A Bitter Pill to Swallow: The Rise and Fall of the Tablet Computer

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Footnotes begin on page 24.

Tablet computers (or tablet PCs) are a form of mobile personal computer with large, touch-sensitive screens operated using a pen, stylus, or finger; and the ability to recognize a user's handwriting—a process known as "pen computing."

The first of these devices, which appeared at the end of the 1980s, generated a huge amount of interest in the computer industry, and serious amounts of investment money from venture capitalists. Pen computing was seen as the next wave of the silicon revolution, and the tablet computer was seen as a device everyone would want to use. It was reported in 1991 that "Nearly every major maker of computers has some type of pen-based machine in the works." [1]

Yet in the space of just a few years, the tablet computer and the notion of pen computing sank almost without a trace.[2] Following a series of disastrous product launches and the failure of a number of promising start-up companies, the tablet computer was discredited as an unfulfilled promise. It no longer represented the future of mobile computing, but instead was derided as an expensive folly—an irrelevant sideline in the history of the computer.

This article traces the early development of pen computing, the appearance, proliferation, and disappearance of the tablet computer, and explores possible reasons for the demise of this particular class of product.

Product Failures in the History of Computing

This article is concerned with the design, production, and consumption of artifacts, and the numerous factors which can affect their success or failure in the marketplace. For any company bringing a product to market, the amount of time and money invested in the research, design, and development of the product itself and in the market research, promotion, packaging, distribution, and retailing of a product means that an unsuccessful product launch is an extremely serious but unfortunately all too real prospect. The risk perhaps is understandably more common when the artifacts are complex technological products in a fiercely competitive field, and where the technology itself is still relatively young, not yet stable, and in a constant state of flux. Consequently, the historical development of the personal computer is (quite literally) littered with examples of products that have failed in the marketplace.

Occasionally, because of poor manufacture, misdirected marketing or promotion, and software not meeting consumer expectations, some of these products could be said to have "deserved" to fail. However, advances in production technologies and quality control in recent years have reduced manufacturing failures (notwithstanding some very well publicized events such as the poor battery life of earlier "iPods," the cracked screens of the first iPod "Nano," and exploding batteries in some Sony laptops[3]). But despite advances in manufacturing quality, there still are numerous examples of well-designed products (often winning design awards) which were heavily promoted and performed as promised, yet still failed in the marketplace. Obviously, merely solving pragmatic problems is no guarantee of success.

Product Failures and Theories of Technological Change

A great deal has been written from a number of different perspectives about why technological products fail in the marketplace. These include economic and business analyses, marketing critiques, design critiques, and sociological enquiries. This body of work is far too large to describe in any depth here, but concludes that there are multiple reasons in each case for product failure in the marketplace.

In *The Invisible Computer*, Donald A. Norman refers to the notion of "disruptive technologies"—technologies which have the ability to change people's lives and the entire course of the industry.[4] It is Norman's contention that this ability to disrupt inherently produces products to which there initially is a large amount of resistance. Norman also believes that company attitudes, including internal politics, the preference for an existing, tried and tested market over the need to develop a new one, and the need to produce profits quickly rather than investing in new products which may take a number of years to reach maturity means that new technologies are not taken seriously enough.[5]

Norman's argument is that, in order to be accepted in the marketplace, three factors have to be right: the technology, the marketing, and user experience. As an example, he quotes the well-known story of the Xerox "Star" computer designed at Xerox PARC in the early 1980s. The Star was a product well ahead of its time, having the first commercially available graphical user interface (GUI), and a design philosophy of user interaction that set the standard for an entire generation of PCs. Unfortunately, it was a consumer product before the consumer existed. The product had not gone through the process of exposure to the marketplace, which normally occurs when a new technology appears, is accepted by "early adopters" of technology, and then is refined for the mass market. The same thing happened a few years later when Apple introduced the "Lisa"—a larger, more expensive precursor to the Macintosh. In both cases, the technology wasn't quite ready. They both were painfully slow, had limited functionality because no one had written applications for them, and were extremely expensive. Therefore, there was no benefit for "early adopters" of technology in using these products, despite the novelty of the GUI , as the lack of application software meant that they didn't do anything other computers couldn't already do. The fate of the Star and the Lisa would have been shared by the Macintosh, had it not been saved by the advent of a "killer application," making it indispensable to specific groups of users. This was desktop publishing software and the invention of the laser printer.[6] Norman's view is that the Star and the Lisa both had superb user experiences, but insufficient technology and marketing.[7] Not having all three was the reason for failure.

This underscores the fact that the reasons for failure in the marketplace of any product are more complex than at first might be imagined. We will explore this notion in other theories that address the same issues.

The theory of the social construction of technology takes the view that a complex range of factors are involved in the success of products, and that social factors have precedence in the process. As a counterpoint to a physical reality affecting outcomes (i.e., the technology itself), social constructionists see a web of relationships between people and between institutions that share beliefs and meanings as a collective product of a society, and that these relationships are the basis for subjective interpretations rather than physical or objective facts. The notion of the "truth" of a socially constructed interpretation or piece of knowledge is irrelevant—it remains merely an interpretation.[8] It is an interpretation, though, which has significant agency.

This is in direct contrast to the theory of technological determinism—the view that technology and technological change are independent factors, impacting on society from the outside of that society—and that technology changes as a matter of course, following its own path, and in doing so changes the society on which it impacts. (A good example is the notion of "Moore's Law," which states that the power of a microchip doubles every year as if it were a "natural" phenomenon). There is an element of truth contained within this, in that technological products do affect and can change our lives, but it is simplistic to imagine that other factors are not at play. Put more simply as "interpretive flexibility," the argument of social constructionism is that different groups of people (i.e., different relevant social groups of users) can have differing views and understandings of a technology and its characteristics, and so will have different views on whether or not a particular technology "works" for them. Thus, it is not enough for a manufacturer to speak of a product that "works": it may or may not work, depending on the perspective of the user.[9]

The above arguments on social constructionism perhaps have been most widely promoted by the sociologists Trevor Pinch and Wiebe Bijker,[10] who use examples such as the developmental history of the bicycle to show how a linear, technological history fails to show the reasons for the success or failure of different models, and that a more complex, relational social model is required.

A slightly different view is held by others, such as the historian of technology Thomas Hughes, who sees technological, social, economic, and political factors as parts of an interconnected "system." In this instance, different but interconnected elements of products, the institutions by or in which they are created, and the environments in which they operate or are consumed are seen as a complete, interdependent network. However, a technological system remains a socially constructed one: "Because they are invented and developed by system builders and their associates, the components of technological systems are socially constructed artifacts." [11] There still is a distinction here between the human and nonhuman components of a system: "Inventors, industrial scientists, engineers, managers, financiers, and workers are components of but not artefacts in the system." [12]

By comparison, Actor Network Theory, associated with the sociologists Bruno Latour, John Law, and Michael Callon, breaks down "the distinction between human actors and natural phenomena. Both are treated as elements in "actor networks." [13] In Actor Network Theory (ANT), all parts of a system or network are equally empowered as actors having an influence on technology—there is no distinction between small or large elements, animate or inanimate, or real or virtual. Technology is conceived of as a growing system or network. The actors (and the relationships between the actors) "shape and support the technical object." [14] An important aspect of the theory is that:

> The actor network is reducible neither to an actor or a network alone nor to a network. Like networks it is composed of a series of heterogeneous elements, animate and inanimate, that have been linked to one another for a certain period of time. The actor network can thus be distinguished from the traditional actors of sociology, a category generally excluding any nonhuman component and whose internal structure should not, on the other hand, be confused with a network linking in some predictable fashion elements that are perfectly well defined and stable, for the entities it is composed of, whether natural or social, could at any moment redefine their identity and mutual relationships in some new way and bring new elements into the network. An actor network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of.[15]

In other words, the role of any particular actor in a network is not fixed, but indeterminate and changeable, being at times dominant or, at other times, insignificant in its agency.

These theories are useful in the analysis of the introduction of complex new technologies, and the tablet computer is an excellent case in point, having a particular level of complexity. As a product, the tablet computer brought together a number of discrete technological advances, each having its own history of development: pen interfaces, handwriting recognition, and touchscreen technology.

The History of Pen Computing: Early Developments in Pen Interfaces

The principle of using a pen device rather than a keyboard to interact with a computer may appear to be a relatively recent development. As a matter of fact, pens were one of the earliest devices to be used in this way, many years before the invention of the computer mouse. Light pens (or light guns) were used in the experimental "Whirlwind" computer built at MIT between 1946 and 1949, when it became operational, for analyzing aircraft stability for the U.S. Navy. In this system, a light pen pointed at a symbol of an aircraft on a display screen produced identifying text about that aircraft. This machine formed the basis of the later TX-0 machine started in 1953 and the SAGE (Semi-Automatic Ground Environment) air defense system (Figure 1) started in 1958; both developed at MIT's Lincoln Laboratories. In the SAGE system, the light gun was used to convert the "blip" on a cathode ray tube (CRT) showing the location of an aircraft or missile into X-Y coordinates. When a blip appeared, a "light gun" was pointed at that point on the screen, and an inter-

Figure 1
The SAGE Air Defense System of 1961 used a light pen on a radar display screen to register the position of aircraft and missiles. Image courtesy of Computer History Museum.

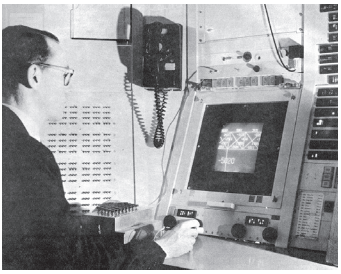

Figure 2
Ivan Sutherland's 1963 "Sketchpad" software was the first computer drawing package, and used a light pen as the principal input/output device. Courtesy of Ivan Sutherland.

nal photocell registered the blip. Since the time taken for the screen display to be refreshed was a known quantity, the time difference between the start of the screen refresh and the light gun registering a blip could be translated into an accurate X-Y position, and a trajectory then could be predicted.

The TX-0 machine was the first in a series of experimental digital computers built at MIT, which included the 1958 TX-2—notably used by Ivan Sutherland in 1963 to develop "Sketchpad"—the first computer drawing software, in which a light pen was used as the principal input/output device, initiating the "direct manipulation" of computer data (Figure 2). The abstract for Ivan Sutherland's Ph.D. thesis describes the use of a pen to interact with a computer:

> The Sketchpad system uses drawing as a novel communication medium for a computer. The system contains input, output, and computation programs which enable it to interpret information drawn directly on a computer display. … A Sketchpad user sketches directly on a computer display with a light pen. The light pen is used both to position parts of the drawing on the display and to point to them to change them. A set of push buttons control the changes to be made such as erase, or move. Except for legends, no written language is used.[16]

Figure 3
A RAND Tablet being used to interpret handwritten commands.
Image courtesy of Computer History Museum.

The Development of Handwriting Recognition

Concurrent with Sutherland's development of the technology needed to draw items directly on a computer screen, others had been working on methods to enable computer users to directly write commands that could be interpreted by the computer as instructions. An early example of a device which could read stylus movements accurately enough to interpret handwriting was the RAND Tablet (Figure 3). After years of development, a 1964 memorandum booklet titled "The RAND Tablet: A Man-Machine Graphical Communication Device" prepared by the RAND Corporation for the Advanced Research Projects Agency (ARPA) stated:

> Early in the development of man-machine studies at RAND, it was felt that exploration of man's existent dexterity with a free, pen-like instrument on a horizontal surface, like a pad of paper, would be fruitful. The concept of generating hand-directed, two-dimensional information on a surface not coincident with the display device (versus a "light pen") is not new and has been examined by others in the field. It is felt, however, that the stylus-tablet device developed at RAND is a highly practical instrument, allowing further investigation of new freedoms of expression in direct communications with computers.[17]

An example of an actual RAND Tablet in the archives of the Computer History Museum in Mountain View, California is, accompanied by an entry which reads:

> The Rand Corporation produced one of the first devices permitting the input of freehand drawings. Also called the Grafacon, the original Rand Tablet cost $18,000. The attached stylus sensed electrical pulses relayed through a fine grid of conductors housed beneath the drawing surface, fixing its position to within one one-hundredth of an inch. Many experimental systems were developed to recognize handwritten letters or gestures drawn on the tablet, such as Tom Ellis' GRAphic Input Language (GRAIL) method of programming by drawing flowcharts.[18]

Tom Ellis was the author of a number of RAND reports describing the development, beginning with Ivan Sutherland's "Sketchpad" research, of a system in which an operator could write instructional commands for a computer directly on the RAND Tablet:

> One fundamental facility of the man-computer interface is automatic recognition of appropriate symbols. The GRAIL system allows the man to print text and draw flowchart symbols naturally; the system recognizes them accurately in real-time. The recognizable symbol set includes the uppercase English alphabet, the numerals, seventeen special symbols, a scrubbing motion [a hand-drawn squiggle] used as an erasure and six flowchart symbols—circle, rectangle, triangle, trapezoid, ellipse, and lozenge.[19]

Ellis's GRAIL system was the beginning of handwriting recognition technology. Not only that, but since the system also contained text-editing facilities such as "character placement and replacement, character-string insertions, line insertions, character and character-string deletions, and line deletions" it formed the basis of word processing technology without the use of a keyboard.[20]

Touchscreen Technology

Touchscreen technology was first developed by Dr. Samuel Hurst while on leave from the Oak Ridge National Laboratory to teach at the University of Kentucky.[21] His initial idea came in 1969, when he was looking for a way to digitize large sets of strip charts. Hurst and a graduate student (Jim Parks) made a two-dimensional digitizer by using two sheets of electrically conductive paper with a sheet of ordinary paper between as an insulator to create a sensor. By connecting two voltmeters—one to each conductor—a needle prick through the strip chart and the sensor supplied an x-coordinate to one voltmeter and, independently, a y-coordinate to the other. This initial invention became the "Elograph," patented in 1972 (Figures 4 and 5). Returning to Oak Ridge and founding the company "Elographics" in 1971, Hurst went on to lead the development of transparent touchscreens, with the first produced in 1978, and five-wire resistive technology, the most commonly used form of touchscreen technology.[22]

> The first instruments were intended for the scientific market, and it was not a significant product because the "digital online" era had arrived and there was not a need for strip charts. It is amazing, in retrospect, that we survived long enough to take a poor product for the wrong market to an excellent product for a good (consumer) market. In a discussion with our patent agent, Martin Skinner, the idea emerged of a transparent touch screen for use with computers, and we were stimulated by Siemens when they paid some of the development costs for early units, but we did not have the insight to think that the touchscreen market would become so important.[23]

Although they had some way to go until they were suitable for use in consumer products, these cutting-edge advances in human/computer interaction meant that, by the end of the 1970s, all of the relevant technologies were in place and thoroughly documented to enable the development of the "tablet computer." It actually took almost a decade until the appearance of the first tablet computer, although this requires some clarification of the definition of the product, as well as the acceptance of various streams of parallel development.

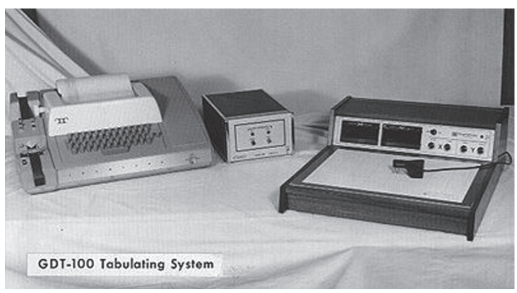

Figure 4
The "Elograph" electronic graphing device, 1971. Courtesy of Tyco Electronics, Elo TouchSystems.

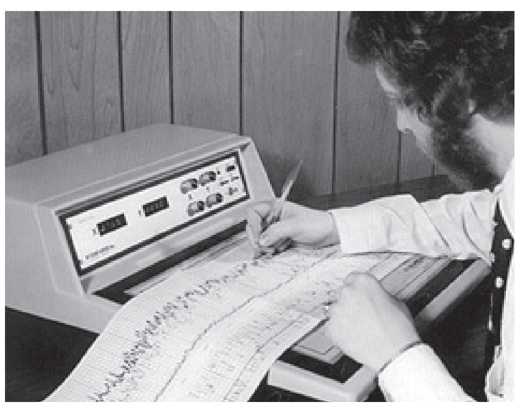

Figure 5
A later version of the "Elograph" being used to analyze strip chart data, circa 1973. Courtesy of Tyco Electronics, Elo TouchSystems.

Tablet Computers

Tablet computers as revolutionary new products experienced a rapid rise in popularity and were the center of industry attention for a few years in the early 1990s. Even though their popularity then underwent a massive decline, they did not disappear altogether, and still are manufactured today in limited quantities. Over the years, they have appeared in a number of forms but can be grouped into some general categories.

Tablet computers that essentially are a large touchscreen covering a processor unit are referred to as "slates." The input is purely through the screen via a stylus or finger, although external keyboards may be attached. The onboard processor allows a full range of computing capabilities. Where portability is a key concern, wireless versions with no onboard processors (called "thin-client slates") also are available. These utilize applications stored on remote servers. The lack of keyboard input is associated with the main use of these tablets in specialized, "vertical" markets such as the healthcare industry or in sales and insurance field work, where the tendency is for standardized forms to be filled in rather than entering large amounts of text.

"Convertibles" attempt to achieve the best features of tablet computers and laptop computers. The large touchscreens are movable, so that they can either act as a normal laptop with the keyboard in front of the screen, or be arranged so that the screen covers the keyboard completely, only allowing pen input. These have been more successful than slates, yet they remain a compromised product. The keyboard means that they inevitably are thicker and heavier than slates, and the touchscreen capability means they are more expensive than normal laptops. There also is a more expensive subset of convertibles known as "hybrids," which have keyboards that can be completely detached, restoring the thin cross-section of slates. In this instance, the "tablet" part of the computer is the screen and processing unit, and the detachable keyboard can be seen as a peripheral component. The distinction might be an important one because, to be termed a true "tablet computer," the screen input (the "tablet") and processing unit (the computer), it could be argued, have to be contained within the same product rather than being a portable computer which, through an additional component, has screen-based input capability.

So for clarification, the defining characteristics of the tablet PC are taken here as being a self-contained personal computer having a large, touch-sensitive screen and handwriting recognition capabilities to allow input by a stylus. With respect to size, tablet PCs have a screen size large enough to allow significant pen input (usually approaching that of a piece of A4 paper), and require both hands to operate if not rested on a stable surface. Although tablets may have the same organizational capabilities of "personal digital assistants"

(PDAs), they have computing capabilities similar to desktop computers. The use of organizing software such as electronic calendars and alarms is not their primary function.

The quote cited earlier in this article—that "Nearly every major maker of computers has some type of pen-based machine in the works."—points to a serious problem for historians of the technology of this period, and requires the inclusion of a caveat. Researching the exact chronology of product releases in the field of portable computing from the late 1970s to early 1990s is fraught with difficulties, and not just because of the sheer amount of competing products that were available. Many products, especially those from smaller start-up companies (which in many cases essentially were one-man bands), were not promoted as widely as those from major manufacturers, and information concerning them is hard to find and even harder to accurately verify. In addition, major manufacturers in desperate competition at a time of rapid technological progress raced to launch short-lived products to such an extent that many of them were outdated as soon as they hit the market—and almost immediately replaced by updated versions. Moreover, in an attempt to gain a head start on competitors, products were routinely announced and promoted sometimes up to a year before their launch, by which time many already had been dropped in favor of a more advanced model, or failed to materialize because of technical, financial, or other problems. These products are known in the industry as "vaporware"—intended products that may have been prototyped but never actually were sold. There also is the issue of parallel development to take into account. Many of the features of these products were first developed in isolation at research institutes and universities, and widely disseminated as actual or theoretical possibilities that then were simultaneously adopted by different companies in their product development. So the issue who was "first" is a complicated one. Finally, many of the accounts of this period, as in this article, include oral histories from the individuals involved at the time. These individuals more often than not were simultaneously involved in numerous projects and, because of the fluidity of the market, often changed employers or started new companies without keeping detailed records. (They are, after all, largely engineers and entrepreneurs—not academics and historians.) It is quite common to discuss the same issues of product chronology and attribution with different people who were involved with the same project, at the same time, and obtain completely different versions of events. As Friedrich von Hayek said:

> The knowledge of the circumstances of which we must make use never exists in concentrated or integrated form, but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess.[24]

For all the above reasons, it is practically impossible to be absolutely certain of all details, so the accuracy of dates and the completeness of chronologies of these products often are questionable. Therefore, the following chronology includes many of the key products, but certainly not all that appeared, especially if there was little difference between competing products launched simultaneously.

Early Products

Historically, the conceptual roots of the portable tablet computer as a discrete product are the same as those for the laptop computer, both arising from original interactive computer concepts proposed by Alan Kay as part of his doctoral thesis,[25] and later developed by the Learning Research Group as the "Dynabook" at the Xerox Palo Alto Research Center (PARC) in the early 1970s (Figure 6).

In 1968, while studying at Utah, Kay conceptualized a computer which brought together his work on interactive computing, the emerging technologies of flat-screen displays and handwriting recognition, and programming developments aimed at children. Kay explains:

> Ed Cheadle and I had been working on a desktop personal computer (the FLEX machine) since early 1967, and in the summer of 1968 I gave a presentation of this machine and software at the first ARPA grad students conference. One of the highlights was a visit to Don Bitzer's lab where the first plasma panel flat screen display was being invented (with Owens Illinois). We saw a one-inch-square display that could light up a few pixels. Flat-screen displays were not a new idea either in fiction, semi-fiction (like *Popular Science* mag), and in the real technological world. Still, it was galvanizing to actually see the start of one!

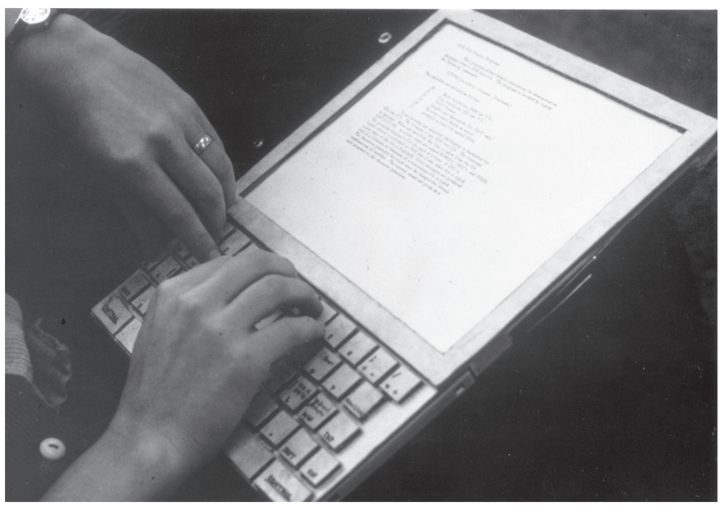

Figure 6
Alan Kay's "Dynabook" concept model, 1968.
Courtesy of Palo Alto Research Center, Inc.

> We knew the transistor count in the FLEX machine and some of the grad students and I sat around one afternoon estimating when those transistors could be put on the back of a big enough plasma panel. (Moore had announced the first version of his law in 1965.) Our estimate was about ten years.… At the same time, Peter Brodie at Westinghouse was also working on a flat panel using liquid crystals.[26]

Later the same summer, Kay visited researchers working on computers for nonprofessional users, including RAND, where Tom Ellis had developed his GRAIL system, and Seymour Papert (a pioneer in artificial intelligence) at a school in Lexington, where he was using his LOGO programming language developed for children.

> This was a transformative experience and on the plane back to Utah I started to think about making a computer for children that could combine some of the LOGO ideas, those of the FLEX machine, and the GRAIL tablet-based system. The ten-years-out problem became a non-problem because I realized there was at least ten years worth of user interface, software, and curriculum development that would have to be done.
>
> When I got to Utah I made a cardboard model of what such a machine would be like. (It was made hollow so we could load it up with lead pellets to see how heavy it could be made before it became a pain, etc.) It had slots on the side for the removable memory and the stylus.[27]

This concept became one of the most radical product proposals of the time. In a paper produced by the Learning Research Group, Alan Kay and Adele Goldberg promoted the concept of the Dynabook as "A Dynamic Medium for Creative Thought":

> Imagine having your own self-contained knowledge manipulator in a portable package the size and shape of an ordinary notebook. Suppose it had enough power to outrace your senses of sight and hearing, enough capacity to store for later retrieval thousands of page-equivalents of reference materials, poems, letters, recipes, records, drawings, animations, musical scores, waveforms, dynamic simulations, and anything else you would like to remember and change. We envision a device as small and portable as possible which could both take in and give out information in quantities approaching that of human sensory systems.[28]

Quite clearly, such a computer was not technically possible at the time (Kay still thinks this is true[29]), and yet his vision of the Dynabook was so powerful that it drove the development of computing technology inexorably towards truly portable computing. Even the name has been inspirational and much emulated. A company called "Dynabook Technologies" was set up in 1987 to develop such a computer, and gained $37 million in financial backing yet never managed to overcome technical problems and went bankrupt in 1990,[30] and Toshiba appropriated the name for its early pen tablets, marketed as "Dynapads."[31]

A number of products have laid claim to being or have been hailed as "the first tablet computer." However, with respect to the definition laid out above, many of these have one or another characteristic missing. Some products had character recognition rather than full handwriting recognition; while others were not self-contained products, but had to be connected either directly by cable or by radio signals to remote processing units or servers. This is an important distinction in design terms because in a unit where the touchscreen is a separate component connected by a cable, it can act as a peripheral input device rather than an intrinsic part of the product form. These factors are important in charting the development of tablet computers as a discrete class of products.

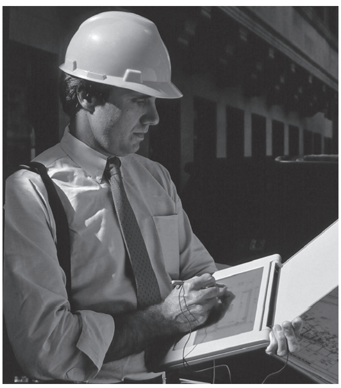

Figure 7
Linus Technologies Write-Top, 1987.
Courtesy of Inter4m.

The first to bring together the three technologies of pen interfaces, handwriting recognition, and touchscreens into a consumer product was Dr. Ralph Sklarew. His product, the "Write-Top" (Figure 7), built in 1987 by Linus Technologies, was "arguably the first portable computer with handwriting recognition."[32] It certainly had all the capabilities of a tablet computer, although it was not termed as such at the time. However, even though it was prototyped as a self-contained unit, the production version (designed by Peter H. Muller of Inter4m) "was a two-part design tethered via a cable."[33] It came close to being a self-contained unit since the touchscreen element could be "latched" onto the base unit to create a "grey sandwich."[34]

Sklarew founded Linus Technologies in 1985 with $11 million in venture capital. They demonstrated their first version to a number of interested parties, including GRiD Systems (see below).[35] He and his partners received patents for a "Handwritten keyboardless entry computer system," and sold approximately 1,500 units before closing in 1990.[36]

Self-contained Tablet Computers

The first successful attempt at a self-contained tablet computer appeared in the form of the GRiDPad from GRiD Systems, conceived by Jeff Hawkins (Figure 8). GRiD Systems was the company that produced the first true laptop computer, the GRiD Compass, launched in 1982.[37] Hawkins states that he came up with the idea of a tablet computer with a stylus interface in 1987, while studying neuroscience at UC Berkeley during a two-year leave of absence from GRiD. "During a neural networking conference, a company called 'Nestor'[38] demonstrated their handwriting recognition software which was based on pattern recognition algorithms. I realized that this could best be put to use in a mobile computer."[39] In the fall of

1987, Hawkins went to an interview with GO Corporation, a promising start-up company, to see if this was the best place to take the idea forward. GO saw itself as a pen-computing business, which worried Hawkins: "There's no such thing as a 'pen-computing' business—you just need a PC with an additional stylus. You don't have 'mouse computing' as a core business. The point is mobile computing, not pen computing." [40] Hawkins believed that GO would fail. Instead, he took the idea with him to GRiD in 1988, and managed the GRiDPad project there; employing IDEO to do the industrial design.[41] The GRiDPad was deliberately targeted at specialist, vertical markets such as the medical profession because this is where Hawkins saw market opportunities. "I never saw pen computers as a replacement for a full PC as GO did. GO was really pushing pens—they lost all sense of reality. They never shipped, whereas the GRiDPad turned over in excess of $30 million in its best year." [42]

The GO computer is a significant piece of "vaporware" if only for the sheer size of the endeavor and amount of publicity that accompanied it. The idea for the product arose during a business flight shared by Mitchell Kapor (founder of Lotus Development Corporation) and Jerry Kaplan, when they had the equivalent of a "religious epiphany" [43] that a portable pen-driven computer could solve all the traveling executive's information- handling problems. Kaplan went on to found GO Corporation in August 1987.

The product was developed to the stage of a working but deskbound prototype of connected components by 1988, yet despite having received in total more than $75 million in financial back-

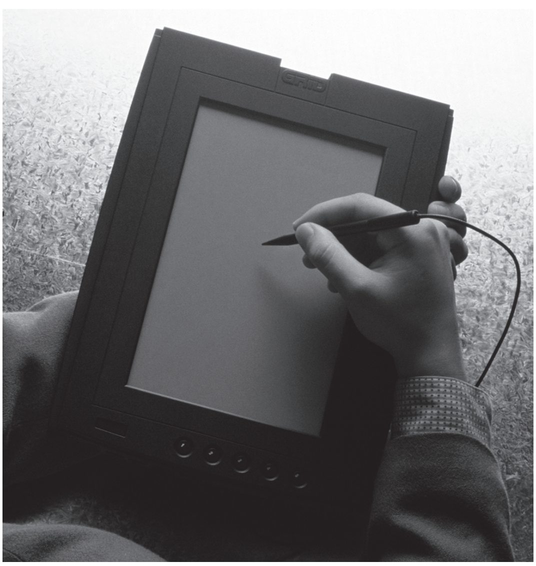

Figure 8 (left)
The GRiDPad, 1989. Courtesy of IDEO.

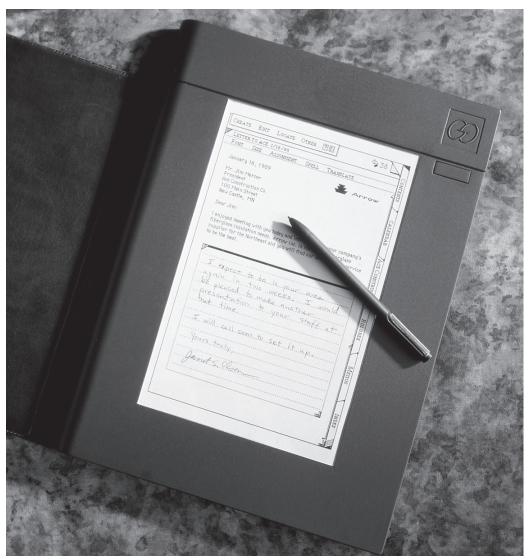

Figure 9 (right)
The prototype GO computer, 1991.
Photo by Rick English, courtesy of IDEO.

ing and the enthusiastic support of IBM and AT&T, it suffered all kinds of engineering setbacks. A working preproduction version was not assembled until June 1989[44] (Figure 9). The final product, with industrial design work by Paul Bradley of Matrix Design and mechanical engineering by David Kelly Design (both later to become IDEO) was done in 1991, by which time the company had changed direction to concentrate on their handwriting recognition interface software called "PenPoint." This put them in direct competition with Microsoft, and when Microsoft launched "Windows for Pen Computing," a huge public relations battle ensued.[45] Not surprisingly, GO lost. Kaplan went on to write an autobiography in which he said: "The real question is not why the project died, but why it survived as long as it did."[46] GO was taken over by AT&T in 1994, and eventually shut down.

GO wasn't the only company that thought the ideal pen-computing operating system was yet to be created. In 1991, the computer magazine *BYTE* ran a review article on yet another new product (Figure 10) aiming to set the standard:

> Many players in the nascent pen-based computing market see the transition from conventional notebooks to pen systems as a chance to bypass the DOS standard and start afresh with more modern technology. Although the era of pen-based systems has barely begun, there are already three competing operating environments. This mad scramble to set new software to norms for pen computers may be a rude shock to users comfortable with the uniformity of DOS.

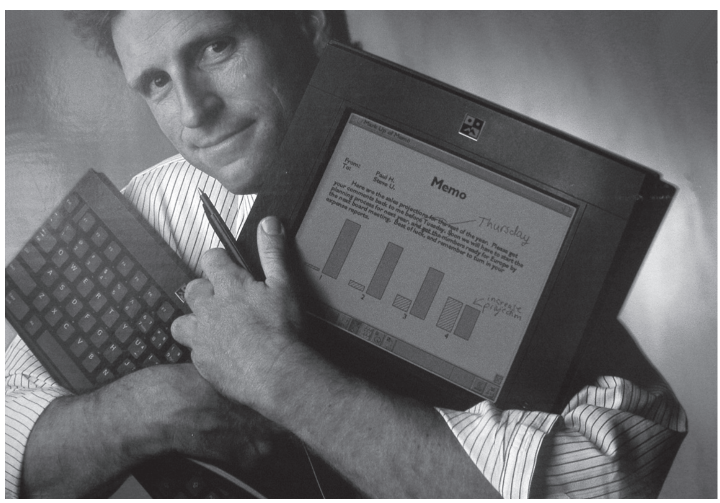

Figure 10
The 1991 Momenta Pentop computer (a contraction of "pen computer" and "desktop") attempted to move the target audience of tablet computers to mobile executives. Photograph of original packaging by author.

> In the midst of all this uncertainty, a fourth environment has arrived from start-up Momenta. One of the most widely anticipated entrants to the market, Momenta's pen-based laptop sports a new GUI that represents yet another effort to define the look and feel of pen computing.
>
> The Momenta computer is different in other ways, too. The company is aiming it at mobile executives, not at the blue-collar and field workers who have until now been the target audience for pen-based PCs. Perhaps most surprising, Momenta is playing down the role of handwriting recognition in the system, saying that the technology is too immature to substitute for a keyboard in many cases. Instead, Momenta sees the pen, in conjunction with its new GUI, as a more intuitive substitute for a mouse.[47]

The competition was indeed tough. Although it was in many respects a radical product and had many innovative features leading to its appearance on the covers of twenty magazines, Momenta International ceased trading in 1992, less than a year after the Momenta Pentop's launch. In an article reflecting on his career, the company's founder, Kamran Elahian, said "We set out to create a computer that would be incredibly easy to use. I was absolutely convinced that we would revolutionize the PC industry." The same article concluded: "There was just one problem. No one bothered to build a market for pen-based computers. In three years, Momenta burned through $40 million.… For a while at least, Elahian held the Valley's title for burning the most capital in the shortest period of time. Momenta was a monumental flop." [48]

A spinoff from GO, called EO Inc. (also sold to AT&T), had some success with two versions of products called "Personal Communicators" in 1993. These units, with industrial design work by frog design, had a built-in modem to provide phone, fax, and electronic mail capabilities. The smaller-screened version, the EO 440 (Figure 11), sold around 10,000 units, but the company collapsed shortly after launching the larger-screened EO 880.[49] Before it collapsed, the company was working on various future possibilities, including a tablet computer with speech recognition.

After his success with the GRiDPad, Jeff Hawkins tried to develop a product "that offered the best of both the laptop and tablet."[50] The result, with industrial design work by IDEO, was the GRiD Convertible, launched in 1993 (Figure 12). This used a clever mechanism which allowed the screen to slide and pivot to cover the keyboard and convert the laptop into a tablet. "Bill Gates loved it. It failed in the market place. I learned at that time that people

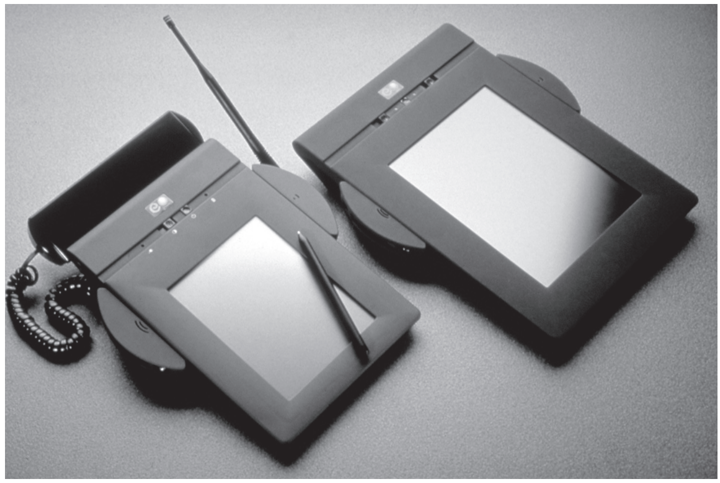

Figure 11
The EO 440 Personal Communicator, 1993.

Figure 12
The GRiD Convertible, 1993. Courtesy of IDEO.

didn't really want to write on their display." [51] Hawkins realized that "people wouldn't pay for or compromise the quality of a laptop for a pen interface." [52]

Divergence

Around 1993, the closely related products of tablet computers and Personal Digital Assistants began to move apart. Apple ran a whole series of projects during the late 1980s and early 1990s to develop tablet computers, most of which were cancelled.[53] These included a notebook-sized, slate-type computer concept codenamed "Figaro" between 1987 and 1991 (which evolved into the Newton), the PenMac, the Macintosh Folio, and SketchPad, all in 1992; and the WorkCase and Newton MessageSlate in 1993. Apple felt that a tablet computer might compete with and divert sales from the Macintosh, so the project was rethought as a PDA.[54]

Figure 13.
The Apple Newton MessagePad 2000, launched in 1997. Courtesy Apple Inc.

The Apple Newton MessagePad eventually was unveiled in May 1992 at the Consumer Electronics Show with a large-scale publicity drive claiming to have produced the "future of computing." It was released the following year, unfortunately to weak reviews. After a number of redesigns culminating in the MessagePad 2000 (Figure 13), the technology was placed into the Apple eMate laptop computer in 1997, and then discontinued altogether in 1998. Although it was produced for six years and won numerous design awards, the Newton was never the success Apple hoped for, and the goal of reinventing personal computing was never achieved. Although it was marketed as a PDA rather than a tablet computer, the unit itself was too large to fit into any pocket, was expensive (the final models costing $1,000), and initially suffered from poor handwriting recognition software, which many regard as the main reason for its failure.[55]

The End of the Line?

The Apple Newton would seem to mark the point at which the tablet computer developed into the Personal Digital Assistant. Some manufacturers did continue to produce true tablet computers, but with little success. The original IBM "ThinkPad" in 1993 was a tablet computer, and Sony produced a Pen Tablet PC in 2001, but it was discontinued due to low sales only a year later.[56] Despite this, a number of manufacturers including IBM and HP still produce a variety of models,[57] and Bill Gates openly defends them, predicting they soon will come into their own as products, and ensuring that the latest version of Windows, "Vista," supports pen computing.

The story of the tablet computer to date covers some fifty years from its conception, with real products being produced for twenty years. The sheer amount of money and effort involved in trying to bring the tablet computer to the marketplace is staggering. As a product group, they have swallowed billions of dollars in investment capital and thousand upon thousands of man-hours in R&D, design, and promotion. Sales remain pitifully low, and yet manufacturers and a small number of users still cling to the concept, convinced of its potential. At Microsoft, the tablet PC is most prominently promoted by one man, Bert Keely, who has the title "Architect, Mobile PCs & Tablet Technology." Keely constantly attends research seminars and computer shows, and appears in the news media demonstrating the advantages of pen computing. He admits that tablet technology has a number of flaws and a long way to go,[58] but remains convinced that the future of pen computing will be "astounding."[59]

Conclusions

So why has the tablet computer not been a successful product? In theory, it had it all—a computer that you could use as if it was a pad of paper. As proposed by the theories discussed earlier, there always will be more than one reason for any product failure. Yet many of the factors mentioned in the case study as to why certain individual tablet computers had failed are issues which subsequently have been resolved. Clearly, the technical problems which plagued early products such as slow processor speeds and software reliability have been overcome. The compatibility of software means that applications for such computers are far greater in number and, while still not perfect, issues of functionality such as the reliability and accuracy of handwriting recognition software have been greatly improved. The manufacturers currently involved are not start-up enterprises lacking in financial support or backing; and the products are now part of large ranges of computing equipment from well-known and respected companies, and have received marketing support of a suitably high level. Yet despite the sales predictions and assurances from Bill Gates, and the enthusiastic promotion of people such as Bill Keely, tablet computers still account for less than five percent of the personal computer market.[60]

Social constructionism suggests that a complex range of social factors are the most significant elements to take into account in the success or failure of technological products. Indeed, it would appear from the technical factors that have been resolved that the only possible barriers left to the acceptance of tablet computers are social ones. The concept of "interpretive flexibility" proposes that different groups of people have different views on the extent to which a particular technology "works" for them. However "natural" a form of communication writing may appear to be, perhaps, as Jeff Hawkins believes, people don't want to write on computer screens, and a pen on a large display is not a good user interface for a computer.[61] The feel of pen on paper is a difficult one to surpass.

> Some of the technology still isn't solved. Paper still has qualities screens don't have. Is the stylus active or passive? If it is active, then they are a problem. The screen resolution still isn't good enough, and there is still a parallax issue. Handwriting recognition still isn't good enough: text editing is still complex to use.[62]

According to Stuart Card, a research scientist at Palo Alto Research Center and an expert in human/computer interaction, the problem of pen computing is self-evident, and revolves around the difficulty of overcoming the physical keyboard:

> The reason pen computing doesn't work well is that the software it works with was designed to be used with a mouse and keyboard—the pen input was added later. PenPoint [the operating system developed by GO] was better as it was gesture-based. This means going back to recall rather than recognition [having to learn and remember how to execute a command rather than intuitively interpreting an icon] but that's okay as long as there are a limited number of gestures, say around five to ten, and the gestures are mimetic rather than symbolic. As an example, it's difficult to spreadsheet with a mouse. It could be easier with a pen if the design of the software works. Currently it is just as difficult to use a pen, or more so as you also have to include handwriting recognition errors. Another is writing URLs [Website addresses]. Handwriting recognition software has algorithms to ignore "nonsense" words, but URLs are random series of letters and no spaces, so that doesn't work. The pen clearly has an advantage if the input is a drawing, but how many people use that? And virtual keyboards are useless for typing—only one key at a time. You will always need a keyboard for bulk text input.[63]

Another factor could involve the complexity of a personal computer, which is clearly accepted if not desired in a desktop PC. This may not be acceptable in such a portable format as the tablet PC. Slow start-up times, large size and weight, and the compromises inevitable in multifunctional products such as a full computer do not cross over well to situations in which the computer is held and carried around by the user, and constantly turned on and off.

It is possible that the semantic associations of tablet computers and the body language employed when using them is an issue. In use, tablets tend to be carried in the cradle of one arm and written upon with the free hand in much the same manner people write on clipboards (indeed, some tablets such as those by "Aqcess" have been designed with detailing to specifically connote physical clipboards). The success of tablet computers in vertical markets suggests that this was not an issue for users carrying out specialized field work with "rugged" products, where the clipboard was and is a commonly used and accepted piece of equipment, but it may possibly have been an issue when attempts were made by companies such as Momenta to overtly move tablets into the executive market.[64]

Factors such as these, which may appear to be small problems, or even insignificant by some, are held by Actor Network Theory to have the potential to be highly significant in the successful take-up of new products. The interesting aspect of ANT, though, is the understanding that the significance of these factors is not seen as fixed, but fluid. At any moment, any factor can move from being a significant actor to an insignificant one, or vice versa, even as the result of forces outside of the network itself. With this level of uncertainty in mind, it must be recognized that the current public attitude toward tablet computers and to pen computing itself theoretically could change at any moment, however unlikely that may seem.[65]

While the tablet computer has failed to capture the public's imagination, the PDA has succeeded—but that's another story. The reasons for the failure of tablet computers, as for any complex technological product, are not straightforward. All or any one of the reasons above; or a combination of small details which together constitute the nature of the experience of using a tablet computer, could be equally responsible. As social construction theory would have it, the acid test of computing equipment is not the technology, but user acceptance. And as Actor Network Theory shows, however small or inconsequential an agent may appear to be in the overall scheme of things, it still can have the ability to make or break any product.

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