nasty cold. By the time I got to Geneva, I was very ill and had to cancel all of my meetings and fly back to the United States.

When I arrived back at my office at the Mill, I discovered that Barry Folsom, the engineering manager of the Components and Terminal Group run by Andy Knowles, had in my absence made a proposal to Ken Olsen. He said that his engineering team could build a product that would compete directly with the IBM PC. Barry had already developed the VT180, called the Robin internally. It was a CP/M add-on board to one of the terminals the Components Group sold. Ken was still longing for his low-end computer, the one I nicknamed "the computer

for clerks and clerics." Barry's proposal was ingenious. He would use the packaging, keyboard, monitor, and other peripherals that we had developed for the Professional, but the motherboard would be different. It would include two CPUs: a Zilog Z80 to run CP/M, and an Intel 8088 (like the IBM PC) to run MS-DOS. Barry said he could get the product done in less than a year and at a price point consistent with Ken's objectives. Since it looked just like the Professional, it would also have all the beautiful packaging that Ken loved. At the same time, Dick Loveland, product manager for the DECmate word processor, said he could do the same thing with a PDP-8 chip, offering a version of the DECmate that would also use the same packaging as the Professional. Ken took these proposals to the Operations Committee for a rubber stamp. All of this happened in the very short time I was away.

I was furious, but I didn't know what to do. I was convinced that Barry knew he could not make his targets. I found myself not only trying to develop and launch the Professional but also managing much of the engineering, manufacturing, and service for two additional products: the Rainbow (Barry's product) and the DECmate II. This would greatly complicate things for the production, service, and sales organizations.

Software was the real killer. Incredibly, Barry and I were actually out in the world competing against each other for software. Barry was very much aligned with the Microsoft world and even brought Bill Gates out to meet with Ken Olsen. I attended that meeting, and it was the first time I met Bill, who was just twenty-four years old at the time. I remember little about the DECmate II project other than that I could no longer get the DECmate engineers to provide word-processing software for the Professional, because they were so committed to the DECmate II. This meant we could not offer Digital's proprietary word-processing software on what was planned as the company's flagship PC product.

Meanwhile, an adamant Bill Gates convinced Barry that as long as our hardware ran MS-DOS, the Rainbow's application compatibility with the IBM PC would be tied to the MS-DOS application programming interfaces. It never occurred to any of us to build the DEC Rainbow into a fully IBM-compatible PC like Compaq would do. Gates believed that software compatibility would happen at the level

of MS-DOS, and he convinced Folsom of this. Gates was completely wrong about this. To get performance out of the PC's cheap hardware, software developers started accessing the underlying hardware, especially for graphics. Compaq and Franklin would soon prove the importance and promise of full hardware-level software compatibility.

Ken, of course, understood these software issues not at all. The company's sales force was greatly concerned about having three products that looked exactly the same but that ran very different software and addressed very different markets. We were confusing both third-party software developers and the various distribution channels. It was awful!

Eventually, Barry, Dick, and I all had to begrudgingly agree that introducing three products would lead to all three failing. We asked Andy Knowles, who had the business responsibility for our products, to organize a meeting between all of us and Ken. At that meeting, we expressed our concerns and recommended that we bring only one of the products to the market. Ken would not have it, saying famously, "Let the customers decide." In response, as I was later quoted in Glenn Rifkin and George Harrar's 1988 book, *The Ultimate Entrepreneur*, I said: ". . . and they did. They bought IBM."

Ken Olsen was exceptionally charismatic one-on-one. He would sit or stand very close to you and speak slowly, like there were only two people in the world, you and him. It was very seductive; you felt like you would do anything for him. I have heard that Steve Jobs had a similar effect on people. Though I met Jobs several times, I never met him in a one-on-one setting, so I can't confirm this. Ken called me often on Sunday evenings, always speaking in his slow, seductive voice. "I know you are very busy," he would say to me, "but I am worried about Joel's ability to do his job." He would ask me to keep tabs on Joel Schwartz, who reported to Andy Knowles and who was responsible for selling the Professional and the Rainbow. Often, after hanging up, he would call Joel at home and say the same thing to him about me. Joel and I would then call each other and compare notes. I found out from others at Digital that this behavior was not that unusual. Ken liked to pit people against each other just like he wanted many product options.

Once, Ken told me how difficult it was to keep a company like Digital successful. He said, "There are a thousand new companies

trying to take away parts of our business. Most will fail, but some will be successful. This means we have to be successful with whatever we do. We can't fail." This is really a critical issue for most successful companies. Ken's words would come back to me later at Intel.

Meeting with Ken in his office at one point, we discussed the importance of marketing. I said that for Digital to be victorious in the PC space, we needed great marketing and good products. Ken disagreed. He said we needed great products and good marketing. We went back and forth.

Eventually, losing patience with me, Ken said forcefully, "You don't understand! We are not capable of doing great marketing." At that moment, I realized that my destiny was not to stay at Digital. I began to think about what my next steps should be. I realized that products like the Pro would have to be marketed to the actual users of the product and not just to the IT departments. That would require a different kind of marketing, but I failed to make my case. I would see the same circumstance again later when I was an executive at Intel, but in that case, Intel made the transition.

The day before a meeting of several hundred senior executives, Ken called me into his office. "People think that I treat you special," he told me. "While that may be true," he continued, "I don't think it's good they feel this way. So, tomorrow at the management meeting, I am going to criticize you. I just wanted to let you know in advance. I still believe in you." I was not surprised, and there wasn't much I could do. I just thanked him for letting me know in advance. Ken was more than a bit Machiavellian.

Sure enough, during the meeting, Ken said, "Did you know that Avram Miller wants to do marketing? Why would someone capable of doing excellent engineering wish to do marketing?" Everyone laughed. I thought not only about how his remarks might affect me personally but also about how they might affect the marketing people who were attending that meeting. In my mind, it was just one more example of Ken not understanding the importance of marketing. He was right; Digital was not capable of great marketing. What kind of marketing people would want to work for a CEO who saw marketing as such a second-class role?

Note the screwdriver in Ken Olsen's hand.

DIGITAL EQUIPMENT FAILS THE PC TEST

In May 1982, we launched all three products. Right after the announcement, I flew on one of Digital's corporate jets to Palm Springs to attend the PC Forum, organized by Ben Rosen, who later became the chairman of Compaq Computer. That night, I had dinner with all the speakers, including Bill Gates, Steve Jobs, Adam Osborne, and Mitch Kapor. Gates and Jobs were both twenty-six years old. I was thirty-seven years old. Sitting in that room were people who would literally change the world. I was one of them.

At the meeting the next day, I gave a presentation on Digital's personal computer initiative. As a representative of the second-largest computer company in the world, there was a lot of interest in what I had to say. At some point during the other presentations, I found myself sitting next to Steve Jobs. We had a few conversations between speakers. I sensed that Steve was considering asking me to join Apple. He did not. I would not have accepted. At that point, I still believed the

Professional would be a great success. While this was the first time I met Jobs, it would be far from the last. I had no idea about the profound impact he would have on my life.

At the conference, Ben took me aside to show me the prototype Compaq Portable, which would be released in March 1983. It made little impression on me. I found it difficult to imagine people carrying around this "luggable," which weighed twenty-eight pounds, looked like a sewing machine, and cost more than $3,000 (more than $7,000 in today's dollars). I did not understand the coming revolution in the computer industry, and it would have been incomprehensible had you told me that, just sixteen years later, Compaq would acquire Digital.