3.0 Personal Computing

Introduction and Definition

"Personal Computing" is a category encompassing the information devices likely to succeed today's personal computers as commonplaces in personal and business lives. Thus this is not a category defined by technology per se; rather it reflects the convergence of technology trends from other categories, expressed in commercial products. This category is essentially one of packaging—what novel forms will various components and software be combined into?

In short, this category represents the trajectory of mass market information tools over the forecast period. Understanding this trajectory allows for exploitation of the economies of scale created by commercial deployment—including lowered cost, increased reliability and expanded understandings of systems performance. For example, if Pentagon planners a decade ago knew what Sun, Apple and SGI would be building today, how would that have affected planning? However, such exploitation is not without risk. Incorporation of complex commercially available systems may expose users to unknown risks of penetration and reliability failures.

Finally, it is vital to acknowledge the crucial role played by different age cohorts in defining this sector. The first PCs were invented by individuals who grew up in a mainframe time-sharing world, and thus it is no surprise that the first PCs (e.g., DOS) were near-perfect simulations of what a timesharing experience would be like at a local level. Now, a new generation raised on PCs is about to enter the workforce with ideas of its own. They are certain to redefine the PC sector as profoundly into something utterly new.

3.1 On the Nature of Consumer Electronic Diffusion

Success in this sector always looks like an S-curve—with a long anticipatory tail leading to a sudden inflection point. Figure 2 depicts exactly this pattern for the consumer devices that have insinuated themselves into our lives over the last few decades. This pattern offers important lessons for technology planners. First, do not overestimate the speed a new technology will go from initial introduction to consumer acceptance—the duration will more likely be decades than years. But once acceptance begins, expect it to occur vastly more rapidly than the apparent lack of earlier diffusion might imply. Fax machines took between 10 and 70 years to reach takeoff depending on how one measures the initial innovation, but once take-off was reached, fax machine penetration in US businesses went from less than 5 percent to over 70 percent in less than two years. It is a safe bet that the same pattern will be repeated by a host of new technologies in this sector over the next several decades.

3.2 Three Waves of Key Enabling Technologies: Microprocessor (1970 -95), Laser (1995- 2005)—and Sensors (2005-)

The primary factors shaping change in this category are social and cultural. Technology plays an essential, but secondary role, merely enabling the possibility of novel devices satisfying human needs and desires. That said, the technologies waiting in the wings will enable some impressive advances in the forecast period. The first decade of the personal computer was very much shaped by the availability of microprocessors cheap enough to afford one on our desks.

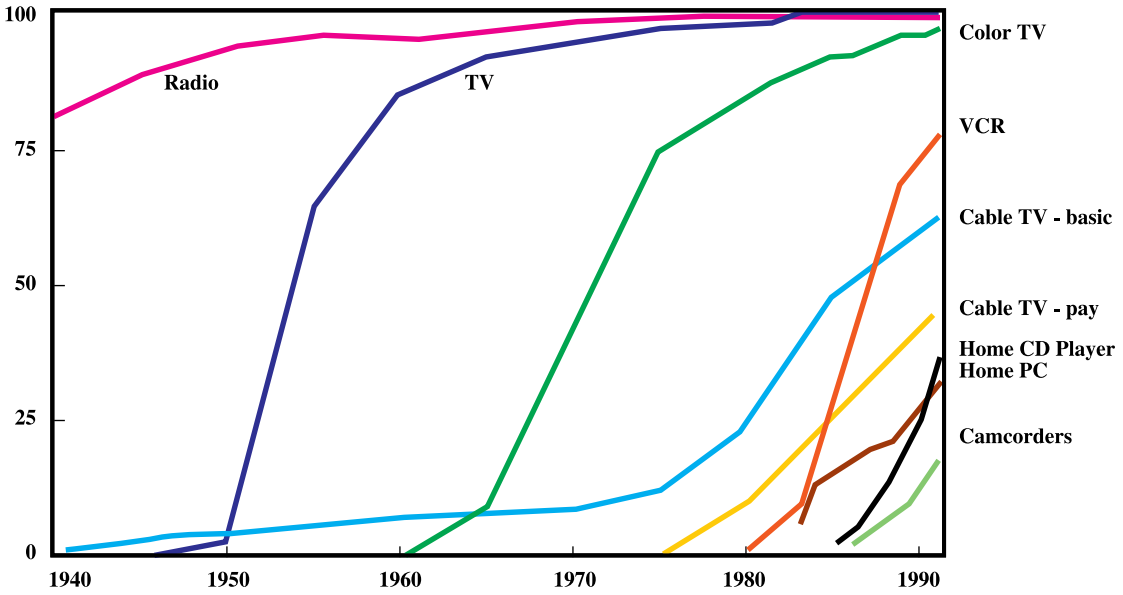

Figure 2 Technology Acceptance - S-Curves

The consequence was a 1980's decade preoccupied with *processing.* We processed everything we could get our hands on—words, images, figures, even video.

Now however, we are experiencing diminishing returns on the addition of processing power to processing-era tasks, and a second wave technology—the communications laser—has replaced the microprocessor as the key enabling technology shaping the personal computer industry. Just as the microprocessor slipping into our lives in the early 1980s hidden in PCs and other gizmos, lasers are slipping into our lives today hidden in everything from CD players to long-distance fiber-optic phone lines. If the 1980s represented a processing revolution, the next 10 years will be above all an *access* revolution in which the devices in this sector will be defined by what they connect users to. This access demand will in turn increase the demand for ever more powerful processors to support increasingly sophisticated access tasks.

Further out—beginning perhaps around 2005—a third wave is waiting in the wings. This third wave will be defined by the advent of inexpensive high-performance sensor technologies. This will trigger a decade preoccupied with connecting our personal computing devices to the real world—giving them the ability to sense objects and events around them. MEMS (micro-electro-mechanical system, chips that combine mechanical functions with electronic functions) technology is an early harbinger of this third wave, but it is by no means the only technology enabling the sensor revolution.

Note that all three technologies appear in all three stages; but at each stage, one technology takes the lead in setting the applications stage. The effect among advances on all three fronts is synergistic. In the 1980s, advances in processing made early use of lasers possible. Now, advances in laser-enabled bandwidth are creating new demand for ever more powerful lasers to, for example, process video images sent down phone lines. And the advent of cheap

sensors will have similar impacts on creating demand for processing and communications between sensor and the ultimate user.

3.3 The Fragmenting PC Industry

The first casualty of the shift from microprocessor to laser is the 1980s-vintage stand-alone PC, now quickly headed for the technological scrap heap because its processing-driven nature leaves it unable to cope with an access-driven world. A "personal computer" is exactly what its name implies, a device designed to stand alone, connected to little else than an AC outlet and, occasionally, a phone line. It is above all a processing engine, into which most information goes in by keyboard, gets cleaned up on screen, and eventually emerges as a paper document from a printer. One can hook a 1980's vintage PC to access-era conduits, like local area networks or remote information sources, but it will quickly begin to gasp and stall under the unfamiliar load.

In fact, what once was the PC market is splitting into three new categories: A new class of device on our desks, novel entertainment systems in our homes, and a third class of ultra portable gizmos that we will carry in our cars, briefcases and even on our persons. A few of these devices will outwardly resemble PCs, but in fact they will be as different from the devices of the 1980s, as today's cars are compared to the original horseless carriages. And for the next decade at least, all will share a common denominator—they will all be access tools, defined by what they connect us to.

3.3.1 Workstations Will Replace PCs on Our Desks

The diffusion of cheap laser technology has already triggered a shift from standalone PC to highly connected workstation. Our new desktop devices superficially resemble PCs, but their functions are access-driven from the start, defined above all by what they connect users to, not by what they process. These new tools will mature into "workstations" in the truest sense of the word, personal windows onto an ever growing ecology of information and computing devices. Some information will still be entered manually, but the bulk will arrive via LAN or external communications channels. Keyboards and mice will be tools for manipulation rather than entry. On the output side, less information will emerge from the printer slot and more will be dispatched in electronic form to other remote workstations and electronic display devices.

The world that workstations open onto is growing explosively, thanks to laser-enabled bandwidth and storage economies. In turn, these new fiber digital highways are encouraging the diffusion of secondary transport modes such as cable and wireless conduits, the surface roads and alleyways of the access decade. The steady stream of surprises swirling off of the Internet is but the harbinger of bigger surprises to come for workstations as information windows. E-mail and Web-surfing are hot for the moment, but weirder exotica like multiple user dimensions (MUDs) and M-bone multicasting are waiting in the wings to further enrich the world our devices access.

The rapid diffusion of the Internet is a key enabling factor in this sector. (see figure 3—Internet Growth.) The Internet has a double effect on diffusion for workstation technology. First, it is an excellent conduit for moving information between workstations, but second and more importantly, it is a technology very much accessible to individual entrepreneurs. It is this latter population that will deliver a steady stream of interesting and destabilizing surprises.

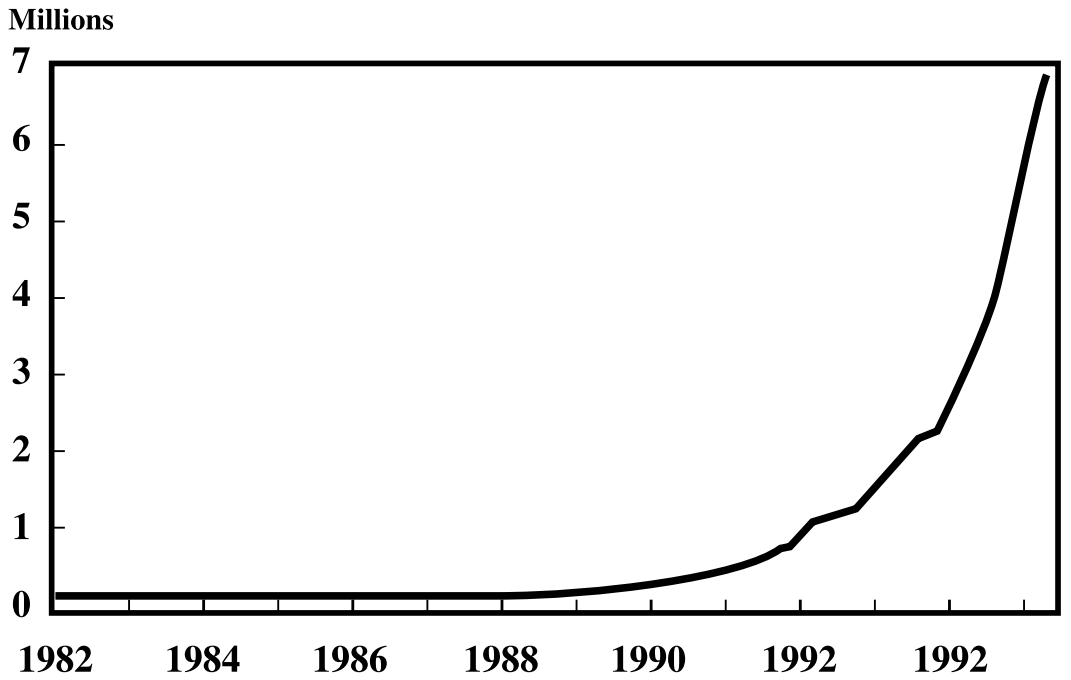

Figure 3 Internet Growth

The explosion of Internet use will also likely yield new kinds of access devices. For example, well before 2000, we will see inexpensive, easy to use terminal devices that rely on advanced Internet technologies (e.g., Sun's Hot Java) to deliver powerful experiences without the need of massive amounts of local processing or storage. If manufactured in volume, these devices could be delivered for costs well below that of a French Minitel terminal.

3.3.2 "Crays on a Tray" In Our Homes

Laser-enabled bandwidth in our homes will also eventually lead to a new class of entertainment devices in our homes. These will grow out of the TV/VCR/ video game player complex that exists today. In effect, we will have a "Cray on a tray" in a box sitting next to our TV monitors, delivering a host of new entertainment services. The most prosaic applications will be movies on demand and simple home shopping. The big winners and surprises will lie elsewhere, in new kinds of group activities evolving out of activities like MUDs on the Internet today.

However, there are two important caveats affecting this sector. First, it will be the slowest of the three sectors to mature, for the simple reason that the deployment of the requisite networks (ideally, a two-way, fully-switched megabit conduit) is proceeding slowly, even in the United States: less than 10 percent of US households by the year 2000. Look for this sector to start coming into its own in the years following 2000, and diffusion of high-performance networked entertainment systems is likely to reach take-off around 2005.

Secondly, this entertainment device will not merge with desktop PCs in the home. There are two screens in our houses: one that we sit 8 feet away from, and watch while leaning backwards on a couch, and a second that we sit three feet away from, and lean forward while we use it. Today, we call the former a TV, and the latter a PC. While the details of these devices will change profoundly, we will still have 8-foot and 3-foot screens in our homes decades from now. And, we will probably have a third as well—screens on the successors to today's phones.

3.3.3 Information Appliances Will Become Fixtures in Our Lives

The third sector emerging from the dissolving PC market will be the far stranger world of "information appliances"-- inexpensive, radically accessible, high-performance information tools utterly unlike the PCs we use today. The difference between PCs and information appliances lies first of all in their specialization of use. Today's personal computers are general purpose tools designed to run a wide range of applications, artifacts of an age when microprocessors were so expensive we could afford to have *only* one on our desks. As David Liddle of Interval Research notes, PCs are the equivalent of Swiss Army knives for knowledge workers, general purpose tools of last resort rather than special purpose tools of first choice. Who would actually use the saw on their knife if they had a real saw within arm's reach?

Information appliances will combine the information richness of personal computing with the low-cost and hardware elegance of consumer electronics. The first information appliances have already begun to appear: Apple's Newton, Sony's MagicLink, and the Sharp Zaurus are but the first tottering steps of these infant sectors. Ten years from now pen-based notetakers and email/fax communicators will hardly draw the attention of passers-by.

But this description belies the sheer chaos and confusion that will accompany the menagerie of information appliances lurking on the horizon. These new tools will come in every conceivable shape and size. Manufacturers will entice us to pack them in our briefcases, stuff them in our pockets, and toss them in our cars. We will even wear some as integral parts of our clothing, a new kind of "information exoskeleton." Many will be silly, faddish gizmos, while a minority will quietly become essential personal tools. But all will share two features in common—all will be intensely personal, and none will remotely resemble a PC.

The diffusion of these devices will be slower than it at first seems. There is no shortage of candidate devices today, but the vast majority are mildly useless curiosities. However within five years, the first useful versions will begin appearing, and a decade from now, we will see some very impressive pocket-sized tools. By then, the diffusion of these gizmos into the work place will create far more headaches for information managers than the PC did a decade ago. For example, unlike PCs a decade ago these gizmos will include built-in communications capabilities spanning everything from simple wire-based telephony to infrared, packet radio, and cellular voice and data. MIS managers despaired of early PCs because they *couldn't* communicate with their mainframe systems. Information appliances will present them with the opposite problem. Conditioned by experiences with desktop workstations and aware of the communications potential of their new portable tools, knowledge workers will be exasperated when companies can't make their information and communications systems interface with these appliances. Just as PC zealots once took matters into their own hands, the appliance owners of the 1990s will quickly learn to communicate on an ad hoc basis with everything from their

workstation to the fax machine and digital copier. An absence of universal operating and communications standards will only add to the confusion.

3.4 A Functional Categorization of Future PCs—by Size

Perhaps the single constant amidst all the turbulence in this category is human physiology—how much can one carry, what are optimum viewing distances, etc. The consequence is that size is a powerful tool for sorting what is certain to be a steadily expanding ecology of gizmos of all shapes and sizes. Here is one sorting:

3.4.1 Less than 10cm (Ounce-Scale Weight) = Wearable Computers

This is an all but unrealized category today, inhabited by a few pagers and some electronic jewelry novelties, and of course, digital watches. These are devices small enough to fit in a pocket or be pinned to clothing. Too small for anything but a minimalist screen, but acceptable for sound i/o. Look for short-hop wireless gizmos in this category that communicate with larger personal devices. For example, pocket dictating machine that uploads speech via wireless or infra-red to PDA or larger machine. This category is unlikely to begin really taking off for another decade, until then remaining a zone of mostly novelties with a few practical exceptions.

3.4.2 *10cm - .25m (up to 1.5 pounds) = PDAs

These devices are as large as book-sized, and book weight, though a video cartridge represents the center of the size/weight form factor of the this zone. This category is already populated with first generation devices (e.g., Newton, MagicLink, Sharp Zaurus, HP 100), and for better or worse, has been dubbed by the industry as PDAs—“Personal Digital Assistants.” Second wave PDAs will arrive in the near term (next two years), and the category will reinvent itself every 2-3 years for the next decade.

3.4.3 *.25m - .5m (up to 5 pounds) = Laptop PCs

This is a well populated category today, moreover the form factor (keyboard, screen, supplemental pointing and input devices) is quite stable, and likely to remain so for the forecast period. However, the components, functions and operating systems will evolve radically over the forecast period. Within 10 years, “portable” will mean under two pounds, and with a form factor that one can carry the device as well as an armful of other items as well.

3.4.4 *.5m - 1m (over 5 pounds) = Desktop PCs

Like laptops, this is also a stable category: screen and keyboard, plus assorted i/o peripherals. And, like laptops, it is a category that will see dramatic evolution, though very much along a continuum. We have already seen this category absorb a profound shift in function from standalone processing engine to highly connected access tool. The access function will now dominate through the balance of the forecast period, but processing will also play a crucial role. Look for major operating system rollover every 8-10 years.

3.4.5 * Over 1m (over 5 pounds) = Entertainment Devices

This is the zone of set-top boxes, TVs and related gizmos. This will be important in terms of exploiting economies of scale. Air Force pilots are already doing situational awareness

training on desktop PC systems employing software that is only modestly modified from commercial versions. This zone could provide far richer training opportunities.

3.5 Factors Retarding/Accelerating the Evolution of PC Sector

A variety of factors are at work that are likely to accelerate or retard advances in this sector. They are summarized below:

3.5.1 Batteries

Best estimates are for no more than 20% improvement in battery performance over next decade. Improvements must come in combination of battery performance and low-power processing. Xerox Parc researcher Mark Weiser has an interesting view of this, thinking in terms of mips/joule (given a D cell = 2^{16} joules): Pentium: 100mips/25 watts=4 mips/joule, 1/2 speed 3.3 volt Pentium: 50 mips/ 5 watts = 10 mips/joule, Motorola 68010: 1 mip/0.5 watts = 1/2 mips/joule. This is an area worth a close look: an unexpected advance in battery performance could have a dramatic impact on the information appliance sector in particular. The consequence is more than mere device life: more power translates into more processing cycles and thus more powerful functionality. By 2005, the average consumer could carry the processing equivalent of a Cray in their pocket.

3.5.2 Basic Research

Product innovation in the PC sector is highly dependent upon a steady stream of enabling technologies. Until now, many of these technologies have emerged from defense-related R&D—for example, CCDs currently used in consumer video cameras. As defense-related research wanes, an increasing portion of this work is being undertaken by private corporations (e.g., Intel and the development of the Pentium and P6 chips). But it is an open question whether this private, highly directed research can effectively substitute for more broad-based government-sponsored research that might lead to far greater innovations and surprises. If defense-related research—indeed, government-sponsored research in general—declines, which stakeholders will take over the basic research "pump-priming" so essential for innovation in this arena. Will the research enabling the devices of 2010 be done at all in 1997?

3.5.3 Competitive Quest for Novelty

The pressure on mass-market manufacturers to come up with new products is enormous. The consequence will be a continuous effort to take some newly available piece of technology and use it as the cornerstone for a new product or product category. In addition, we are likely to see the creation of entirely new industries on a decade-scale basis. Just as the personal computer industry appeared out of nowhere in 1980, look for new industries to emerge around sensor-centric systems and autonomous systems in the decades ahead.

3.6 Visions/Discontinuities and Implications

This is an area that is likely to create discontinuities even as it realizes earlier visions. For example, it is in this sector that Vannevar Bush's 50-year old vision of the Memex is likely to take the form of a real product. This section offers a speculative exploration of possibilities.

3.6.1 Information Exoskeleta

We end up wearing a small ecology of information devices on or near our persons—gizmos in our pockets, on our wrists, in our briefcases. These devices increasingly intercommunicate via a personal network and serve multiple access and processing functions. Business users in particular are heavy users. This is the civilian equivalent of the Army's wearable infantry information systems now under development.

3.6.2 Non-Interactive (Autonomous) Computing

The current information systems paradigm makes human/computer interaction the main event, and this category's title assumes that it will remain the main event. Perhaps more machines will operate without human interaction on the behalf of humans, than will interact with humans directly. Will our homes be run by a small community of devices constantly in touch with each other, but which never directly interact with the humans they serve?

3.6.3 Consumer Infobots

Will we see cheap, small infobots become a reality in the forecast period? These infobots could become alter-egos on networks, hunting down information, conducting transactions, and monitoring critical pieces of data. (See Intelligent Software Agents, Chapter 5.)

3.6.4 MUDs

MUDs—Multiple User Dimensions—are teetering on the verge of becoming a major consumer event in the next two to three years. Email will seem quaintly un-hip. Within the decade, look for consumer systems optimized for MUD-like interactions. MUDS are covered in greater detail in Groupware, Chapter 14.

3.6.5 Civilian War-Fighting

What seems exotic to the Pentagon today will likely become a consumer hobbyist attraction within a decade or two. Transform today's combat virtual reality (VR) networks into the commercial sector, and you have the biggest themepark in cyberspace, with 15 year-olds flying fighter simulators in battles against others of their age cohort. We note that the developers of a leading fighter simulation in 1995 have purposely fuzzed and degraded performance on the next version to be released, for fear of giving Third-World aviators a powerful and inexpensive simulation that could put US pilots at a disadvantage.

3.6.6 The End of WIMP Interfaces

WIMP (Windows, Icons, Mouse, Pull-down menus) interfaces have become the norm in the PC sector over the last decade. We are likely to see their survival for the next decade, particularly given the rapid acceptance of Windows 95. However, it is critical to keep in mind that this interface metaphor is already over 20 years old, and is merely one of many possible ways of interacting with computers. WIMP interfaces won't disappear, but they are likely to take a back seat to newer metaphors over the next three decades.