

especially if Microsoft were to stop improving Windows. As noted above, the UNIX operating system, which is comparable in complexity to Windows 98 or Windows NT, has been cloned by Linux. Nor is it necessary to clone *all* of an existing product in order to compete very effectively with it. For example, as an option for Windows NT Server edition, Microsoft developed, without Novell's help, software that emulates some of the functions of the Novell NetWare operating system. This option makes it easier for customers to install a Windows NT Server in a computing environment that makes use of Novell networking products.

3. Pirated Copies of Windows

206. Software piracy is rampant throughout the world. Microsoft operating system products are routinely copied illegally onto new personal computers during the manufacturing process. In addition, counterfeit copies are available in the retail channel and on street corners as well. Microsoft estimates that it will lose more than \$1 billion in Windows revenue this year to software piracy. There is currently no convenient technical means of stopping piracy. It represents criminality on a grand scale, but it is a fact of life. The effect of this harsh reality is that Microsoft must keep Windows prices low in part to reduce incentives for customers to acquire their operating system software illegally.

B. Competition from Other Operating Systems

1. The MacOS

207. In 1984, building upon innovations first demonstrated at the Xerox Palo Alto Research center and other industry efforts, Apple launched the Macintosh system, which helped refine and popularize the graphical user interface. The Apple Macintosh

quickly became popular because it was easy to use. In short order, the Macintosh system claimed significant share of desktop computer sales (20% in some countries) and led important sectors such as desktop publishing and education. As noted above, if Apple had adopted a different business model and more freely licensed its Macintosh software, Windows may never have succeeded.

208. Microsoft's operating system products today compete with the latest Apple Macintosh operating system, currently called MacOS 8.5. Although Apple's operating system does not run on the Intel x86 architecture, every personal computer purchased from Apple is one fewer Intel-compatible personal computer that could have been outfitted with a Microsoft operating system. Indeed, Apple's marketing and advertising revolve largely around claimed benefits of the Apple Macintosh over computers running Windows. (One tag line: "PC" means "perpetually complicated.")

209. Apple's customers also can run Windows applications on their Macintosh computers using Insignia Solutions, Inc.'s SoftWindows 98 software product. Microsoft granted Insignia Solutions a license to include Windows 98 in SoftWindows 98 so that Macintosh users would not be limited to the pool of applications available for the Macintosh.

210. Although Apple has stumbled in recent years, its core technology remains sound and has always provided a source of strong competition to Microsoft, particularly when combined with the intense loyalty of many Macintosh users and with Apple's strong position in industries such as education and publishing. More recently, Apple appears to be on the rebound under the leadership of its founder, Steve Jobs, and with the recent introduction of its new iMac computer. Recent figures indicate that Apple's share

of sales of new personal computers is significantly rising again, proving that good management can address Apple's woes.

2. The UNIX Operating Systems

211. Since the introduction of MS-DOS in 1981, Microsoft has faced stiff competition from the various "flavors" of UNIX operating systems that run on Intel x86 personal computers, as well as on workstations with other microprocessors. Indeed, workstations are competing more directly with high-end personal computers all the time.

212. In the past, UNIX development efforts have resulted in operating systems that were not particularly easy to use, were primarily used with expensive hardware and offered insufficient compatibility with one another. The industry has continued to invest heavily in UNIX-related efforts, however, and this investment is yielding important and increasing competition to Windows.

213. Numerous vendors have developed their own flavors of the UNIX operating system, first developed at Bell Laboratories in the 1970s. For example, Sun, a leading supplier of workstations, offers a UNIX-based operating system called Solaris, which Sun has ported to run on personal computers running Intel x86 microprocessors. Several other vendors, including IBM (AIX), Hewlett-Packard (HP/UX), Data General (DG/UX) and Silicon Graphics (Irix), also offer UNIX-based operating systems for workstations. In June 1993, Novell purchased AT&T's UNIX business and began offering a version of UNIX for Intel x86 personal computers called UnixWare. The Santa Cruz Operation ("SCO") later acquired UnixWare from Novell and offers its own version of UNIX for Intel x86 personal computers.

214. The early 1990s witnessed the emergence of several consortia that invested considerable sums of money to develop UNIX-based operating systems. For instance, the Open Software Foundation took the Mach code base, produced a version of UNIX called OSF/1 based on that code base, and ported OSF/1 to Intel x86 personal computers. As part of this effort, the Open Systems Foundation developed a user interface or “shell” called Motif. The OSF/1 system was designed to appear more familiar to Windows users, and had members of the consortium elected not to continue marketing their own flavors of UNIX, OSF/1 could have become much more popular.

215. Another important variant of UNIX is “FreeBSD.” As its name implies, FreeBSD is indeed free of charge; it is a robust version of UNIX known best for its high quality networking software. The source code is also freely available under a license similar to that used by the Apache Web server, thus enabling the FreeBSD developers to take advantage of the same “open source” groundswell that Linux leverages. Like its more popular cousin Linux, FreeBSD enjoys a growing population of users and developers who contribute to the product.

3. *Linux*

216. I believe that the most significant form of UNIX competition today is from an operating system called Linux (a UNIX clone). Linux is the creation of Linus Torvalds, at the time a student in Finland who started a project to re-write UNIX without using code from the original AT&T version. In October 1991, Mr. Torvalds put the fledgling code into the public domain and then enlisted help from other developers, an endeavor made easier by the rapidly increasing use of the Internet. Today, Linux is an operating system that consists of several million lines of code—comparable in size,

capability, and complexity to Microsoft's Windows 98 and Windows NT operating systems.

217. Linux runs on many popular microprocessor architectures, such as Intel's x86, Compaq's Alpha, Silicon Graphic's MIPS, Motorola's PowerPC and Sun's SPARC. Intel is reportedly also assisting in the development of a version of Linux for Intel's new 64-bit Merced microprocessor architecture. In addition to running on many microprocessor architectures, Linux has a number of other competitive advantages, including the fact that it is free and perceived to be "cool" (a significant factor among "early adopters" who recommend new technologies to others).

218. Signs that Linux is generating the kind of enthusiasm that can make an operating system successful abound. Over the past year, for example, usage of Linux has surged, particularly in the influential academic community. Observers estimate that five to ten million people currently use the operating system on personal computers or workstations, and that number is growing rapidly. Linux is also popular as server software, especially among Internet service providers.

219. While the number of Linux users is still modest compared to the number of Windows users, popular software products can gain usage share extremely rapidly. For example, use of Netscape's Web browsing software went from zero to about 70 million in three years, based on Netscape's published figures.

220. Applications support for Linux is also growing rapidly. Within the past few months, leading software vendors have announced that they will create Linux versions of their flagship products. For example, the leading database vendor, Oracle, recently announced that it is developing a Linux version of its market-leading Oracle 8

database. One of Oracle's chief database rivals, Informix, quickly followed suit, and Mr. Soyring testified that IBM is porting its principal database product, DB2, to Linux as well. (In fact, IBM announced on November 20, 1998 that its Linux version of DB2 will be free.) Netscape is developing Linux versions of its enterprise server software, and most of Netscape's client software is already available for Linux. Corel offers a Linux version of its popular WordPerfect suite of business productivity applications, and it is free. Star Division of Germany offers its StarOffice, a full suite of business productivity applications. StarOffice, recently priced at about \$300, is now free for individual users. Sun is porting its Java Development Kit 1.2 to Linux.

221. Commercial software vendors such as Red Hat and Caldera now offer compatible versions of Linux at a nominal charge. Although Linux can be and routinely is downloaded for free off the Internet, Red Hat and Caldera plan to earn revenues from related software and services such as training and support. The presence of such supported versions of Linux promises to make the operating system more appealing to corporate customers.

222. Caldera offers a product called OpenLinux that consists of the base Linux operating system, a graphical user interface called KDE (which includes a tightly integrated Web browser), the DR-DOS operating system, the popular Apache Web server, Netscape Communicator, software that provides interoperability with Novell NetWare, StarOffice and other software. The price for this entire package of software is just \$59.

223. We have provided the Court with a short videotaped demonstration of Caldera's OpenLinux running on a standard Intel x86 personal computer and supporting desktop productivity applications very similar to those commonly used today, including

StarOffice. (See DX 2164.) StarOffice is a suite of business productivity applications that closely emulates the features, functionality and appearance of Microsoft Office, making it relatively easy for customers who are used to Microsoft Office running on Windows to switch to StarOffice running on Linux (or one of the many other platforms for which it is available, such as Sun Microsystems' Solaris, IBM's OS/2 and the Apple Macintosh). StarOffice can be downloaded from the Web free for individual (non-commercial) use.

224. Red Hat offers a similar package of Linux software at very low prices. Red Hat's chief executive officer, Robert Young, recently stated that Red Hat's objective is "to lower the value of the operating system market." He added: "Microsoft makes \$5 billion in operating system sales. If I get that market, I automatically make it a \$500 million market." (*The New York Times*, September 28, 1998.) Intel and Netscape each recently signaled their enthusiasm for Linux by investing in Red Hat.

225. Other members of the industry are equally enthusiastic about Linux. An Informix manager, Steve Lambright, recently stated: "We see Linux poised in the same vein as the Web was two or three years ago, when it was just beginning to take off." (See DX 2249.) Such views are becoming commonplace. Just last month, Marc Andreessen of Netscape stated that Linux is "extremely hot," observing that "[it] is free, it's stable, it's fast and scalable, it's UNIX, it's the OS of choice on the Internet, and it runs on cheap Intel hardware." (See DX 2250.) Indeed, Mr. Andreessen stated a few months ago that the combination of Netscape Communicator and Linux could be the software that unseats Windows.

226. Leading computer manufacturers such as Sun Microsystems, Dell, Gateway, Toshiba, IBM and Hitachi are now offering (or have announced that they soon will offer) computers with Linux preinstalled, and many smaller computer manufacturers offer Linux workstations as well. Other computer manufacturers are likely to follow suit. This month at MacWorld in San Francisco, Linux PPC Inc. announced the latest release of its version of Linux for Apple computers (called "LinuxPPC"). Apple has also developed a version of Linux for its computers, called "mklinux." Even software publishers are getting into the act: Corel Computer will soon offer a new line of personal computers called "Netwinder LC" (the "LC" stands for "Linux Computer"). The Netwinder is a personal computer running Linux and equipped, of course, with Corel's flagship WordPerfect suite of business productivity applications (as well as Netscape Communicator 4.5). In short, Linux is a product that Microsoft and other operating system publishers ignore at their peril.

227. Linux exemplifies many of the characteristics that make the software industry so competitive—particularly ease of entry. The first version of Linux was created not by a commercial enterprise, but by a lone developer while still in school. Since then, developers all over the world, collaborating via the Internet, have improved the operating system by leaps and bounds. Today the number of developers working on improving Linux vastly exceeds the number of Microsoft developers working on Windows NT. Linux developers are currently working on "Windows-like" user interfaces—"Gnome" and "KDE"—to simplify its operation.

228. It is unlikely in any other established industry that a single person, aided only by independent volunteers, could create a product that would emerge to challenge the industry leader. Yet this is the story of Linux, and the nature of the software business.

4. IBM's OS/2

229. In the mid-1980s, Microsoft and IBM started a joint project to develop an operating system called OS/2. Unfortunately, Microsoft and IBM had different objectives for the operating system: Microsoft wanted to develop a consumer-oriented system, whereas IBM wanted to develop an operating system that was compatible with its line of mainframe computers. As a result of this conflict, the initial versions of OS/2 were market failures, causing Microsoft and IBM, after spending much money and effort, to pursue different paths in 1990. While Microsoft focused on developing Windows NT and Windows 95, IBM continued to develop OS/2, pinning its hopes on OS/2 2.0.

230. IBM's OS/2 2.0 operating system partially exploited the features of 32-bit microprocessors. It also benefited from a large marketing budget and IBM's huge sales force. IBM further announced that it would produce versions of OS/2 for personal computers based on its PowerPC chip collaboration with Motorola and Apple. As such, OS/2 presented very serious competition to Windows from 1992 to 1995. If Microsoft's "dual Windows" strategy for meeting demand for operating systems that took advantage of 32-bit microprocessors had failed, IBM would have had time to remedy the shortcomings of OS/2, and the market might very well have gone to OS/2. My colleague Jim Allchin describes why IBM achieved only modest success with OS/2 more fully in his testimony.

5. Other Operating Systems

231. Although Linux has received the most attention lately, many other operating systems compete with Microsoft's products on the Intel x86 microprocessor architecture. For example, Be, Inc., a company founded by a former senior Apple executive, offers the Be Operating System or "BeOS." The BeOS is designed with special capabilities for working with multimedia content and communications-based applications, which are certain to be major growth areas in the years ahead. Intel has funded Be's development of a version of the BeOS for x86 personal computers, and continues to provide Be with financial support. Recently Hitachi announced it would offer its customers personal computers with the BeOS preinstalled.

232. A range of other operating systems are available today or are now under development for use with large mainframes, minicomputers, network computers, game consoles and new generations of small "information appliances." Given the nature of software and the unrelenting pace of change in the underlying hardware and communications capabilities, nearly any operating system can evolve into a very direct competitor to Windows.

233. Unless Microsoft continues to innovate and pay attention to customers' needs, one or more competing operating systems will surely replace Windows, directly or indirectly, in a relatively short period of time.

C. Competition from "Middleware"

234. Another important source of competition to Windows are "middleware" products. To understand middleware, one can think of the architecture of most computers as consisting of a series of "layers." The base layer is the microprocessor.

The next layer, above the microprocessor, is usually an “operating system.” An operating system provides the user with a way of managing the resources of his or her computer and provides a set of services that the next layer of software programs, typically called “applications,” can use. These applications make requests to the operating system (typically through APIs) to perform various tasks on their behalf (*e.g.*, reading information from and writing information to the hard disk, sending and receiving information from a network, getting mouse movement from the user, and so on). below shows the generic layered computer architecture.

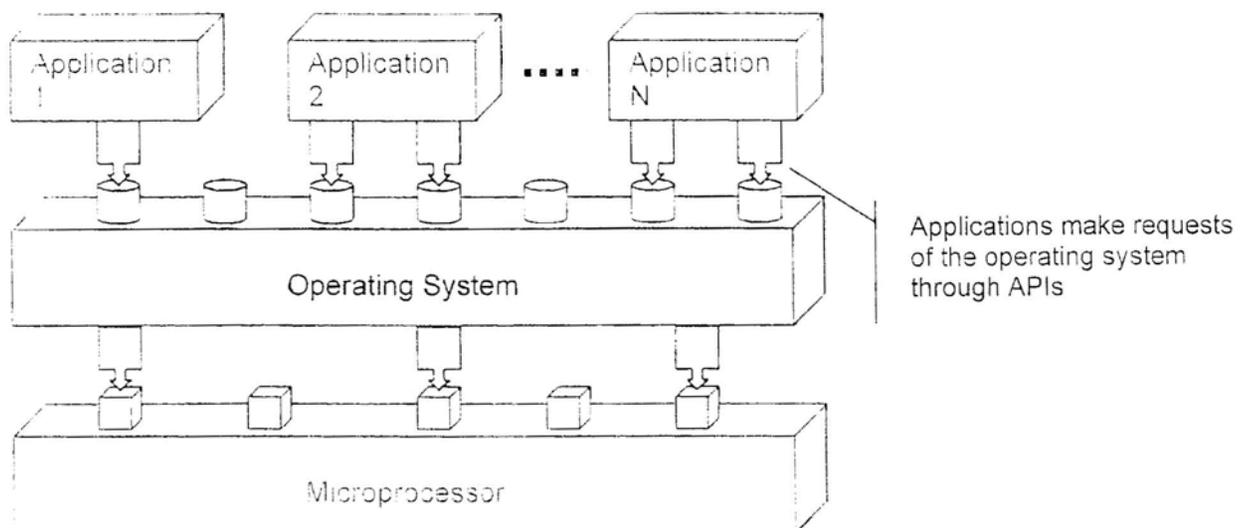


Figure 1: Layered Computer Architecture

235. Various software publishers provide products that constitute an additional software layer that sits between the operating system and application software. This additional layer, often referred to generically as “middleware,” can provide a broad set of services to other software programs via APIs and may also include its own user interface. In so doing, a “middleware” product serves as a platform for software development, subsuming functionality otherwise provided by the operating system, and thus plainly

competing directly with operating system software. Figure 2 shows a layered computer architecture with a middleware layer.

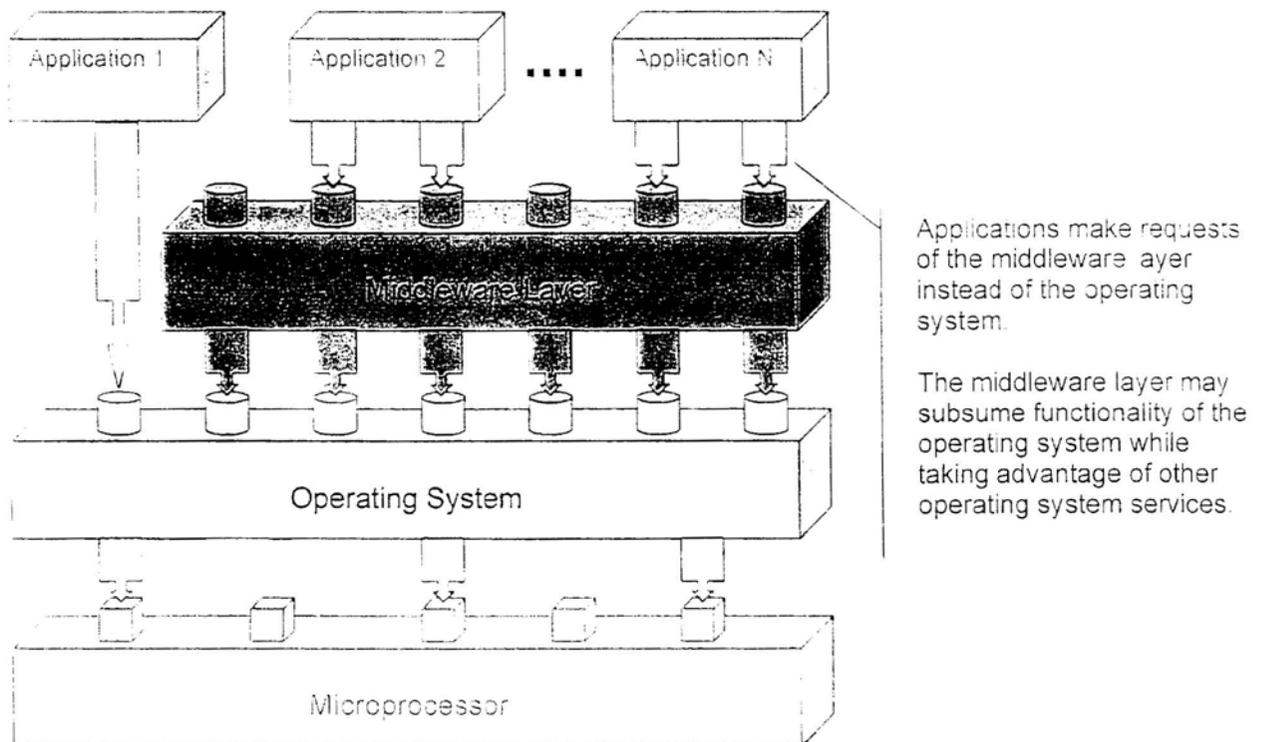


Figure 2: Middlewre Layer Competes with Operating System Layer

236. If a middleware product provides a set of APIs to software developers that makes them more productive and enables them to create better software products, the value of any underlying operating system will, of course, be greatly reduced. Over time, the developer of any successful middleware product could continue to add functionality to the point that the underlying operating system was rendered unnecessary or could be swapped out for another operating system.