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A Wearable communications device

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A Wearable Communications Device

by

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GLOSSARY

Baud: The signaling rate of a line. It's the switching speed, or number of transitions (voltage or frequency changes) that are made per second.

Bit: The smallest element of computer storage. It is a single digit in a binary number (0 or 1).

Byte: The common unit of computer storage from micro to mainframe. It is made up of eight binary digits (bits). A byte holds the equivalent of a single character.

Cray Supercomputer: A 75 MHz, 64-bit computer with a peak speed of 160 megaflops. Introduced in 1976 by Cray Research, Inc., it was the fastest computer at the time.

EPROM: (Erasable Programmable Read Only Memory) A memory chip that holds its content without power. It can be erased either within the computer or externally and usually requires more voltage for erasure than the common +5 volts used in logic circuits. EPROMS are used in devices that must keep data up-to-date without power. See Flash RAM.

Ethernet: A local area network (LAN) developed by Xerox, Digital and Intel. It is the most widely used LAN access method. Ethernet connects up to 1024 nodes at 10 Mbps over twisted pair, coax and optical fiber.

Flash RAM: Derived from EPROMS, flash chips are less expensive and provide higher bit densities. Flash is becoming an alternative to EPROM because it can be easily updated.

LED: (Light Emitting Diode) A display technology that uses a semiconductor diode that emits light when charged.

Modem: (MOdulator-DEModulator) A device that adapts a terminal or computer to a telephone line. It converts the computer's digital pulses into audio frequencies (analog) for the telephone system and converts the frequencies back into pulses at the receiving side.

MS-DOS: (Microsoft-Disk Operating System) A single-user operating system for PCs from Microsoft.

PAN: Personal Area Network. A number of portable devices worn on the body that are networked together either wirelessly or allowed to communicate with each other through some other medium.

PCMCIA: (Personal Computer Memory Card International Association) A non-profit trade association founded in 1989 to standardize a method for connecting peripherals to portable computers. PCMCIA cards are used to attach modems, network adapters, soundcards, radio transceivers, solid state disks and hard disks to a portable computer. The PCMCIA card is a "plug and play" device which is configured automatically by the PCMCIA Card Services software.

Piezoelectric: The property of certain crystals that oscillate when subjected to electrical pressure (voltage).

Pixel: (PIX [picture] ELement) The smallest element on a video display screen. A screed is broken up into thousands of tiny dots, and a pixel is one or more dots that are treated as a unit.

QWERTY: The standard type English language keyboard. It was originally designed to slow typing to prevent keys from jamming.

Resolution: The degree of clarity of a display or printer image, usually specified in dots per inch (DPI)

Throughput: The amount of data a communications channel can carry, usually in bytes per second. Also the rate at which a processor can work expressed in instructions per second or jobs per hour or some other unit of performance.

CHAPTER 1

INTRODUCTION

Objective

The purpose of this thesis is to develop a concept for a wearable communications device. Proposed for the market of ten years into the future, this device will integrate today's multiple communications devices and be capable of wireless global communications.

Originally, this project began the summer of 1996 while I was an intern at Eastman Kodak company as an industrial designer. This was a dream opportunity, as Kodak allowed me almost complete freedom to investigate the subject of "Wearable Electronics." My focus was to be projected ten years into the future and required specific attention to image capturing. Although this was definitely to be a futuristic design, the burden on me was to be as realistic and convincing as possible. In three months, I researched, developed scenarios, explored several concepts, and ultimately, further developed one concept solution and made a formal presentation to an audience of approximately thirty people within Kodak.

In the beginning of the Kodak project, I was intrigued by the idea of "wearable electronics." However vague it seemed at the time, I soon became

extremely enthusiastic about it. During my research in the first two weeks, I found that other people, institutions and corporations were making this same foray into the future. As it turns out, many of the technologies necessary to implement "wearable electronics" already existed or showed signs of rapid development. Perhaps my vision would manifest itself earlier than our goal of ten years. With a better understanding of the potential of wearable electronics and further synthesizing of information gathered, I became convinced that this subject indeed has a promising future and is worthy of further investigation as a thesis project. By virtue of this summer internship at Kodak, my familiarity with this subject, combined with a personal desire to explore further, provided excellent opportunity for this to continue to evolve.

What

Exactly what, one may ask, is this wearable communications device and what can it do? As stated earlier, this device is proposed for ten (10) years into the future and is intended to integrate today's multiple communications devices and be capable of wireless global communications. The success of the wearable communications device is contingent on meeting the following minimal criteria:

1. wearability
2. accessibility: convenience and proximity
3. connectivity

The requirement that this communication device be wearable is paramount. First of all, being wearable is the major feature distinguishing this device from all other communications equipment save for a pager (if one wishes to consider this wearable). A quick listing of the current electrical communications implements will yield the following:

1. wired telephones
2. cellular telephones
3. pagers
4. personal computers (including laptops)
5. fax machines
6. PDAs (personal digital assistants)
7. electronic mail (e-mail)

These implements are intended to increase productivity, either allowing or enhancing communications, be it by text, voice or images. The accessibility of these current implements is limited, some requiring wiring and others needing set-up. For example, when relying on a laptop to communicate, one must unpack it, open the clam-shell case and proceed to start up. Accessibility is further compromised if it is indeed operated on one's lap instead of a work surface. Similarly, cellular phones and PDAs are hardly accessible when one considers that these are usually packed away in a briefcase or bag. And how

often are these bags by our side when we need them most? To have these communications tools with you anywhere at anytime suggests that they be wearable. After all, why not make our communications close and personal like our clothes? This to me seems to be a reasonable direction to explore in order to make these accessible and convenient.

Why

Once we have a device that is accessible to use almost anytime or anyplace, what should we be able to do with it? Remember, the reason for it would be for communication. By communication, I wish to include the channels of text, voice and images. Realizing that we currently have multiple devices by which to communicate, this device may integrate their functions. By doing this we would have a medium capable of utilizing all three communications channels. The user should be able to combine these channels most appropriately in order to communicate effectively. In order to tap into these channels, the need to interface these devices is important. This is the nature of connectivity. Consider the following devices and their respective communications channels:

Device	Channel
cellular phone	voice
pager	text
computer	text, voice, images
fax machine	text, images
e-mail	text, images

TABLE 1. CURRENT DEVICES AND THEIR COMMUNICATIONS CHANNEL

With the exception of the computer, fax machine and the advent of e-mail, all of these implements were originally conceived as separate and independent communications devices. As such, they operate independently. Taking into account the ubiquitous presence of these machines and the desire to integrate them, it is, therefore, essential that this new device have the ability to "talk" with them utilizing all three channels.

Traditional product design tends to treat new products as discrete objects that perform certain tasks or functions. Typically these are regarded as inanimate boxes or sculptured objects aimed at making life easier. How do these objects become integrated within our lives? Designers of these products often prefer to consider only the object and its function and either overlook the rest or leave the human considerations to the human factors people. I consider this to be a missed opportunity. Instead, the product designer should consider the relationship of the user to the object, how these objects are to integrate with their lives and what roles these objects will serve? The terms "object" or

"device" are unfortunate because our conditioning prevents us from thinking of them as more than inanimate things. Try to think of an object in terms of a human-like persona. This is a concept Apple Computer popularized with its Macintosh computer systems. Remember your friendly Mac? Why doesn't this approach prevail?

The androidal approach just suggested is appropriate in considering a wearable communications device. Essentially, it is because I seek to create a device that performs tasks that were previously performed by people. This device or persona, let's say, is always with you, can speak any language (channel) and can act as:

1. a smart agent who seeks and gathers information for you.
2. a personal assistant who keeps your schedule and offers reminders.
3. an augmented memory able to recall data and facts, reminding you of past encounters or events.

How

In designing a communications device to integrate the existing communications technology, one needs knowledge of these existing devices in terms of functions, performance and limitations. My research will focus on personal computers, computer networks, cellular phones and PDAs to understand how each relates to one another. It covers the following areas:

1. existing wearable concepts and solutions

2. technology
    - mobile computing
    - wireless
    - display
    - image capture
    - MIT wearables
    - voice recognition
    - power supply
    - PANs (Personal Area Networks)

Following the research phase, I began to make conclusions and propose conceptual solutions. Again, the problem is how to integrate these multiple communications devices. The solutions will address the problems of :

1. wearability
2. accessibility: convenience and proximity
3. connectivity
4. developing a human-like persona

This activity materialized in the form of a "sketch package." The sketch package is a creative problem solving exercise that communicates ideas graphically. Additionally, the sketch package is an effective medium to order one's thoughts and to document the progression of ideas. The sketch package consists of a minimum of three scenario-building exercises. Essentially, the sketch scenarios are short storyboards illustrating a fictional character(s) using a futuristic communication device to accomplish a task. These scenarios describe various possible solutions covering a wide range of users. In addition, they point out

several key issues that a final design resolves. The primary focus of the scenario building is to describe what one can do with such a device and less emphasis is on what it looks like or the technology that would allow it to happen. Consideration of these details will occur at a later time. After completion of the sketch package, I choose several key issues from the scenarios and design a device that resolves the issues and performs similar functions described therein.

Scope

As stated earlier, this wearable communications device is proposed to occur ten years into the future. Since the present date is 1997, my intention is to conceive this device as a reasonable solution to the communications needs of people in the year 2007. Perhaps the final results of this project may seem bizarre, futuristic, or very unlikely to some, but my design will be based on meeting the previously stated criteria. The method by which I do this will depend on a broad understanding of existing communication technologies. Emerging and state-of-the-art technologies will also play a role in determining the results. The final outcome of this project, therefore, is not simply random predictions of the future, but rather one based on reasonable speculation about advances in current and emerging communications technology. This is to say, one should not be misled to think that the proposed solution would be possible today, rather it would be contingent upon further technological developments.

Due to the current momentum and monumental commitment of capital on the part of national and worldwide organizations, technology is moving at an unprecedented rate. This is fortuitous in regards to this project and its implications to communications in the future. As one becomes more aware of the current state of technology, it becomes increasingly apparent that this technology will continue to evolve to become an omnipresent part of our lives. While some implications of this circumstance loom on the dark side, on the positive side I believe we are in for an exciting future of almost endless opportunities. Look onward and prepare yourself for the digital future!

CHAPTER 2

RESEARCH RESULTS

Wearable Research

To my initial surprise, much effort is being devoted to the development of wearable electronics, especially wearable computers. "Nearly every major computer company is currently developing wearable hardware."[1] For the purposes of my writing, a wearable device or computer would be defined as a compact, highly portable, electronic device powered by its own batteries or alternative portable power supply. By contrast, it is the opposite of a desktop system tethered by wiring and cables. Most of the development in this area is a direct result of the miniaturization of electronic parts. Recall, for example, the evolution of computers from room size mainframes to the personal computer (PC), to the laptop computer. The latest breed of highly portable miniature devices called Personal Digital Assistants (PDAs) are scaled-back versions of laptop computers and function as electronic organizers, as well as provide wireless communications. The paradigm witnessed here in the miniaturization of computers, is simply to make computers smaller and smaller without carefully considering the functions. Finally, the PDA takes advantage of the fact that highly portable devices don't necessarily have to provide all the functions and

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[1] A.J.S. Rayl, "Dress Code: The ultimate PCs will be worn," *Omni*, December 1992, 20.

capabilities of a desktop computer. "PC's in 2005 primarily will be for communication rather than computation."[2]

The first generation of wearable computers is in response to the desire to have hands-free access to computers. "In fact the first wearable MS-DOS-based pen computer-called the PalmPAD-was introduced last spring (1992) at a 'fashion' show in Manhattan complete with runway models." This system was developed by GRiD systems for warehouse workers and others who need to collect data and track inventory."[3] Other suitable applications where wearable computers offer benefits are in the paramedical field and for mobile reporters. Computer maker NEC, in fact, has instructed their designers to design and mock-up "a wardrobe of wearable computers".[4] One of the most plausible examples of their efforts is a paramedical kit called the TLC (Tender Loving Care) PC. Designed to assist in emergency medical situations, this device records a patient's vital signs, scans for surface injuries and compares the patient's situation with a medical database before dispensing medical advice to the examiner. All of this is accomplished hands-free for the paramedic. "NEC's paramedical kit may sound far fetched, but all the technologies it employs already exist."[5] Another such wearable computer, called the "Navigator," developed by engineering professor Dan Siewiorek at Carnegie Mellon

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[2] Randy Ross, "Fashionable Computing PC Wear in 2005," *PC World*, February 1995, 54.
[3] Rayl, "Dress Code: The ultimate PCs will be worn," 20.
[4] Bob Johnstone, "Ultimate Fashion," *Far Eastern Economic Review*, 10 October 1991, 86.
[5] Ibid.

University, is a device that serves to give one directions on a journey from place to place. "This device includes a head-mounted display, 80386 microprocessor and hard drive worn on the belt, contains a voice recognition system and communicates with the Global Positioning System (GPS)."[6] In trying to find one's way, a person wearing this device would ask the computer a question, upon which, the computer will respond by presenting a map with directional arrows indicating the correct path on the display. Although only capable of performing a single task, this scenario serves to illustrate one of the many different functions that benefit from being worn on the body.

Perhaps the most common thread reflected in research on this subject is the widespread idea that wearable computers are destined to make fashion statements. Images of NEC's designs are, in fact, exhibited in a style of high fashion. With articles titled: "From Desk To Neck: The PC As Fashion,"[7] "Wearable Computers, Designs Offer High Function and High Fashion"[8] and "Fashionable Computing, PC Wear in 2005,"[9] computer companies and designers envision an opportunity to make a fashion statement from these high tech gadgets as they become increasingly personalized. "In fact, you might even select your PDA based on its attitude more than any other criteria."[10] This

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[6] Larry Krumenaker, "A Wearable Computer," *Discover*, February 1994, 30.
[7] David Kirkpatrick, "From Desk To Neck: The PC As Fashion," *Fortune*, 13 January 1992, 79.
[8] "Wearable Computers, Designs Offer High Function and High Fashion," *The Futurist*, September-October 1992, 26.
[9] Randy Ross, "Fashionable Computing, PC Wear in 2005," *PC World*, February 1995, 54.
[10] Ibid.

attitude is based on the conviction that wearable computers are inevitable . "In five years everyone will have one of these things...The big question is, what kind of computer will you wear?"[11] The notion that wearable computers will evolve into highly personal devices is further perpetuated by the fact that these machines will act more like people as they include "human-centric" technologies. "These 'human-centric' technologies include speech recognition, which lets a PC respond to your voice, and text-to-speech, which lets a PC read digital information out loud."[12] Contrary to the high profile fashion statement is the notion that wearable electronics will disappear into our clothing: "...new types of computers that do their jobs so unobtrusively that they almost disappear."[13]

Although crude, wearable computers are a reality today. Much effort is concentrated on this subject by major research institutes and corporations. Regardless of the many predictions made in this arena, one vision is very clear: the next generation of these devices will be worn on the body and will become a part of everyone's lives.

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[11] Fleming Meeks, "What kind of computer will you wear?" *Forbes*, 14 August 1995, 159.
[12] Ross, "Fashionable Computing," 55.
[13] Paul C. Judge and John W. Verity, "Making Computers Disappear," *Business Week*, 24 June 1996, 118.

Mobile Computing Research

As alluded to earlier, computers have advanced rapidly during their relatively short history. This section on mobile computing will provide a general overview to point out some of the limitations mobile computing faces. Additionally, in response to these limitations, new directions and solutions to those problems will be addressed.

Today's work environment has become increasingly mobile. "According to the U.S. Bureau of Labor Statistics, 56% of the U.S. workforce (69 million people) is mobile - defined as those spending 20% or more of work time away from the immediate work area or in mobile occupations."[14] More of the workforce is on the go, or works away from a home office. A new breed of mobile professionals is demanding different tools to get the job done. Evidence of that resides in the following figures from the high-technology research firm of Frost & Sullivan: "World sales of mobile battery-powered computers will more than double from $30 billion in 1995 to nearly $80 billion by the year 2001, growing at an 18% compound annual growth rate...sales of portable computers are growing twice as fast as sales of desktops, with some companies even replacing desktops with portables." [15] These figures reveal a tremendous opportunity for business to fill the void. However, keeping up with the pace in

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[14] John Teresko, "The Quest For More Power," *IW*, 3 June 1996, 40.
[15] Ibid.

this high-tech arena will never be easy, as this industry is known for innovation and rapid change. In his article, "The Quest For More Power", John Teresko maintains that the last decades of the 20th century will be remembered for the frantic pace of innovation in electronics and its codification in Moore's Law. [16] Moore's law comes from Gordon Moore's observation in the 1970's that memory-chip capacity doubles every two years. This is a rapid pace indeed!

As certain as technology will change the desktop computer, the mobile computer is sure to change. "There's not much left that mobile computers don't do as well or better than desktop systems. And when the remaining challenges are solved, mobile technology will significantly change the face of computing.[17] To confront these problems, significant efforts are being made, especially in regards to power supply issues. Because battery technology is fairly mature and improving slowly, most recent improvements allow portables to run longer due to better power management. Since this is the case, perhaps alternatives to the battery paradigm can be explored.

Mobile computers, naturally being on the move, have different requirements of the display. Obviously, the desktop cathode ray tube-type (CRT) monitor would not qualify as being mobile. Current models of mobile computers utilize a liquid crystal display (LCD) as the preferred type of display.

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[16] John Teresko, "The Quest For More Power," 40.
[17] Andy Reinhardt, "From Here To Mobility," *Byte*, June 1995, 100.

While this technology has advanced rapidly to the point of maturity, other promising, contending technologies are field emission displays (FEDs) and active-matrix electroluminescent (AMEL) panels. Some of the new challenges in the domain of displays are:

1. Brightness
2. Resolution
3. Viewing angles
4. Power consumption

Another factor challenging mobile computing is the need to easily access data while on the go. Wireless connections offer the greatest benefit, however, and presently "...this [data access] is not easily accomplished because wireless infrastructure is not as mature as the wired phone system."[18] To make matters worse, there exists a lack of standardization among numerous possible networks. Consumers should easily be able to connect to a network using a wireless PCMCIA modem or similar device. However, too many networks and protocols are competing for the mass market. Further development and industry-wide standardization could offer improved wireless connections.

If the current state of mobile computing can be attributed to the miniaturization of electronic parts, the future is bright for the coming generations of highly mobile electronic devices. For example, data storage devices, like

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[18] Andy Reinhardt, "From Here To Mobility," *Byte*, June 1995, 102.

many other components, have become dramatically reduced in size and are shrinking yet. In an article published in *Popular Science*, titled "Scoping For Data", Robert Langreth contends that "computer data storage devices may one day be literally microscopic. Cornell University engineers have developed a scanning, tunneling microscope that may eventually create computer storage systems that are the size of a fingernail yet can hold as much data as several thousand of today's hard disk drives."[19] This is good news given the interest in miniaturization.

Perhaps solutions to some problems deserve a radical, new approach. This approach to problem solving applies to the computer industry, especially since some say we are approaching the physical limits of microprocessors. One such approach to this problem is biological computing. Writing for *Popular Science* magazine, Mariette DiChristina says that "... bio-chemical reactions in the brain's...fluids and tissue perform many tasks faster than a Cray super-computer...[yet] your brain can probably recognize 500 people on the street."[20] Hence, researchers are looking into the potential of alternative computing solutions that offer benefits such as image or pattern recognition, giving the computer more human-like reasoning ability.

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[19] Robert Langreth, "Scoping For Data," *Popular Science*, August 1995, 34.
[20] Mariette DiChristina, "Better Computing Through Chemistry," *Popular Science*, August 1995, 34.

Along with tremendous advances in computing power in mobile electronic devices is a new concern focusing on EMI (Electromagnetic interference). EMI results from fast microprocessors common in mobile phones, CD players and laptop computers. The electromagnetic noise emitted from these devices is known to interfere with planes' or ships' navigation instruments, heart monitors and defibrillators. To combat these problems, either proper shielding will have to be provided, or the electronics will have to be designed properly from the beginning. Jocelyn Kaiser admits in the *New Scientist* that, "Even products like laptops, which are notoriously noisy, don't need an ounce of shielding if they are designed properly."[21]

Given that mobile computing shows extremely rapid growth and innovation, new mobile devices may eventually out-pace desktop models in performance. Along with this development arise numerous challenges in terms of developing power supplies, displays and wireless communications. These requirements differentiate the mobile from the desktop systems and are proving to be a challenge. However great the challenge, researchers and scientists are responding with new, innovative approaches to these problems. Given the amount of effort and return in favorable results, the future of mobile computing is definitely encouraging.

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[21] Jocelyn Kaiser, "Please Extinguish Your Laptop," *New Scientist*, 2 December 1995, 37.

Wireless Research

As a result of people being increasingly on the move, our communications needs are changing. The introduction of cellular phones to the mass market served to illustrate the potential of wireless communication; the ability to be reachable anytime and anywhere. People's desire for convenience has spurred tremendous growth in cellular services. In his article titled, *The Wireless Wars,* Don Boroughs states that "...the industry is adding 17,000 customers a day, which translated into growth of 48 percent over the past 12 months (1994)."[22] This early interest in portable communications through cellular networks, an analog medium, generated further interest in other wireless communications. "Mobile workers who have experienced the liberation of cellular phones are now demanding the same freedom for their digital communications."[23] The ability to accommodate wide range communications of voice and data, wirelessly, at this point is still a challenge. However, new advances in digital wireless technologies and improved wireless networks promise to ease this task.

In the year 1985 an important event occurred to benefit wireless communication. The FCC created the Part 15.247 regulation that permits unlicensed operation in the ISM (Industrial, Scientific and Medical) bands of

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[22] Don L. Boroughs, "The Wireless Wars," *U.S. News and World Report,*" 31 October 1994, 73.
[23] Salvatore Salamone, "Radio Days," *Byte*, June 1995, 107.

902 to 928 MHz, 2.4 to 2.483 GHz and 5.725 to 5.85 Ghz. This action meant that these blocks of radio spectrum could be freely used by portable communications devices. Unlike cordless telephones used at home, this spectrum could take advantage of either one of two technologies that offer secure and quiet communication. These modulation techniques are known as "frequency hopping" and "spread spectrum."[24]

"Spread spectrum was cloaked in secrecy for many years because of its origins in high-security military systems. Spread spectrum allows large numbers of PCS [Personal Communication Service] users...[to] operate their cordless phones simultaneously with uncompromised security and without interfering with one another."[25] Another advantage of spread spectrum technology is that it makes more efficient use of the spectrum as compared to analog cellular. One should note that the radio spectrum is a limited resource and this is an issue, given the rising popularity of wireless devices. Spread spectrum, however, does have an immediate disadvantage to cellular. Phasing spread spectrum into existing cellular networks would mean instant obsolescence of billions of dollars' worth of equipment in the hands of the public and cellular-service providers."[26]

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[24] John Gallant, "Digital Wireless Networks," *EDN*, 4 March 1993, 82.

[25] Dan Strassberg, "Spread-spectrum communication rises from military roots to star in wireless world," *EDN*, 22 December 1994, 59.

[26] Ibid., 60.

Given that cellular networks are already in place, a system made to utilize this existing infrastructure would make sense. The PCS (Personal Communication Service) does just that.

> The PCS concept includes plans to reduce the costs of portable communications by using a smaller cell size than the 6-mile radius of cellular phones. Proponents contemplate a time when users will maintain constant contact with their personal computers and their home phones using portable PCS handsets. Users will have a unique user address instead of separate phone numbers or mailing addresses to receive E-mail and voice messages immediately at work, home, or on the road. [27]

In addition to PCS, other companies have developed a CDPD (Cellular Digital Packet Data), enabling wireless transmission of packet data over existing cellular systems.

Wireless communication is possible utilizing either one of several different technologies. At this point wireless communication is considered immature, in part due to the competition between cellular and digital technology. One of the greatest concerns of wireless service is coverage. According to industry sources, overall, about 80 percent of the U.S. population can get access to wireless networking, with 90 percent of major metropolitan locations having coverage.[28] Thus, having access to voice or data while traveling may not always be dependable, especially since different companies

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[27] John Gallant, "Digital Wireless Networks," *EDN*, 4 March 1993, 86.
[28] Salvatore Salamone, "Radio Days," *Byte*, June 1995, 108.

offer services in different areas. In 1995 there are four major choices for wireless service providers:

- The existing cellular phone network is the most familiar method, because all you have to do is connect an analog modem to a cellular phone jack.
- CDPD (Cellular Digital Packet Data) is offered by the large telecommunications service providers, including AT&T, Bell Atlantic Mobile Systems, Nynex, GTE, Southwestern Bell, McCaw Cellular, and Sprint.
- RAM Mobile Data is a service of Bell South Mobile Systems and RAM Broadcasting.
- Ardis is a joint venture of Motorola and IBM.
- The two leading providers are Ardis and RAM Mobile Data.[29]

Both services offer data transmission rates of 19.2 Kbps in most large cities, though smaller cities may be limited to 4.8 Kbps. A throughput rate of 19.2 Kbps is not bad compared to a maximum of 19.2 Kbps, the maximum rate of a wired system with a current modem connected to a phone line. Compared to an Ethernet connection of 10Mbps, this is slow. However, data rates of 100Kbps are being planned by Metricom, which will offer service in five major U.S. cities.

This data on wireless communications is enough to confuse almost anyone, particularly the consumer. The conclusion from this, if any sense can be made, is that wireless communication is still immature and lacking standards. Due to these reasons, however, businesses are anxious to build wireless networks to provide customers with seamless, wide coverage and faster throughput. In a move that will "profoundly change the way people in

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[29] Salvatore Salamone, "Radio Days," *Byte*, June 1995, 108.

America communicate," the FCC is cooperating by auctioning off blocks of radio spectrum to the highest bidders.[30] This is promoting intense competition, thus driving down prices and promoting standardization across the industry, while creating an entirely new and enormous industry in wireless communication. The bottom line to consumers is the ability to effortlessly communicate anyplace and anytime.

Display Research

As an integral part of computer and information systems, the display is perhaps the most important component. Every information device incorporates a display of some kind, whether it be a cathode ray tube (CRT), liquid crystal display (LCD), or other type of display. Mobile computing and the surge of small information appliances created a huge industry demanding small, lightweight, portable displays that the traditional CRT could not provide. This section reports on the current status of current display technologies and other technologies that will propel mobile devices into the next century.

Perhaps the most common display, other than the CRT, is the LCD. LCDs are greatly improved since their early years and are considered robust technology. Today, color active matrix liquid crystal displays (AMLCDs) and passive matrix liquid crystal displays (PMLCDs) measuring ten to eleven inches

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[30] William J. Cook, "It's a brave new wireless world," *U.S. News & World Report*, 4 October 1993, 93.

with screen resolutions of 800 X 600 are common on laptop computers, whereas, according to an article in *Byte* magazine, "Five years ago, color screens on laptops were quite rare".[31] To the extreme, using a different type silicon, one company is planning LCDs measuring up to 2560 X 2048 pixels.

Of the two types of LCDs, AMLCD and PMLCD, the AMLCD provides more vivid color and faster screen updates. AMLCDs which are fabricated with amorphous silicon, use a transistor at each pixel site that regulates the passage of light through the panel, thus improving image quality. As a result of this sophistication, AMLCDs are more difficult to manufacture, thus making them more expensive. Displays fabricated from other types of silicon also show potential for making high resolution displays. Such technologies, known as field emission displays (FEDs) and active matrix electroluminescent (AMEL) are not expected to show up on the mass market for several years though.[32]

LCD technology is mature, however some areas need improved performance. For example, contrast and brightness are the primary concerns. For multimedia applications, the display's response time to moving objects on the screen is an problem. Displays capable of playing video at a rate of 30 frames per second (NTSC standard) should resist submarining (tendency of objects to temporarily disappear). As the market expands, one should not be

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[31] Chris Chinnock, "Color to Go," *Byte*, June 1995, 115.
[32] Andy Reinhardt, "Mobility," *Byte*, June 1995, 101.

surprised to see generations of displays that confront the problems facing mobile displays.

> The market is likely to expand in coming years as new technologies enable the production of high-resolution displays that measure 3 inches (diagonal) or less. These displays will be the visual interface for communications devices designed to be carried around or even worn on the body. This market is just now emerging and could become quite significant in five years.[33]

Evidence of this nature suggests that we are only at the beginning of great solutions for mobile displays.

Out of the efforts to create small, lightweight, portable displays, evolved a new category of headmounted displays or HMDs. Designed to provide hands-free accessible information, small displays are being built into headset gear. Chris Chinnock, writing for *Byte*, states that "HMDs are being touted as a new kind of interface for some types of portable computers."[34] In the meantime, applications for this gear range from games and entertainment to industrial uses. HMDs are commonly used in virtual reality games where the user wears a headset equipped with one or two small displays and speakers for stereo sound. Many different models are offered from a variety of manufacturers for this market. One such headset, the "i-glasses!" system from Virtual I/O "allows users to view full color video images and the peripheral environment

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[33] Chris Chinnock, "Color to Go," *Byte*, June 1995, 122.
[34] Ibid.

simultaneously."[35] Other attractive features allow the user to see through the device when it is turned off. This device weighs just 7 ounces and contains two 0.7 inch LCDs having 138,000 pixels per LCD. Furthermore, this device provides a heads-up, 30 degree diagonal field of view and an image that the user perceives as an 80 inch TV screen at an 11 feet viewing distance. Such devices as these are common and very popular in the video gaming and entertainment markets.

For industrial uses, HMDs are an immediate benefit in that they provide a hands-free computing environment. For example, an aircraft or automobile mechanic wearing a HMD can access technical manuals or view assembly drawings without putting down a tool. This scenario is currently being used by both the U.S. military and Boeing aircraft company. Similarly, some inventory workers are benefiting from HMDs.

Even though HMDs and LCDs offer reasonable and viable solutions to mobile displays, they are not optimum. HMDs offer a somewhat realistic simulation of 3D environments, but at the cost of donning inconvenient and clumsy looking head gear. Some researchers and visionaries predict future 3D mobile displays utilizing holography. *Wired* magazine recently inquired into the future of holography. David Pescovitz writes that "While virtual reality may be grabbing the media's attention, startling advances in holography are promising

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[35] Fran Granville, "Headset Provides Realistic 3-D Images," *EDN*, 22 December 1994, 12.

to bring true-color 3D images into our homes and hospitals. And you don't need bulky headsets to see them."[36] Researchers are predicting a family of imaging devices of the future based on holography. Items such as holophones, holoprinters, holographic medical imaging devices and holographic storage devices amounting to a one billion dollar industry are predicted as early as 2010.

> While a current estimate puts the holographic industry's revenue at US $150 million per year, our experts say that new uses of holograms will drastically expand the market over the next few years. Fischbach (James Fischbach, president and CEO, American Propylaea Corporation) whose company is working with automobile manufacturers on a hologram system to view future car models, says "If the Big Three (automakers) include holography in new development, the market will explode".[37]

Other predictions focusing on medical imaging say that in the not-so-distant future physicians will examine holograms, suspended in mid-air, of patients' organs. While these statements are only predictions, current projects applying holography in research projects show real merit. For example, in 1993, MIT's Media Lab sent a hologram through 70 meters of coaxial line. Information such as this indicates that holography may have an application in the growing market of future mobile devices.

Even moving beyond holography, display devices utilizing other technologies that generate real-looking 3D objects are appearing. These types

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[36] David Pescovitz, "The Future of Holography," *Wired*, July 1995, 60.
[37] Ibid.

of displays are generally referred to as 3D volumetric displays and do not use lasers as do holograms. Two such companies currently making such devices are Dimensional Media Associates (DMA) and Dimension Technologies, Inc. (DTI). Recently in the spotlight at the Smithsonian, DMA's creation, the HoloGlobe, is a display containing a four-foot, full-color, full-motion, 3D image of a globe that floats in space. The exhibit is viewable from different angles without the use of special 3D glasses, virtual-reality gear, headsets or lasers. This display, which is based on a technology called High Definition Volumetric Display (HDVD), "...can use input from a variety of image generation and storage sources: real-time processed data, real objects, television, computer monitors, flat panel displays, etc."[38] DMA claims that the effect is images so real that viewers want to reach out and interact with them.

Another similar device called the "Virtual Window," introduced in 1993 by DTI, utilizes flat panel LCD technology to generate real-looking 3D images. This device also does not require viewers to use headsets or glasses. Displays not requiring optical aids are classified as "autostereoscopic."

The benefits achieved with autostereoscopic displays are obvious. Most importantly, these displays allow users to better understand and interact with complex data. In an effort to remove common constraints related to HMDs,

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[38] Press Release, "Gore Calls DMA's Floating-Image 3-D Technology "Spectacular," Dimensional Media Associates, Inc., 22 West 19th Street, New York, NY 10011.

much research and development is being directed towards creating 3D displays. As a result of these efforts, commercial quality hardware for autostereoscopic displays started arriving as early as 1992. A few of the applications that benefit from these displays are:

- visualization of multi-dimensional graphs
- molecular structures
- aircraft cockpit displays
- medical imaging
- structural imaging
- architectural visualization.[39]

Although still in the early stages, these autostereoscopic technologies prove to be valuable in many situations. As these technologies advance and become less expensive, people will come to expect 3D display in much the same way we expect color television.

The market for mobile displays is soon expected to boom. LCD technology appears to be improving while filling the market with relatively low cost displays, due to economies of scale. Other promising technologies capable of providing three-dimensional, full color objects that float in mid-air and are small enough to be worn on the body, are predicted to be the displays of the future. Although the technology is very immature, several companies have risen to that challenge and have partially fulfilled the dreams of mobile

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[39] Jesse Eichenlaub and Alexander Martens, "3D without glasses," *DTI News* (Press Release), Dimension Technologies, Inc., 315 Mt. Read Blvd., Rochester, NY 14611, 10.

computing. Perhaps in the near future a real working version of Star Trek's "Holodeck" will emerge from science fiction to reality.

Image Capture Research

People have a need to capture images for many different reasons; for remembering occasions, documentation purposes or for expressing themselves. Photography, in its long history, has seen many improvements. As a result, new processes, techniques and equipment continue to evolve. This section reports on the current status of image capture technology.

In terms of recent image capture devices, the advancement of digital technologies now allows more options for people wanting to capture images. One such advancement, the APS (Advanced Photo System), is a hybrid of both traditional silver-halide and digital techniques. The APS film cartridge is much like that of 35mm film, however the APS cartridge contains a magnetic layer that can digitally record lighting and flash conditions for each shot. Future plans suggest having the ability to record additional information such as audio tracks.

The APS film format was developed in collaborative efforts by photo industry giants including Kodak, Fuji, Canon, Minolta and Nikon. The APS system boasts features such as:

- simple film cartridge loading
- ability to select different print sizes per frame
- small film canister, resulting in smaller cameras
- ability to store per frame data, e.g. date, lighting conditions, future plans for audio, etc.
- some camera models allow users to change film midway through the cartridge
- cartridges can be plugged into devices allowing them to be viewed on a TV[40]

While these features may sound attractive, people do not seem ready to abandon traditional 35mm film technology. Perhaps the most obvious reason for this is that image quality is not one of the enhancements. By and large, traditional 35mm techniques already deliver reasonable image quality. Another significant reason users are reluctant to choose the APS format is cost. Edward Baig, writing for *Business Week*, notes that "APS cameras run 15% to 30% higher-and you'll pay a premium for film and processing."[41] Processing centers are not as commonly found as for traditional 35mm film. Other conveniences such as one hour turn-around are uncommon as well. Although APS undeniably boasts convenient features for capturing images, these disadvantages may limit the success of APS.

Moving beyond the APS hybrid, digital image capture devices are gaining momentum. These cameras allow fast and easy transfer of images to

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[40] Edward C. Baig, "The Next Great Leap For Shutterbugs?," *Business Week*, 22 April 1996, 150-51.
[41] Ibid, 151.

personal computers. Digital cameras employ an image capture device called a CCD (charge-coupled device) which eliminates the need for film. Both computer and photography companies are filling the marketplace with digital cameras. For example, digital point and shoot cameras from Apple, Casio, Chinon, Kodak and others for around $1,000, while professional versions can cost up to $10,000.

While capturing images digitally does not require the use of film, digital images do not generally equal the image quality of 35mm film. Even expensive digital cameras can't match the sharpness of photos taken with a $15 disposable camera. The greatest advantage, however, is the ability to swiftly place images in an electronic environment and to achieve the compact sizes allowed by miniature electronics in a digital camera. In addition to these benefits, Ricoh has a digital camera model, the RDC-1, which is about the same size as a microcassette recorder and can even record sound.

While the manufacturers of these digital imaging devices are aware of their limitations, efforts are being made to improve their performance. For example, Polaroid has entered the digital market with a model that can capture images at 24 bit color depth at a resolution of 1,600 x 1,200 pixels. The Polaroid PDC 2000/60 can store 60 images in 60 Mbytes of built-in EPROM.

Images can then be downloaded to a personal computer for storage, electronic publishing, output, etc.[42]

Similar to still image capture, digital imaging technology offers similar benefits in the area of motion video. Advantages afforded by tiny CCDs allow tiny video cameras to serve as monitors in medical and industrial fields when size is critical. For example, Panasonic offers several Digital Signal Processing Color CCD Micro cameras in which the camera measures one-half inch in diameter. These are often connected to endoscopes for use in orthoscopic surgery. Similarly, in video surveillance work or security applications where size is critical, several models are capable of recording color motion video. The Mini Peach is advertised as the world's smallest video camera:

> Originally chosen for covert surveillance work;
> To be so cheap, as to not require recovery,
> To be so strong, as to withstand rough handling,
> To be so small, as to become "invisible.[43]

While originally developed for industrial or medical applications, these tiny digital cameras are finding their way into consumer products like digital video cameras. The benefits of such include size reductions and the elimination of mechanical parts.

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[42] Kelly Ryer, "Polaroid takes a shot at digital camera users," *MacWeek*, 11 March 1996, 10.
[43] "Mini Peach Camera," [WWW page]; available from http://www.threaded.com/tlcltd/products/minipeach.html; Internet; accessed 28 June 1996.

MIT Wearable Research

Perhaps one of the leading research institutions delving into the subject of wearable computing is Massachusetts Institute of Technology (MIT). Since MIT is a major researcher on this subject, this section is devoted to presenting key issues facing wearable computing and present and future markets for wearables.

Key Issues

Fundamental to all computing or communications is the ability to interact with a machine or device through an interface. A major difference between wearable computers and conventional desktop models is, of course, size. The size requirement of a wearable computer dictates small, unobtrusive interfaces. Consider two of the most basic traditional methods of interfacing a computer: a display (for seeing people), and a keyboard. Clearly, alternative methods of input/interaction are necessary for a wearable interface.

Thad Starner, a doctoral student at MIT's Media Laboratory, Vision and Modeling Group, has one possible solution for the next generation interface. In fact, Mr. Starner has been described as a "cyborg"- half human, half computer. For a display, he uses the "Private Eye" manufactured by the Phoenix Group. Starners display weighs only 1 oz., uses a single row of 280 LEDs and a scanning mirror to display a screen at 720 X 280 pixels to the users eye. This graphics display is mounted in a pair of sunglasses to be close to the user's

eye. As a result of having the display close to the eye, the projected image is equivalent to a large screen display while the focus can be put anywhere from 10 inches to infinity.[44] In an interview for the *New Scientist,* conducted by Peter Thomas, Mr. Starner spoke on future graphic display solutions involving neural prostheses, which strongly suggests a cyborg. Basically, installing neural prostheses is an invasive method that involves altering or attaching foreign material/hardware to human tissue or organs. Although some neural prosthetics described in science fiction have desirable qualities, the likelihood of such is far off, if not impossible. Furthermore, Mr. Starner cites resistance from the medical community to experiment with such visionary scenarios. More realistic visions include a contact lens-like display that can be inserted on the surface of the eye without touching the retina.[45] For now, graphic displays like the Private Eye and several other commercially available models are providing small, relatively unobtrusive graphic interfaces for wearable computing.

The other basic input method provided by a traditional QWERTY keyboard presents another fundamental challenge. Here again, the size constraint prohibits a conventional keyboard as an input device. Starner uses a small, one-handed keyboard called the Twiddler keyboard from HandyKey. One major drawback many people are concerned with is the need to relearn or

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[44] Thad Starner, "The BU-ACM Lectureship Series-Thad Starner," [WWW page]; available from http://cs-www.bu.edu/students/acm/lecturers/thad.html; Internet; accessed 28 June 1997.
[45] Peter Thomas, "New Scientist Wearable Computing Interview," [WWW page]; available from http://lcs.www.media.mit.edu/projects/wearables/newsci.html; Internet; accessed 28 June 1997.

modify behavior with a new interface. Such is true with the Twiddler keyboard; it requires users to relearn how to type. The Twiddler, though, is said to be efficient and easy to learn in a short amount of time. Another interface possibly suitable for wearable computing, is a pen based graphics user interface (GUI). This interface requires the user to write on a small, touch-sensitive LCD screen with a pen or stylus while software interprets the characters to convert them into electronic characters. These interfaces have become marginally popular lately with Apple's Newton and US Robotic's Pilot, along with several others. However popular, Starner discounts these interfaces for several reasons. For wearable computers it is important to minimize size, while graphic user interfaces require large areas for writing and display. This is a problem since these issues are in conflict. Secondly, Starner states that handwriting is not intuitive, since we spend a great deal of time learning how to form characters of the alphabet. Lastly, one of the greatest concerns is that handwriting recognition is not 100 percent accurate and the processing power necessary to operate it is extraordinary. This fact and the realization that handwriting is just too slow perhaps suggest a better alternative such as speech recognition.[46]

Realizing there is a huge distinction between wearable computers and desktop machines, some fundamental needs do not change. For example, as examined in the last section, one needs an interface and a method of input.

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[46] Thad Starner, "The BU-ACM Lectureship Series-Thad Starner," [WWW page]; available from http://cs-www.bu.edu/students/acm/lecturers/thad.html; Internet; accessed 28 June 1997.

Another major necessity is a constant power supply. MIT is experimenting with alternative power supply concepts to enable wearable computers. In fact, a study of "human powered wearable computing" at MIT revealed some promising results. "The body produces at least 81W at any given time and over 1 kilowatt maximum. If only a fraction of this can be harnessed without encumbering the user, a wearable computer can run without ever needing an electrical socket."[47] One of the most promising concepts involves generating power from one's shoes while walking. Creative, practical solutions for generating the required power are abundant. Other solutions propose that power can be generated from sources very close to our bodies, like our clothing![48]

Other key problems to resolve to enable these small computers involve consistency and standardization. Consistency, as Starner explains it, means that one's interface should remain constant no matter what type of machine or software one is to interact with. In other words, your wearable computer's interface would control other machines such as workstations running a variety of operating systems, bank machines, etc., and that you could customize your interface on the wearable to solve your needs. This interface would then become intimate; one designed for long term relationships.[49] Much effort must

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[47] Peter Thomas, "New Scientist Wearable Computing Interview," [WWW page]; available from http://lcs.www.media.mit.edu/projects/wearables/newsci.html; Internet; accessed 28 June 1997.
[48] Ibid.
[49] Ibid.

be devoted to create and maintain hardware and software that is consistent and compatible with one another. Wearable computing users will have to rely on infrastructures that they can connect to at any time and any place.

Markets

MIT's research and development of wearable computing can benefit several key niche markets. Basically anyone who has a need for real-time information stands to benefit. A short-term market, according to Peter Thomas, is the US Army. The Army has already field tested augmented soldiers and is spending considerable amount of effort to further their usefulness. Other examples include brokerage firms or news correspondents who tend to be on the go, yet need up-to-date information to remain competitive. Although wearable computing is still in a stage of infancy, Starner concedes that, in the long term, everyone from students to secretaries to CEOs will be affected in some way.

> Just like automobiles, paging, and cellular phones, wearable computing will be focused at first on rich specialty markets that have insatiable needs for real-time information. Then, as the general population gets exposed to these devices and production lines get established, larger markets will come into play and users will find their own applications. This will have tremendous repercussions in the hardware, software, communications, and service industries.[50]

These markets have tremendous potential and it is only a matter of a short time before they explode.

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[50] Peter Thomas, "New Scientist Wearable Computing Interview," [WWW page]; available from http://lcs.www.media.mit.edu/projects/wearables/newsci.html; Internet; accessed 28 June 1997.

Perhaps one of the biggest future markets for the wearable class is in the software area. According to Starner, the so called “killer application” that will propel wearables is “augmented memory”. To understand augmented memory, one can use the analogy of a “Remembrance Agent” who acts like a personal assistant to provide constant reminders of critical information. Augmented memory may have the ability to recognize faces and is a system that continually monitors one’s environment and automatically suggests useful information to the user based on context. This imaginary remembrance agent may also have the ability to learn its users’ preferences and adapt itself to respond with helpful information. Systems like this appear to have tremendous potential to help organize, maintain and recall vast amounts of information, much like a personal secretary.

Voice Recognition Research

Making computers more portable or even wearable presents some obvious, major obstacles in both hardware and software. The previous example of a wearable computer at MIT that utilizes the Twiddler keyboard attempts to resolve the hardware problem by simply making the input device smaller. How about making it disappear altogether? Perhaps there is a better input method than a keyboard and mouse!

Voice recognition capability may be the answer. Recent advances in software have made interacting with personal computers easier and more effective by allowing the computer to respond to the user's voice. One such program called Power Secretary 2.0 takes dictation. The user simply talks to the computer instead of typing on a keyboard. According to Power Secretary 2.0 user David Pogue, "[After spending about] one hour training the program by uttering prepared sentences; it then takes about a week of full-time usage before the program's dictation accuracy improves to tolerable levels."[51] The software works by first training the program. This example illustrates the point that even though users may pronounce or speak differently, the software has the ability to adapt to the user instead of the inverse. This could be a tremendous advantage for a wearable computer.

Sure, this example sounds great for using dictation to input text, however, what about interacting with a graphics user interface (GUI)? Traditionally, this input is provided by a mouse. A true portable or wearable class machine does not support a conventional pointing device. Again, software packages are able to remedy this situation as well, at least for current desktop or laptop models. For example, Pogue reports on a program titled QuicKey 3.01 by CE Software, which allows a user to navigate conventional operating systems by voice commands. This software can be trained, as well, so that one can launch programs, manipulate menus and close windows by voice command. All tasks

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[51] David Pogue, "Look, Mac-No Hands!," MacWorld, August 1995, 157-58.

previously executed by keyboards and pointing devices can now be performed hands-free, quickly and easily.

As great as this solution sounds, a couple of major drawbacks must be considered. Perhaps the most glaringly obvious problem with voice recognition would arise due to changes in the user's voice. Consider the consequences if a user lost his/her voice due to a cold. Or what if the user's voice changed slightly due to a cold? Secondly, consider the impact that environmental noise may have with a voice recognition system. In noisy environments a voice recognition system may try to interpret ambient noise as input from the user. Conceivably, these issues may be resolved by the software's ability to adapt to the user. Looking further ahead, imagine a room full of people each talking to his or her computer. This scenario would require that voice recognition systems be good enough to distinguish their respective user's voice from other voices in the immediate environment.

Given these limitations with voice recognition, there are very promising applications for this improvement. The ability to interact with computers by voice definitely has advantages in terms of ease of use, efficiency and intuitiveness. For those with physical disabilities, this method of interaction would be an obvious advantage. Similarly, the increase of repetitive stress injuries associated with traditional keyboard input is very likely to generate enough interest to perfect voice recognition systems so that they may well be as

common as mice are in the 1990's. This major innovation is definitely enabling for wearable computing.

Power Supply Research

Possibly one of the greatest challenges to overcome, before wearable computing becomes more viable, is to develop a small, light weight and efficient power supply. Laptop computers, for example, currently are powered by large, heavy batteries that discharge in a few hours. Traditional power supplies based on conventional alkaline or lithium-ion batteries are considered to be mature with little hope of becoming smaller or more efficient. Thus, alternative power supplies are being considered. Again, one of the most knowledgeable institutions exploring wearable computing, MIT is seriously facing the power supply issue. Thad Starner has explored several possible methods of utilizing energy from our own bodies to power a computer. This section summarizes the six different conceptual methods of human powered computing as presented in an article by Mr. Starner titled, "Human Powered Wearable Computing."[52]

The body is considered a "store house" of energy. The amount of energy consumed and produced by the human body is quite amazing. For a frame of reference, compare the following human energy expenditures versus common power requirements:

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[52] Thad Starner, "Human-powered wearable computing," *IBM Systems Journal*, nos. 3&4 (1996): 618-29.

Human Energy Expenditures		Common Power Requirements	
Activity	Watts	Item	Watts
Sleeping	81	Desktop Computer (without monitor)	10^2
Sitting	116	Notebook Computer	10
Conversation	128	Embedded CPU Board	1
Housekeeping	175	Low-power microcontroller chip	10^3
Carpentry	268	Avg. human power use over 24 hours	121
Sprinting	1630	Avg. human diet	1.05×10^7

TABLE 2. HUMAN ENERGY EXPENDITURES AND COMON POWER REQUIREMENTS. Source: Thad Starner, "Human-Powered Wearable Computing," *IBM Systems Journal*, nos. 3&4 (1996): 618-29.

This table proves that our very own bodies are capable of producing enough energy to power a wearable computer. However convincing, this energy must be captured and transferred efficiently in order to be useful.

Body Heat

The human body naturally gives off energy in the form of heat. Actually, the amount of possible heat energy is significant: 2.8-4.8 W. This figure assumes that all heat energy is captured and turned into energy without loss. Starner points out that capturing all of the body's heat energy is quite impractical and that even capturing a fraction of that would still be both uncomfortable and impractical. Thus, this method of power supply is very limited.

Breath

Breathing is another naturally occurring and necessary body function. Capturing and utilizing energy from this source is very limiting as well. One method proposed by Starner involves using an aircraft-style mask where power is generated by a turbine and generator when the user exhales. The resulting power generated is only .40W. Another method is to "fasten a tight band around the chest of the user" so that when the user inhales, the change in the chest's circumference produces mechanical energy. This mechanical energy is converted to power by way of a small ratchet and flywheel and yields approximately .42W, based on Starner's calculations. Again, this is not enough power relative to the amount of inconvenience and stress added to the user.

Blood Pressure

Although seemingly bizarre, the concept of using one's blood pressure to power a wearable computer shows immediate possibilities. Average blood pressure from a healthy person can generate approximately .93W (at rest) based on Starner's calculation. This figure could be doubled by an activity such as running. This concept, however, is extremely impractical due to the fact that this energy would be dangerous to harness, especially since harnessing this energy would increase the load on the heart. "However, even if 2 percent of this power is harnessed, low-power microprocessors and sensors could (be) run.

Thus, self-powering medical sensors and prostheses could be created."[53] This option is not reasonable for the short term in regards to wearable computing.

Upper Limb Motion

Several studies were performed by Braune and Fischer on power generated from upper limb motion. The results were surprising:

maximum power generated by bicep curls	=	24W
maximum power generated by arm lifts	=	60W

TABLE 3. POWER GENERATED FROM UPPER LIMB MOTION. Source: Thad Starner, "Human-Powered Wearable Computing," IBM Systems Journal, nos. 3&4 (1996): 618-29.

These figures were generated from examples requiring extreme effort from the user. More reasonable figures are derived by dividing these numbers by a factor of 8, which is roughly the amount of effort required for an enthusiastic gestural conversation. This would yield a minimum of 3W. Finally, using a pulley system to harness this energy, this number is reduced to 1.5W due to losses to friction in the mechanical system. Using a method such as this, Starner concedes, would be extremely inconvenient. A less "encumbering" system proposed by Starner to harness this motion would be to utilize piezoelectric material in clothing at the joints. This is a flexible material that generates an electric charge due to bending. Recoverable power from this solution based on calculations is only .33W. Let's keep looking for alternatives!

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[53] Starner, "Human-powered," *IBM Systems Journal*, nos. 3&4 (1996): 621.

Walking

According to Starner's research, walking appears to be the most reasonable method of producing power. The impact of the ball of the foot striking the ground is 30 percent greater than the force of one's standing weight alone. A simple calculation reveals that a 68 kg person's heel traveling 5 cm vertically generates 67W of power when walking. This is a tremendous amount of power! Even though a person is not consistently walking, some of this energy may be stored for later use. The challenge is how to harness this power. Starner suggests using piezoelectric materials to convert mechanical energy to electrical energy. Of the two piezoelectric material choices, PZT (lead zirconate titanate) and PVDF (polyvinylidene flouride), PVDF is the most appropriate for this application. For example, a shoe insert made of PVDF could be used in place of conventional sole material; "...the natural flexing of the shoe when walking provides the necessary deflection for generating power from the piezoelectric pile."[54] Other advantages are that the PVDF is easy to cut, and it could be used "as a direct replacement for normal shoe stiffeners."[55] Using this material in this manner and assuming a small woman's footprint with an area of approximately 116 cm^2 and a mass of 52 kg, 5W of electrical power could be generated at a brisk walking pace.

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[54] Starner, "Human-powered wearable computing," *IBM Systems Journal*, nos. 3&4 (1996): 624.
[55] Ibid.

Another possible method of harnessing this power is a spring system mounted in the heel of the user's shoe. Through the process of walking, a spring compresses and a ratchet and flywheel system coupled to the spring generates energy. According to Starner, some initial mock-ups and calculations reveal a possible 8.4W of available power using this method.

Finger Motion

Starner's research into human powered computing considers many creative possibilities. The ability to power a small computer from finger motion due to typing on a keyboard, however, does not seem very likely. For example, two experiments using two different types of keyboards resulted in an average of 6.9mW and 19mW of power generated. Taking into consideration the fact that one is not constantly typing, this method does not show much promise. Even so, it is important to consider all the possibilities.

In conclusion, Starner's human-powered, wearable computer research project explores many creative methods of generating electrical power from the human body. The greatest challenge presented here is how to convert this energy to electrical current without losing too much energy in the process. Similarly, the challenge is to capture this energy without creating excess strain or inconvenience to the user. Of all the possibilities presented here, the obvious winner takes advantage of the tremendous power generated by simply walking. Starner maintains that power for a human powered wearable computer can be generated by simply replacing conventional shoe sole

materials with piezoelectric material or adding a spring system to the bottom of the soles.

Personal Area Network Research

The proliferation of small, portable, electronic devices such as cellular phones, pagers and Personal Digital Assistants (PDAs) illustrates our desire to communicate while on the go. Currently these numerous devices operate independently, as they are designed to perform specific tasks. This results in a certain amount of redundancy, requiring additional input from the user. For example, since a message from one's pager cannot be electronically transferred to one's cellular phone, the user must take the information and manually input it into the cellular phone. Thus, the ability for these separate devices to communicate electronically could automate such tasks. Conceptually, one's own body could act as a communications medium through which various body worn electronics could communicate. This system

technology, known as PAN (Personal Area Networks) is being developed by IBM scientists at Almaden Research Center in San Jose, California.[56]

The PAN concept originated at MIT through a thesis project by Thomas Zimmerman. Zimmerman, currently at IBM, along with other researchers, has developed a PAN prototype roughly the size of a deck of playing cards. This device was demonstrated publicly at the Las Vegas Comdex computer industry trade show in November of 1996. "[The PAN prototype] can transmit a pre-programmed electronic business card between two people, via a simple handshake. What's more, the prototype allows data to be transmitted from sender to receiver through up to four touching bodies."[57] Conceivably, the same network could be used to exchange data between separate devices worn on different parts of one's body.

PAN works by transmitting a tiny electrical current through the body. This is very effective, as the body's natural salinity makes it an excellent conductor of electric current. Although the thought of sending data by electrical signals through the body sounds frightening, it is completely safe. Zimmerman interestingly states that "The current used is one-billionth of an amp (one nanoamp), which is lower than the natural currents already in the body. In fact, the electrical field created by running a comb through hair is more than 1,000

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[56] "Personal Area Networks," [WWW page]; available from http://www.research.ibm.com/research/pan.html; accessed 28 June 1997.
[57] Ibid.

times greater than that being used by PAN technology."[58] The current prototype transmits at a rate equivalent to a 2400-baud modem, however, theoretically, this method could transmit data at a rate of 4,000,000 bits per second.

PAN may be used in a variety of ways that enable wearable computing and make communication easier and more efficient. Consider these applications of PAN technology as identified by IBM researchers:

> 1. To pass simple data between electronic devices carried by two human beings, such as an electronic business card exchanged during a handshake.
> 2. To exchange information between personal information and communications devices carried by an individual, including cellular phones, pagers, personal digital assistants (PDAs) and smart cards. For example, upon receiving a page, the number could be automatically uploaded to the cellular phone, requiring the user to simply hit the "send" button. This automation increases accuracy and safety especially in driving situations.
> 3. To automate and secure consumer business transactions. Among the many examples: A public phone equipped with PAN sensors would automatically identify the user who would no longer have to input calling card and PINs. This application significantly reduces fraud and makes calling easier and more convenient for users.
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>   By placing RF (radio frequency) sensors on products such as rental videos, stores could essentially eliminate counter lines and expedite rentals and sales. The customer would simply carry the selected videos through a detecting device that would automatically and accurately identify the customer and his selections, and then bill his account accordingly.
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>   Health service workers could more safely and quickly identify patients, their medical histories and unique medicinal needs by simply touching them. This application would be

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[58] "Personal Area Networks," [WWW page]; available from http://www.research.ibm.com/research/pan.html; accessed 28 June 1997.

> particularly helpful in accident situations or where the patient is unable to speak or communicate.[59]

While PAN technology is still in the development stages, it has been proven to work effectively to network wearable electronic devices. Previously these devices required hard wiring that encumbers users. PAN technology has advantages over infrared communications where line of sight is required. This would not be suitable for wearable devices worn on various parts of the body. Similarly, infrared is susceptible to interference where numerous infrared communications take place simultaneously.

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[59] "Personal Area Networks," [WWW page]; available from http://www.research.ibm.com/research/pan.html; Internet; accessed 28 June 1997.

CHAPTER 3

SCENARIO BUILDING

Scenarios

Following the research phase my activities focused on building scenarios. This scenario building exercise was introduced to me while I was an intern at Eastman Kodak Company. The purpose of scenario building is to promote creative thinking so that new ideas can be generated and recorded.

Process

The idea and process of scenario building was presented to me by Mr. Monte Lavine at Eastman Kodak Company in June of 1996. This process is actually a design methodology which is currently being used by a few cutting edge industrial design firms. The goal is to promote and encourage creativity by using fictional characters to describe fictional activities. During this activity the creative mind is allowed to dream and think freely by removing all limitations including physical, technological, behavioral, etc. The end results of these scenarios often compare to fantasy, science fiction or cartoons. This methodology encourages and permits this kind of creative thinking.

The scenario building process begins by a brainstorming session that attempts to identify either a common or particular problem associated with a task or activity. Through a series of illustrations the scenario shows a proposed

solution to the problem. Although the scenarios for this thesis revolve around problems associated with communication, this methodology could apply to any creative problem solving endeavor. The main objective here is to propose a solution to the problem at hand that shows immediate benefits or convenience to a user or user group. The primary objective is to be as creative and uninhibited as possible to build not so obvious scenarios bordering on fantasy. Additionally, the scenarios provide a context in which a future product might exist.

After a preliminary brainstorming session to identify several problems, characters were developed. These characters are fictional people who will appear in cartoon-like illustrations that describe the task or activity. The characters should represent the diverse range of possible end users of a wearable communications device. Finally, the characters and illustrated scenarios should be realistic in the sense that they represent an appropriate solution to the problem.

The last phase of the scenario building exercise is to write a script. Scripting scenarios is very similar to scripting animation or movies. The script first describes the character(s) and their situation. Next, the script proceeds to describe the action or events the character encounters. Finally, the script shows resolution, or how the character resolved his/her problem. Each main event that takes place is described in a key frame. Key framing is a concept used in

traditional animation where an illustrator describes the critical actions or events of an animated story. The same concept is applied here to describe an event in a short series of illustrations. Lastly, each key frame is illustrated using the character(s) to graphically communicate the scenario.

Results

This attempt at scenario building generated three different scenarios with three different sets of characters for each. The objectives for each scenario are the same. Each scenario was required to meet the following minimal criteria:

1. wearability
2. accessibility (convenience and proximity)
3. connectivity

Again the device described in the scenario is ultimately intended to enhance communications.

Scenario I: *Kirk and Sigfried* (see figure 1)

Kirk and Sigfried are 12 year old school kids. They are electronic pen pals of the future. Half way around the world, they communicate by *Teleos*. *Teleos* is a friendly and easy to use communication device worn on their sleeves. In addition to meeting the minimal criteria previously stated, it identifies several key issues:

- provide language translation
- combine text, voice, images
- voice command operation
- display holographic images
- provide image capture
- permit world wide wireless operation
- permit connections to other peripherals

Scenario II: *The Ambrose Family* (see figure 2)

Introducing the Ambrose Family: *Ian*, a 14 year old boy; *Illiana*, his 16 year old sister; *Natalie*, the mother and *Franco*, the father.

The Ambrose family is on a family vacation at Disneyland. Each of them is wearing an *"ethoscope badge"* that lets them keep in contact with each other if they get separated. The *ethoscope* badge addresses the issues of:

- voice command operation
- video messaging
- image capture
- combine text, voice, video images
- small, retractable user display
- projection for group display

Scenario III: *Dr. Tulley* (see figure 3)

Dr. Tulley is a medical doctor who is traveling to make a presentation at a medical school. The scenario introduces *OmniEgo*, a wearable device that allows him to do everything from keeping in touch, to performing virtual surgery. In addition, the following key issues are presented:

- ability to connect to database(s)
- voice command operation
- video conferencing
- holograhic image display
- ability to connect to other peripherals
- world wide wireless operation
- interactive 3D display

Although these are extremely fantasy oriented scenarios, they serve as effective, creative, brainstorming exercises. Again, these scenarios describe ideas that may not be practically served by today's technology; however, the intention is to illustrate concepts that could be a great benefit for communicating in the future.

CHAPTER 4

DESIGN DEVELOPMENT

Immediately following the scenario building exercise, the task was to choose a scenario to further develop. After choosing a scenario and further defining the objectives and key issues to resolve, the process required preparing several concepts to present to the thesis committee. After commentary resulting from this meeting, a final design solution could be chosen, and work on design refinement could begin.

Criteria Selection

The three scenarios, developed in the earlier phase of this process, generated several different and wide ranging ideas for a wearable communications device. Each scenario attempts to meet the minimal criteria of the project while presenting its own unique key issues. The key issues raised by these scenarios then become a second set of criteria that drives the design. These key issues then determine the product features that will ultimately become part of the finished design.

Perhaps the most difficult part of the scenario building exercise is selecting which key issues to use as part of the design. During my previous experience at Kodak, I simply listed all of the key issues from my seven

scenarios, and asked several other industrial designers in the department to prioritize them for me. Then I was to select the key issues with the most votes, and the decision was made. The problem with that approach was that there was little consensus among the group, and the result was that none of the key issues out-ranked the others. As a result, I prioritized the issues myself. Drawing on this experience, by the same process, I selected the key issues. The result is more or less a synthesis, of all three scenarios. The resulting key issues and overall objectives are shown below:

Key Issues	Overall Objectives
• voice command driven	• integrate multiple communications devices
• voice messaging	• allow communication channels of :
• audio/video conferencing	⇒voice
• video monitoring	⇒images
• 3D volumetric display	⇒text
• 3D graphic input environment	• wearability
• virtual simulation	• accessibility
• image capture	• connectivity
• image editing	• develop human-like persona
• two-way worldwide wireless operation	

TABLE 4. KEY ISSUES (DERIVED FROM SCENARIOS) AND OVERALL OBJECTIVES (DERIVED FROM CHAPTER 1)

Concepts

While the overall, primary objectives for this project remained the same since the beginning, synthesizing the key issues from the scenarios helped

further refine the requirements of the project. The next step was to develop several concepts to propose to the thesis committee.

Accommodating these key issues into a comprehensive design required a broad knowledge of computer related technology. All of the areas of previous research on this topic were helpful in this respect. Drawing on this accumulated knowledge, it became obvious that at least five different main components were required. The following is a minimum list of components required by the design:

- Power Supply
- Central Processing Unit (CPU) and Data Storage
- Display
- Input Device
- Image Capture Device

The problem then, is how to arrange these components so that they can be worn on the body while accommodating the features described by the key issues. Three different concepts describing different component configurations were developed.

Concept 1 (see figures 4-6)

This concept combines a central processing unit (CPU), data storage and voice input into one unit called the PAN (Personal Area Network) Transceiver. The PAN Transceiver is worn around the neck as an undergarment, and is

responsible for managing electrical power and data transfer between the other components. A power supply is provided by piezoelectric film that generates electricity when the elbows and knees bend. This may be accomplished either by piezoelectric material inserted into the clothing at these joints or a separate piece of clothing containing piezoelectric film that slips over these joints, perhaps like knee and elbow pads. This concept provides two different types of displays. Both a two-dimensional and a three-dimensional display is incorporated into a wrist mounted unit. This solution allows the option of working in either a two-dimensional or three-dimensional mode. Additionally, user input is accomplished by two different means. The unit operates by voice commands from the user. An image editing stylus serves to edit images as well as to record user input in a graphic environment. Lastly, in order to serve the issue of image capture, a head mounted image capture device or CCD (charge-coupled device) is contained within an eye glasses-type unit.

Concept 2 (see figures 7-9)

Concept 2 also combines the CPU, data storage and voice input components into one unit called the PAN Transceiver. The PAN Transceiver, as in the previous concept, manages electrical power and data transfer between the other components worn on the body. The PAN Transceiver can be considered to be at the heart of the entire system. This unit works by sending tiny electrical signals through the skin, thus it must maintain constant contact with the skin (see Personal Area Network Research, page 49). For this concept,

the design for the PAN Transceiver takes the form of a neckband which holds a broach-like image capture device containing a CCD, and is worn around the neck. A power supply is accommodated by a pair of "power shoes", which are actually shoe insoles that are simply inserted into a regular pair of shoes. Conceptually, every time the user's heel strikes the ground, the impact-absorbent material of the insole converts the kinetic energy into electrical current, which in turn gets transmitted to the PAN Transceiver. This concept proposes a small, flexible display that rolls up much like a scroll. Since the display is expandable, the user can have a large display when necessary to view or edit a large image. Deviating from the prescribed key issues, this design only employs a two-dimensional display. In addition, the wrist mounted design integrates a small hand-held stylus, which allows the user to navigate on the two-dimensional display or edit an image displayed therein. As another method of user input, this design is proposed to be voice command activated. This feature is most intuitive, while allowing hands-free operation. As mentioned earlier, an image capture device is integrated into a round, broach-like object worn around the neck. This device contains optical sensors that follow the movement of the head, which in turn focuses the CCD on whatever the user is watching. The resulting benefit is hands-free image capture, which makes constant video monitoring possible.

Concept 3 (see figures 10-11)

Again, for Concept 3, the solution for a CPU and data storage is integrated into a single PAN Transceiver unit. This time, though, this component is worn about the waist in an undergarment much like underpants or a garter belt. This seems reasonable since this component must maintain skin contact. Electrical power to operate all components is generated by piezoelectric material around the knee joint, much like what was proposed in Concept 1. Excess power that is generated is stored in the shoe soles to be available for consumption when the user is sedentary for long periods of time. This concept shows both a two-dimensional and three-dimensional display. The two-dimensional display is a review display which also allows image editing with a pen-like image editing stylus. Separate from the two-dimensional display, the three-dimensional display projects a three-dimensional image into the air several inches away from the unit. This concept is very much like a holographic display. Admittedly, this is a bit fanciful. However, this is currently accomplished, but at the cost of big, bulky hardware. Here again, two methods of user input are provided by the image editing stylus and voice command. An image capture CCD is closely integrated with the three-dimensional display projector around the wrist. A unique feature here is that the display/image capture unit can rotate around the wrist in order to change from display mode to image capture mode.

These three concepts are the first attempts at trying to resolve the key issues introduced in the scenarios. Additionally, they are intended to meet the overall objectives outlined earlier in this thesis.

Committee Review

The three concepts just described were the first concept/design efforts. At this point, a review from the thesis committee could help provide suggestions, direction and feedback.

Eight 11 x 17 inch boards were prepared to describe the three concepts (see figures 4-11). Presented with the overall objectives and the key issues, these two-dimensional sketches were rough illustrations of the body-worn hardware components. The goal of the meeting was to determine the optimum configuration of the components. In short, how could these components best be worn on the body?

Attending this meeting was the complete thesis committee, as well as a special guest, Monte Lavine, who was my advisor during my internship at the Eastman Kodak Company. During the presentation, it became quite obvious that a comprehensive solution was still far off. The three concepts did not fully address all of the key issues. Perhaps the concepts were too similar or failed to completely explore all the possible hardware configurations. This became a

concern of the committee and myself. This meeting failed to resolve to my objective. However, some issues were discussed at length, which provided new directions.

Two of the main concerns raised during the meeting were the issues of image capture and display devices. The committee was intrigued with the image capture device presented in Concept 2, where the image capture device was always looking where the user looked. As for concerns regarding a display, the committee wondered why I had not included a heads-up display as part of the solution. Perhaps it would make sense to integrate the display and image capture device in a heads-up display. A solution similar to this was explored in the "wearable electronics" project at Kodak the previous summer. Perhaps this idea should be explored a little more. In addition, the necessity of having a three-dimensional, volumetric display was questioned.

The committee was aware that my desire was to determine the ultimate configuration for all of the hardware components. This was not possible during this meeting, so an alternative was proposed. One suggestion was to redesign and mock-up all three concepts and conduct user testing to determine the ultimate configuration. Time would not permit this. Since consensus on one concept was not possible, and all three concepts showed merit in at least one aspect, my conclusion was to combine those meritorious aspects into one, comprehensive solution.

CHAPTER 5

DESIGN REFINEMENT

Following this thesis committee meeting, my task was essentially to combine the positive aspects of the three scenarios into one comprehensive solution. This was the result of not being able to simply choose one concept in the meeting. The challenge was to choose a location and method for a power supply, CPU and data storage, display, input device and an image capture device. The challenge was on to determine the ultimate configuration for these components.

Within a few weeks, the solution for the overall component configuration was determined. Briefly, all components were accommodated by four separate parts. Four major components combine to complete the overall communications system (see figure 12). The components are:

- Head Set
- Voice Sensor
- Wrist Set
- Power Shoes

Head Set (see figure 13)

A head set and wrist set are perhaps the two major components in the system. The head set contains a heads-up display, a mount for a removable image capture module and a tiny ear insert to provide audio input to the user. A heads-up type display was discussed in the thesis committee meeting. One of the benefits of this solution is that the display can be located close to the user's eye so that it provides a hands-free display. The user can simply see the display by looking forward as if he/she were looking through a pair of glasses.

This head set is best described to be like a pair of conventional, mini head phones. It is placed over the top of the head, and has two end pieces similar to the tiny speakers of the head phones. The head band is proposed to be made of a flexible, spring-like material that provides a gentle, compressive fit on the user's head. Instead of having a speaker on each end of the head band, this head set design has a circular shaped form on each end of the head band to distribute the load from the spring of the head band. These circular shaped forms also provide needed space to house electrical components necessary for this device to operate.

On the user's head, a flexible display arm holds a transparent display just out in front of the user's right eye. This display arm has the ability to rotate up and down, either away from the user's eye or directly in front of the eye, depending on the user's need. Additionally, this display arm is flexible along

part of its length so that the display can be adjusted laterally, side to side, horizontally in front of the user's eye. This display arm is also designed to mount a removable image capture module. Towards the end of the arm and several centimeters behind the display, the display arm makes a small "S" curve so that the image capture module can snap into the display arm. This is facilitated by a positive-negative relationship between the display arm and the image capture module. The result is a ball and socket-type snap-fit that positions the image capture module so that it is always looking forward. This head set unit is designed to accommodate people with glasses. The display is held in place forward of the eye glass lenses, and the head band is carefully designed not to conflict with eye glasses.

Part of the advantage of a head set-type design is the proximity to the eyes and ears. It includes audio signals as a rich method of communication, hence the necessity to include a method of audio input and output. For audio output, this head set design further takes advantage of this proximal relationship to the head, by locating a small ear insert that delivers low volume audio signals into the user's ear canal. This tiny component is located on the end of a small, flexible wire coming off the end of the right circular end piece of the head band. This strategic location places the ear insert as close as possible to the user's ear. Like the display arm, this piece is flexible so that the user is able to fine-tune the adjustment to his/her preference.

One of the great advantages this communication device provides is the ability to communicate with images. The image capture module is designed to be removable in order to provide flexibility for the user. The user can mount the image capture module in one of two locations: either on the head set or wrist set. When mounted in the head set, optical sensors located in the transparent display work to aim the image capture module at whatever the user is watching. This facilitates the automatic eye tracking feature of the CCD, and provides hands-free operation. Two optical sensors, located on the back side of the display, focus on the pupil. As the pupil moves, the position of the CCD in the image capture module adjusts so both the eye and image capture module are looking in the same direction. The head of the image capture module is designed as a transparent dome so that the CCD can rotate inside of it as it automatically adjusts according to the position of the user's eye. Electrical contacts on the main body of the image capture module allow data to flow between this head band unit and the other components. The electrical conduit is completed when the image capture module snaps into position on the display arm.

An alternative location for the image capture module is on the wrist set. An advantage to locating the image capture module in the wrist set is a greater range of image capture methods. When located in the wrist set, one can capture images from a perspective other than that from one's own eye. This location, in effect, allows the user to see around corners, over tall objects, etc.

The user simply points his/her hand in the direction of the subject to capture the image. Feedback from the image capture module is presented in the heads-up display as a sort of viewfinder. With voice commands, the user can "fine-tune" the image in the viewfinder. Ideally, the user has the ability to frame the shot, zoom, focus and capture the image presented on the heads-up display by quietly speaking the proper voice commands to the unit.

The small, transparent display is accommodated on the end of the display arm. It is designed to be viewed by the right eye, since more of the population is right eye dominant than left. Note that this decision is based on the realization that this design is for illustrative purposes, and nothing prevents it from being designed for the left eye dominant. This display is provided to allow graphic interface. As such, it provides the means of user interface. Although the display is only the size of an average eye glass lens, clever use of optics allows the user to focus on tiny images displayed, while making them appear to be larger. The user interface viewed through this display actually appears to be off in the distance, in front of the user instead of just a few inches from the eye. Real, working displays such as this are in use today. For example, displays measuring 0.7 inches wide can display images that are perceived as an 80 inch TV screen when viewed from a distance of 11 feet are

commercially available for industrial and entertainment uses.[60] A special feature also provided with this display is the ability to view the virtual world over the real world. Images appear on a transparent background through the display so that the view is not totally obscured. When the entire unit is inactive, the display is transparent. Whenever communication activity occurs, or when the user needs to activate the unit, the display becomes active and presents the user interface. This idea is similar to the Macintosh operating system when it enters sleep mode, except that you can see through the monitor as if it were only a piece of glass.

Voice Sensor (see figure 13)

Primary input and output of this communication system is achieved through voice. As discussed earlier, audio is delivered to the user via a tiny, audio ear insert. Voice input from the user to the unit is easily accomplished. To accommodate voice input, a voice sensor is located at the front of the neck, around the base. The hardware consists of a tiny disk, approximately two centimeters in diameter, that picks up vibrations produced by the vocal cords. This piece can either be adhered to the skin with light adhesive or clipped onto a garment so that skin contact can constantly be maintained. When the user quietly makes a verbal command, the voice sensor reads the tiny vibrations of the vocal cords, interprets the command and prompts the system to respond or

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[60] Fran Granville, "Headset Provides Realistic 3-D Images," EDN, 22 December 1994.12.

react accordingly. The voice signal from the user does not have to be completely audible, since the voice sensor responds to vocal cord vibration, not airborne sound. For even more convenience, the user may customize his/her own commands as a sort of shorthand or shortcut. This way, voice input is further simplified. Interaction between this device and the user is intuitive and simple. Voice capability provides a simple, logical communication link between the user and this device. One may simply speak to his/her communication unit and expect it to respond as if it were another human being.

Wrist Set (see figure 14)

The second major hardware component of this system is the wrist set. While this wrist set may easily be mistaken for a wrist watch because of its form, the similarities stop there.

Perhaps the most important component of the whole communication system is located on the wrist set. The PAN (Personal Area Network) Transceiver takes a circular form and is integrated into the wrist set. As indicated in my initial concepts, the PAN Transceiver is responsible for managing all data and electrical input/output between all system components. The PAN Transceiver receives electrical energy from a power source and distributes it to the head set and voice sensor units so that they can operate. Similarly, it manages the input and output of digital data between these same components. Essentially, the result of this system is a computer with all its parts

distributed to two main components worn on the body. Conveniently, all of the data information and electrical current is passed through the body. The body provides the medium through which the system communicates. Thomas Zimmerman, an expert on this subject at IBM, explains, the body's natural salinity makes an excellent conductor and it is completely safe. Zimmerman and researchers at IBM have prototyped units using this PAN concept. Their work demonstrates that this is completely possible and safe. In fact, their prototype uses lower current than that naturally occurring in the body.[61] Since the body is the medium through which these components communicate, they must all maintain constant contact with the user's skin.

For this final design, the main central processing unit (CPU) and data storage unit are also integrated into the wrist set. The large, circular form containing the PAN Transceiver also provides an area to house tiny microprocessor chips. These microprocessors, like today's computers, perform millions of mathematical functions per second. In this design, there are two circular forms. One large, circular form contains both the PAN Transceiver and CPU, while another small, circular form contains yet another CPU as well as a data storage unit. These circular forms are designed so that they conform to the curvature of the wrist. The relationship of these forms is such that they provide a negative space that traps the image capture module. The image capture

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[61] "Personal Area Networks," [WWW page]; available from http://www.research.ibm.com/research/pan.html; Internet; accessed 28 June 1997.

module simply snaps into place. As for the data storage unit, its area is certainly much smaller than many currently produced units. However, recent technologies such as *Flash Ram* or *EPROM* can store significant amounts of re-rewritable data on an area the size of a credit card or smaller.[62] As these technologies continue to evolve, the issue regarding data storage will become obsolete. Data storage accommodated in such small areas will be possible in the near future.

The two other major components contained in the wrist set are to accommodate user input. These components, a 3D navigation wand and touch pad, allow input in a graphical user interface (GUI) that is viewed in the heads-up display. Recall from the previous section, a voice sensor allows user input by way of voice. The combination of these methods of input allows the user the greatest amount of flexibility to interact with this device. Each input device is provided to be most suitable for the particular function or application.

The 3D navigation wand is provided to accommodate user input in a three-dimensional mode. Recall from the key issues, virtual simulation was identified as a desirable function. This wand is a flexible, rubber-like shaft that conforms to the wrist band on the wrist set. The tip of the wand fits into a small hole on one side of the finger touch pad. On the opposite end of the wand, a

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[62] "Personal Area Networks," [WWW page]; available from http://www.research.ibm.com/research/pan.html; Internet; accessed 28 June 1997.

small ball snap-fits into the side of the small circular form containing the CPU. Being flexible, it can be removed from the wrist set, straightened and then secured in place by snapping it back on the wrist set.

To use the wand, the user takes the wand out of its secured position and holds it in front of the heads-up display. By giving the proper voice command, the user enters a three-dimensional user interface. The navigation wand simply allows the user to give input in three dimensions or navigate a virtual space in the third dimension. This method of input is similar to many three-dimensional computer aided design (CAD) programs. By allowing the user to input in the third dimension, virtual simulation is possible. This feature is a part of the key issues this design seeks to accommodate.

The other method of user input in a graphic environment is afforded by a finger touch pad. The finger touch pad is a cylindrical form that looks like the face of a watch. Instead of being flat or convex, the surface of the finger touch pad is slightly concave to provide a depression for finger tips. Like the 3D navigation wand, the touch pad is used to navigate the user interface. Since not all tasks require user input in three dimensions, the touch pad makes more efficient navigation in a two-dimensional mode. For this reason it only works for two-dimensional navigation. Examples of touch pads like this are commonly found for both laptop and desktop computers. Essentially, touch pads are substitutions for mice. As the finger moves across the touch pad surface, a

pointer or cursor follows on the heads-up display. The user makes a selection by simply pressing one of the three small buttons located on the perimeter of the finger touch pad, or by giving a voice command.

Power Supply (see figure 12)

The last component to complete this system is a power supply. A sustainable power supply is critical for supporting a mobile design of this nature. Traditional battery power alone is very limited. Batteries wear down after a few hours in traditional laptop computers. The solution for this final design borrows from concept 2. "Power Shoes" generate electric energy as the user walks. Given that people wear shoes most of the time, a reasonable solution would be to design a shoe insole that generates electrical energy. Conceptually, this insole is made of an impact absorbent material and has piezoelectric material embedded within it. As the user's foot strikes the ground, the piezoelectric material converts mechanical energy to electrical energy.

This concept has been studied in depth by Thad Starner, a researcher at Massachusetts Institute of Technology (MIT). Writing for *IBM Systems Journal*, Starner concludes with quantifiable results that this method is most suitable for powering a wearable computer.[63] Happily, these insole inserts can be easily manufactured and replace insoles already in place in most shoes. The insole could be designed so that excessive energy is stored (like batteries) in the

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[63] Starner, "Human-powered wearable computing," *IBM Systems Journal*, nos. 3&4 (1996): 624.

material itself. This would provide power to the unit when the user is inactive for long periods of time.

The four components just described in this chapter make up the final design for the scope of this project. The design seeks to satisfy both the overall objectives and the key issues earlier stated. For a comprehensive description of how this design meets these objectives, a final scenario was illustrated (see figures 15-22). In addition, to more clearly visualize the finished design, an appearance model was made. This model, which includes the four components just described, was made of ABS plastic, then painted and finished to resemble the proposed material. For presentation, the model is displayed with the aid of a mannequin (see figures 12-14).

Scenarios Revisited

At this point in the project, a new scenario needed to be developed. The original three scenarios were revisited. This time a more complete scenario showing the communications device in use, performing specific tasks, would best describe the possibilities of this futuristic design. Here again, the method was basically the same as before.

The original Dr. Tulley scenario most closely illustrates the functions of this design. A new scenario was developed, using the original as a starting point. This time the scenario features a female character acting as Dr. Tulley.

Fifteen frames describe Dr. Tulley and her wearable communications device named Tivia.

The name Tivia is actually an anacronym for text, image, voice, interactive agent. Remember, Tivia allows communications through these channels. Naming this device Tivia is also significant for reasons described in Chapter One. Unfortunately, we are predisposed to think of inanimate things as objects, devices or machines. Tivia's functions are actually artificial intelligence built by sophisticated hardware and software. Tivia performs tasks originally performed by humans; by a secretary, administrative assistant or done personally. Therefore, it is reasonable to use Tivia, the personification of a machine, as a metaphor. This is similar to HAL, the approach Arthur Clarke used in *2001; A Space Odyssey* and later by Apple Computer in their Macintosh operating system. Tivia's personality ideally prevails in all aspects of interaction via the graphic user interface and voice interaction. Secondly, Tivia and the user primarily interact through voice communication, just like one might ask a colleague or secretary for assistance. Tivia is always on call to act as an intelligent agent who manages information and acts as a communications aide. Finally, one of the primary objectives for this project was to develop a human-like persona. With this in mind, Tivia was conceived.

Originally, the final presentation of the scenarios was to be in the form of an interactive multimedia presentation, complete with images, text and sound.

This seemed appropriate for the nature of the project. Due to limitations of time and some technical difficulties related to sound, the multimedia presentation consisted of only text and images. For the thesis show in the Bevier Gallery, a computer was set up with a web browser so that curious people could navigate to see all of the scenarios as well as the objectives of the project.

CHAPTER 6

CONCLUSION

The ways in which people communicate in the next will differ profoundly from current means. Our global community, always on the go, is just beginning to address the complexities of communication through many different information systems. Today, our environment is cluttered with many different pieces of hardware that are designed to help us communicate. Cellular phones, pagers, laptop computers, fax machines, etc. are commonplace. Their primary purposes are to allow communication, yet they can rarely "talk" to one another because they communicate through different media. Incompatibility of information systems is a continuing problem. Why can't we have the ultimate combination where one single device or piece of hardware integrates all of our current communication equipment? Better yet, imagine a communication device so small and compact that is worn on the body and can allow one to communicate with sound, images and text. Our future communication demands such a powerful tool. The human intelligence, hardware and infrastructure already exist today to realize part of this fantasy. Like the ubiquitous presence of pagers and cellular phones today, a multitude of powerful, intelligent communication implements are very likely to be with us wherever we go; to help us communicate effortlessly while utilizing all of these rich communication channels.

These scenarios presented herein, although fanciful, can take place. First, however, several major breakthroughs in technology will have to happen. One of the obvious issues to resolve is the power supply issue. However convincing, the human-powered computing theory is, real applications utilizing these concepts will have to take place. Secondly, wireless infrastructures will have to be built up to accommodate high bandwidth associated with data transmissions. Parallel to these developments, processors and data storage technologies will continue to improve in speed and quality. Soon, all of these technologies can be married together to deliver the ultimate wearable communication device.

Although much needs to happen before these scenarios are a reality, the current momentum in this trend lends incredible optimism. Research and technology in many of the areas presented here continue to evolve. Massachusetts Institute of Technology (MIT) continues to be the leader in "bleeding-edge," wearable computing projects. At the same time, other key people within MIT's Media Lab are developing "smart agent" and "augmented memory" software that makes managing information easier. These efforts are on the right track to make these dreams a reality. Running parallel to academic research, many companies in the communication and computer industries are trying to corner the market that is focused on mobile communications. The computer industry is producing a class of small, portable "Palm Computers" that

are an evolution of laptops. Perhaps the next evolution will be something like this wearable communication device. *Look onward to the digital future!*

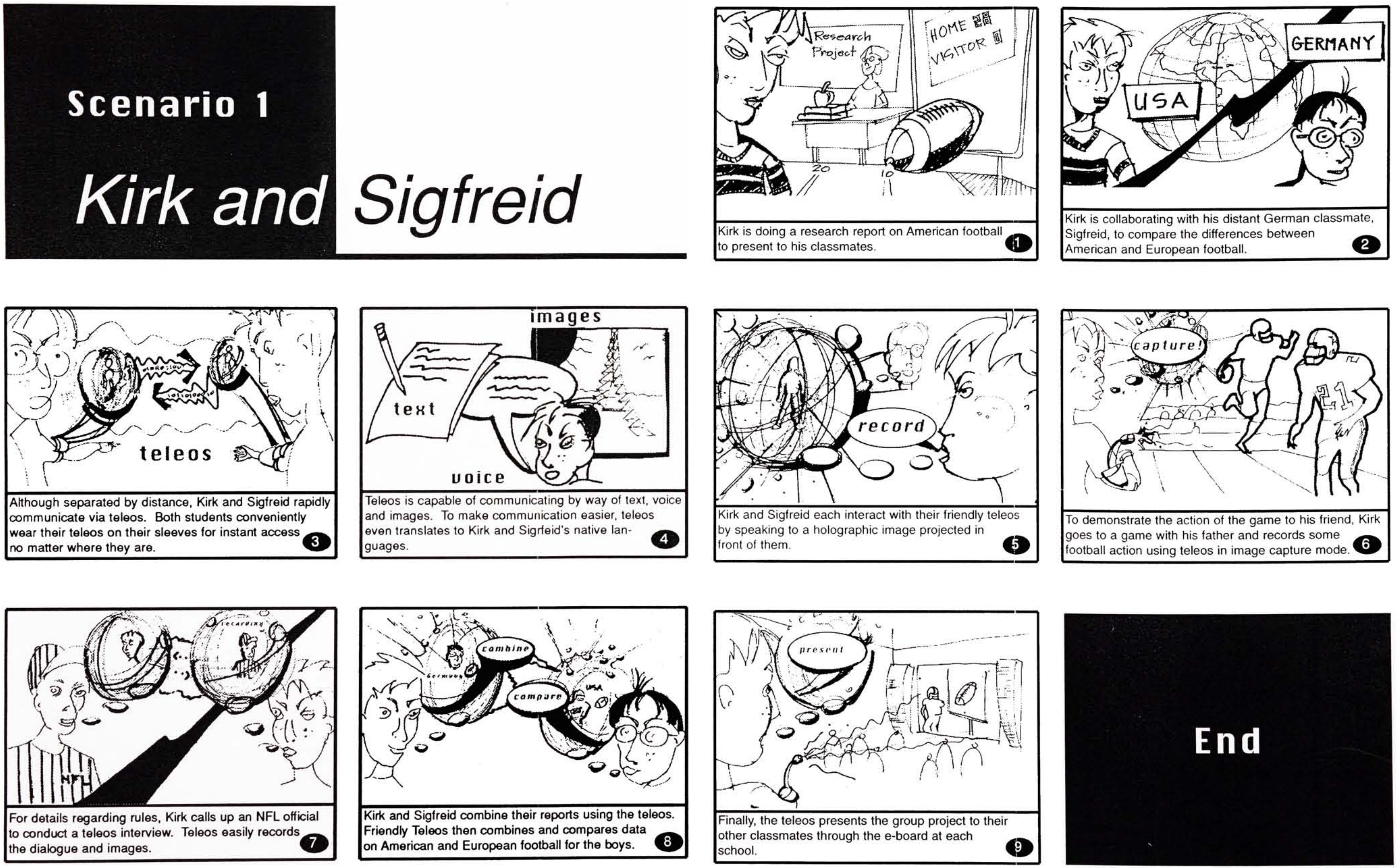


FIGURE 1. KIRK AND SIGFRIED SCENARIO

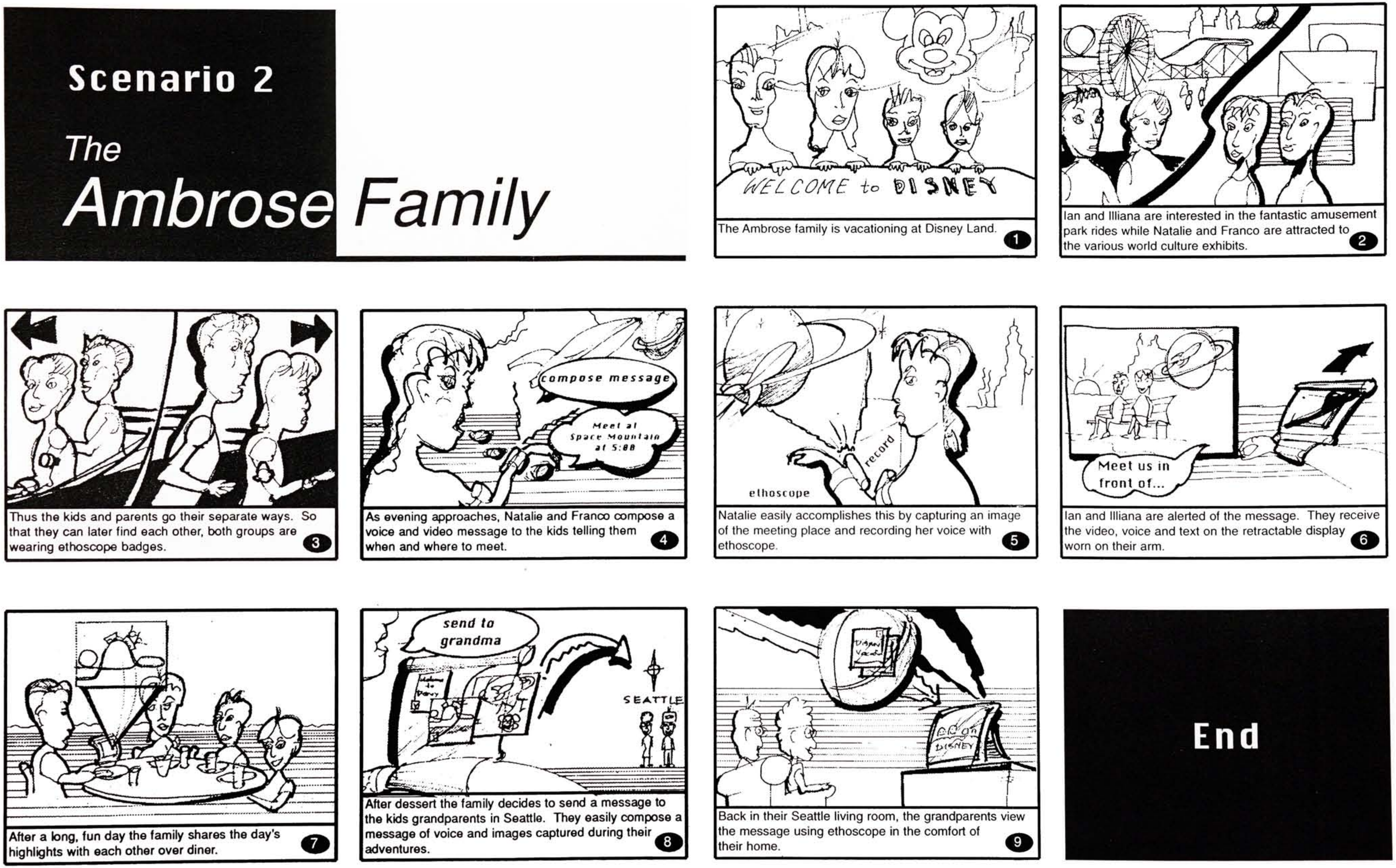


FIGURE 2. THE AMBROSE FAMILY SCENARIO

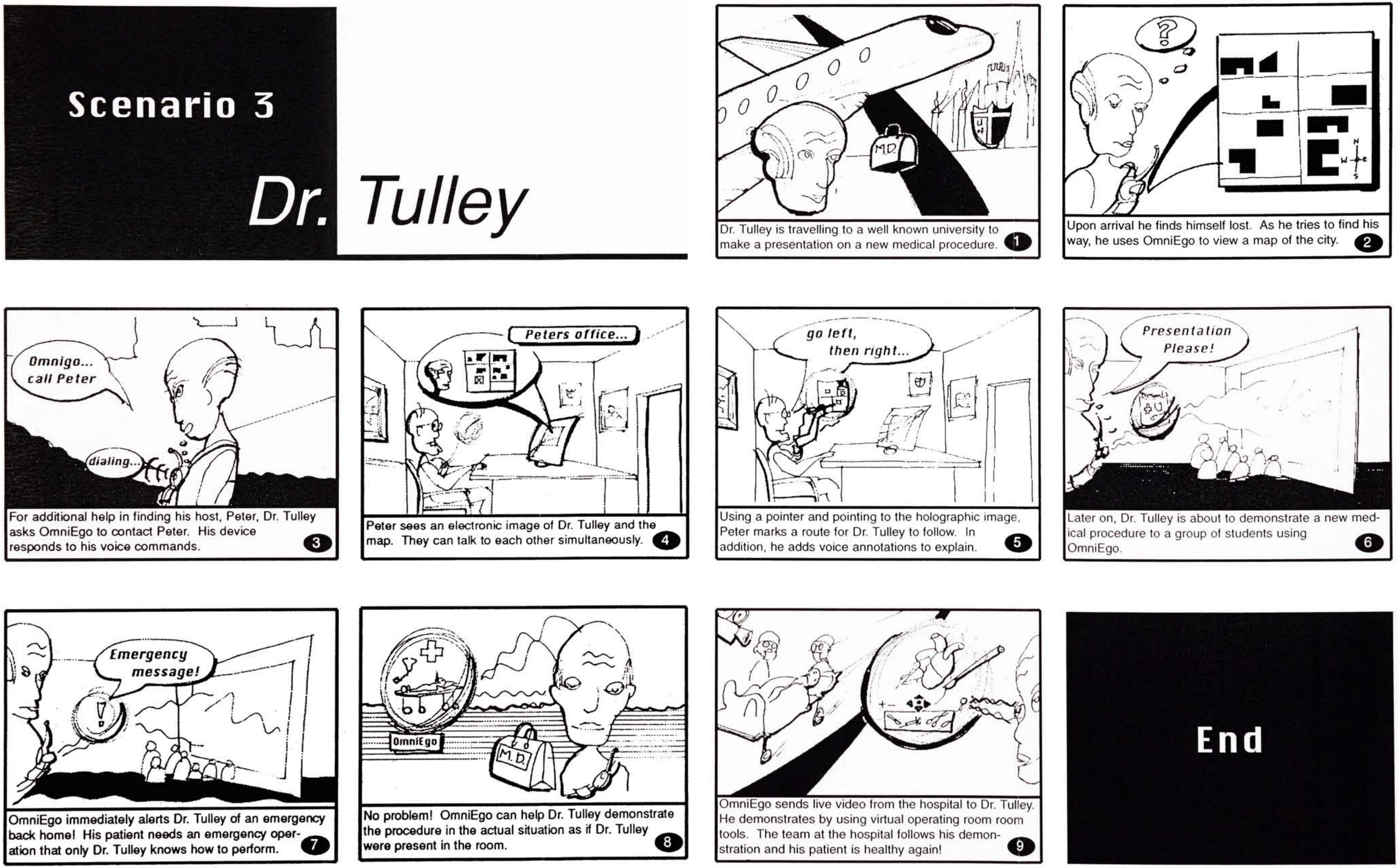


FIGURE 3. DR. TULLEY SCENARIO

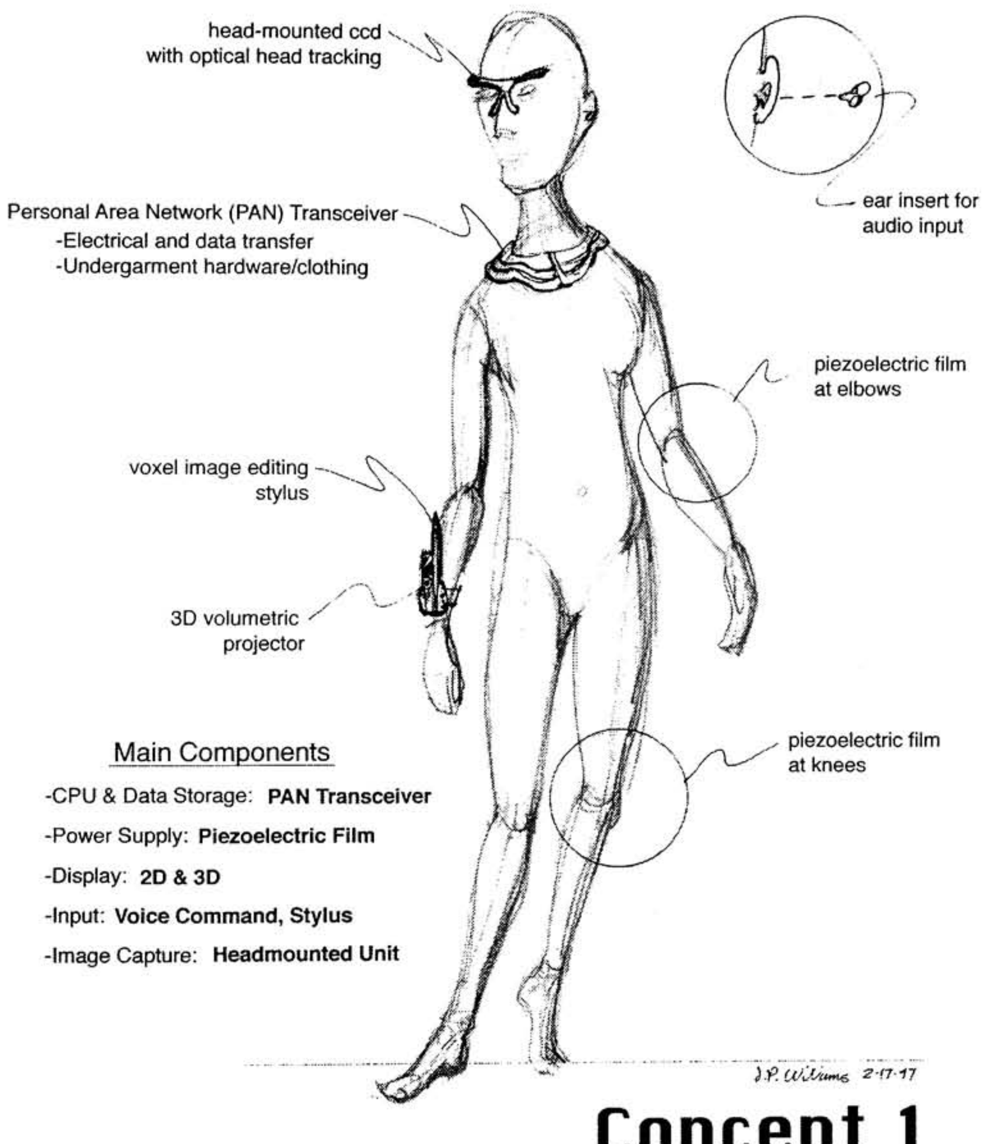


FIGURE 4. CONCEPT 1: COMPONENT CONFIGURATION

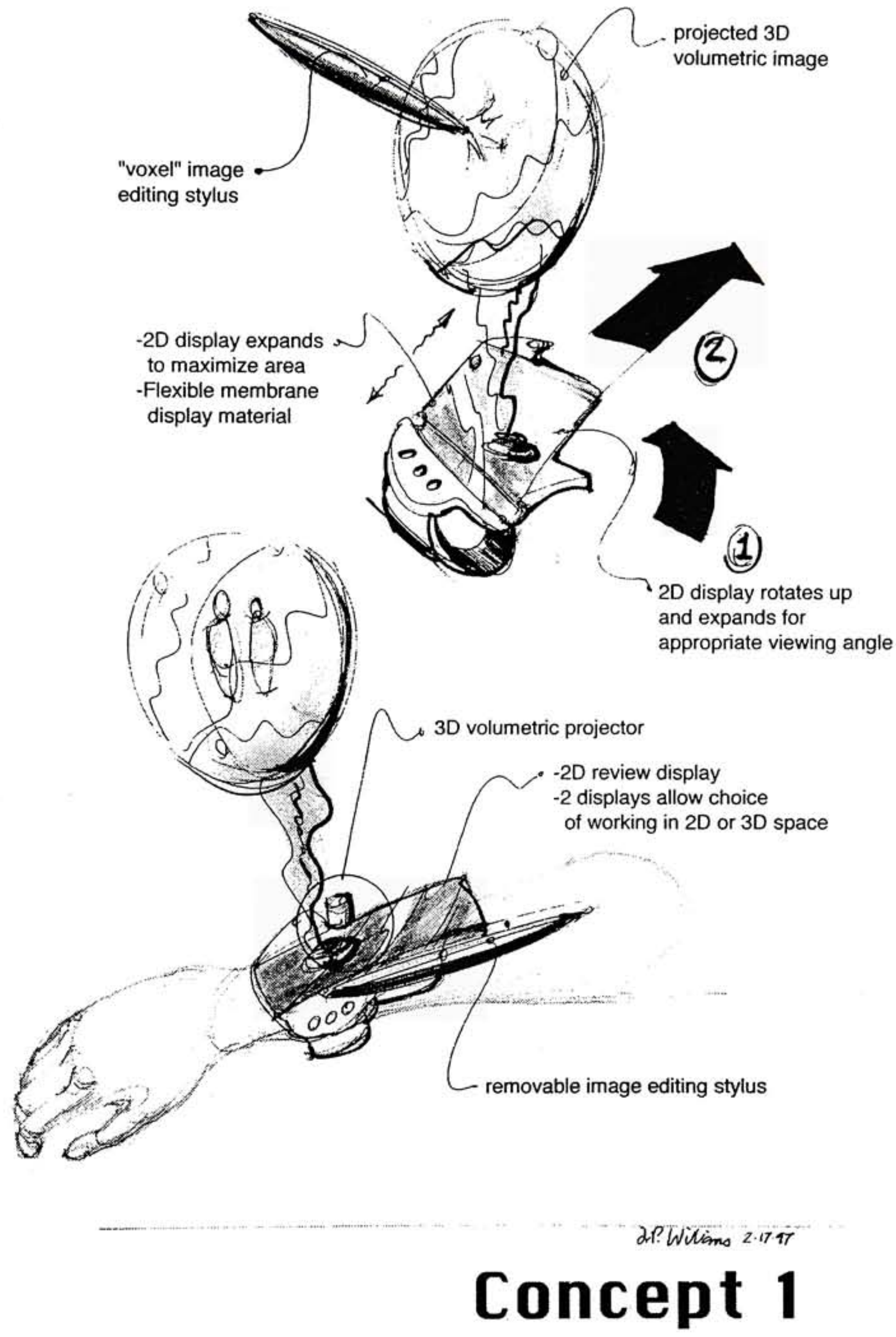
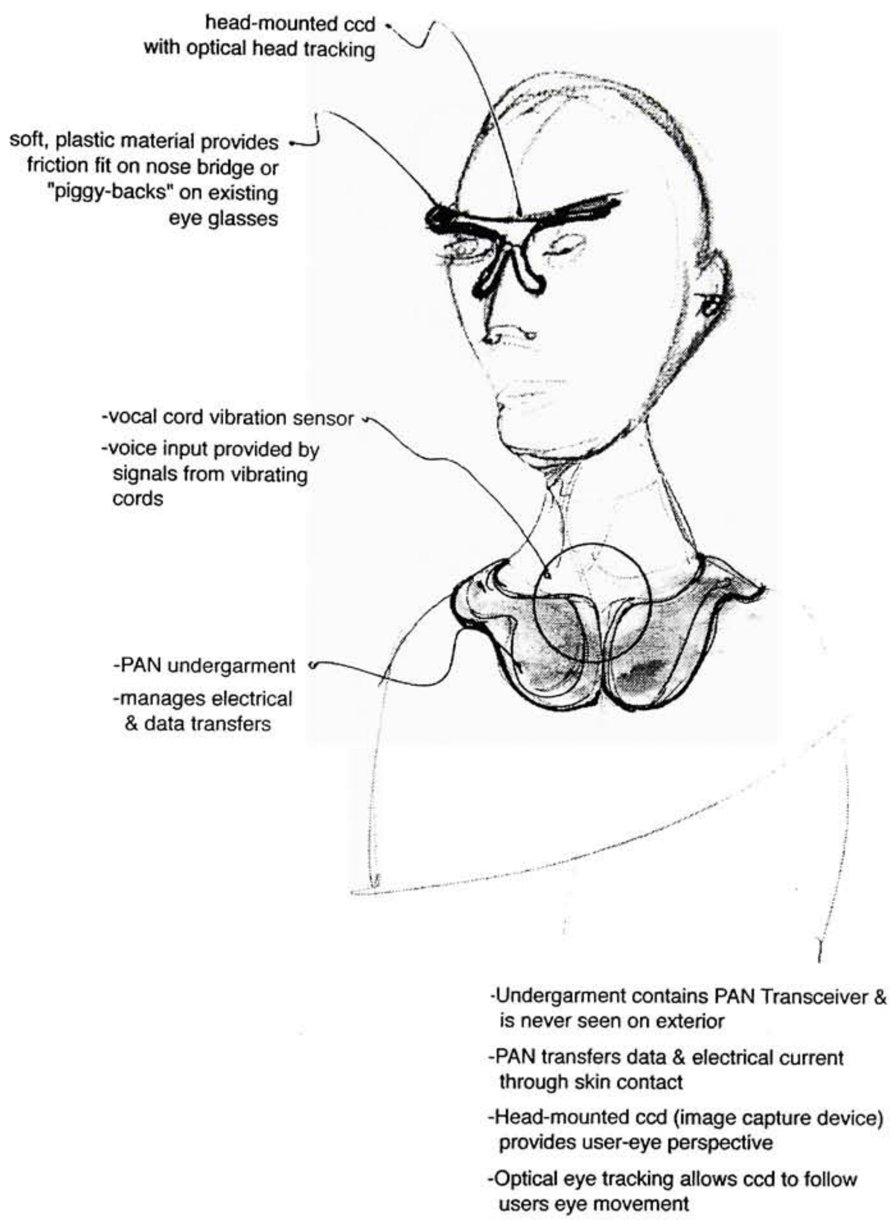


FIGURE 5. CONCEPT 1: DISPLAY & IMAGE EDITING STYLUS



J.P. Wilkins 2.17.97

Concept 1

FIGURE 6. CONCEPT 1: PAN TRANSCEIVER, VOICE INPUT & IMAGE CAPTURE DEVICE

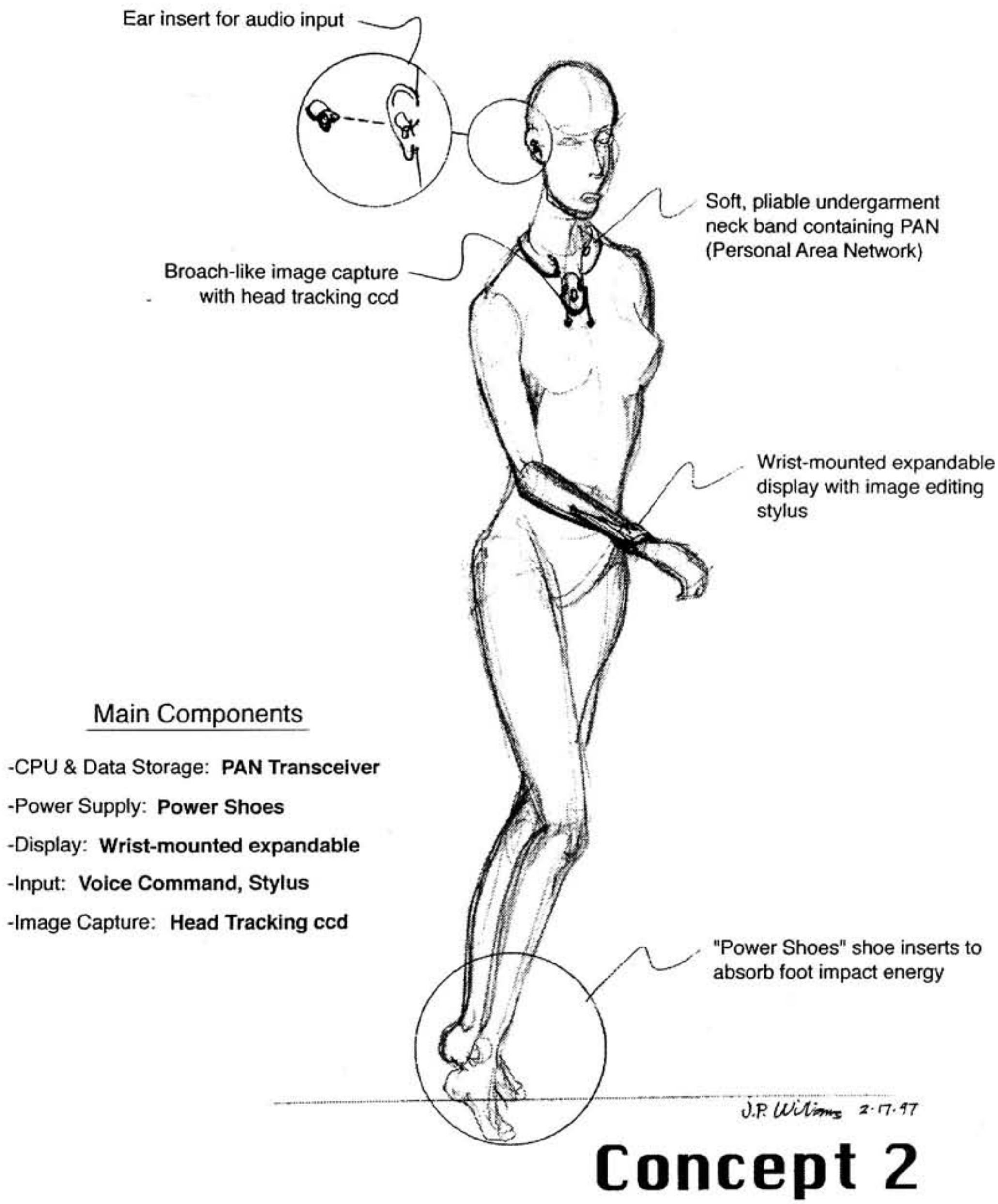


FIGURE 7. CONCEPT 2: COMPONENT CONFIGURATION

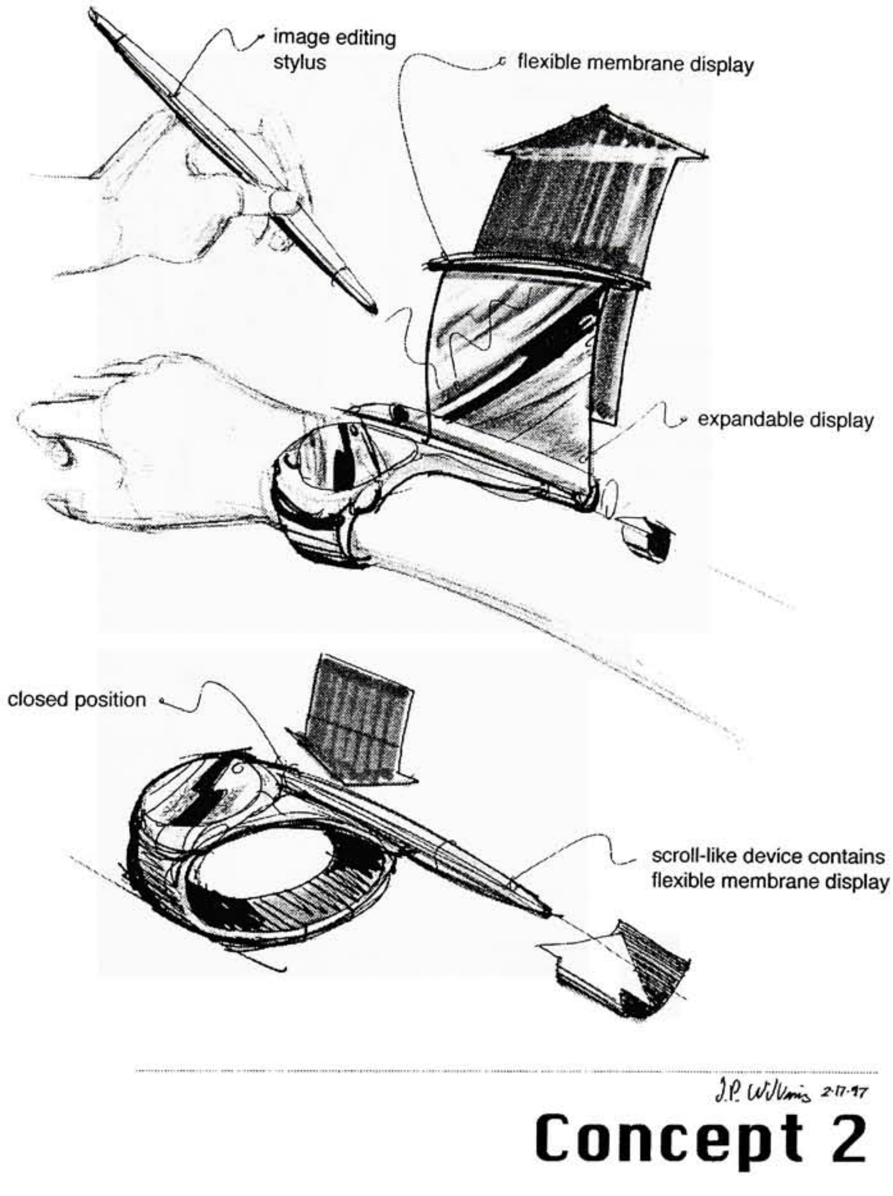
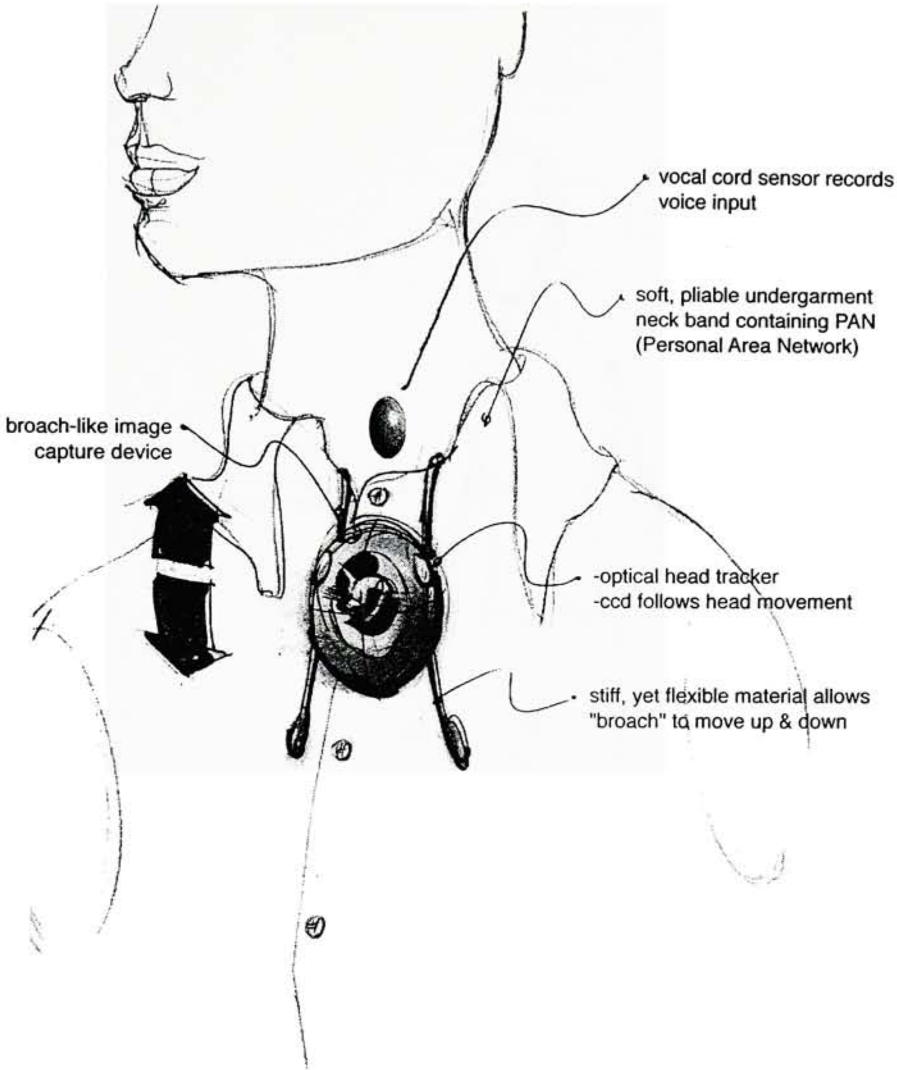


FIGURE 8. CONCEPT 2: DISPLAY & IMAGE EDITING STYLUS



-exterior broach-like hardware for image capture

-undergarment neckband makes skin contact to allow PAN to communicate with other components on the person

-hands-free head tracking image capture

Concept 2

FIGURE 9. CONCEPT 2: VOICE INPUT & IMAGE CAPTURE DEVICE

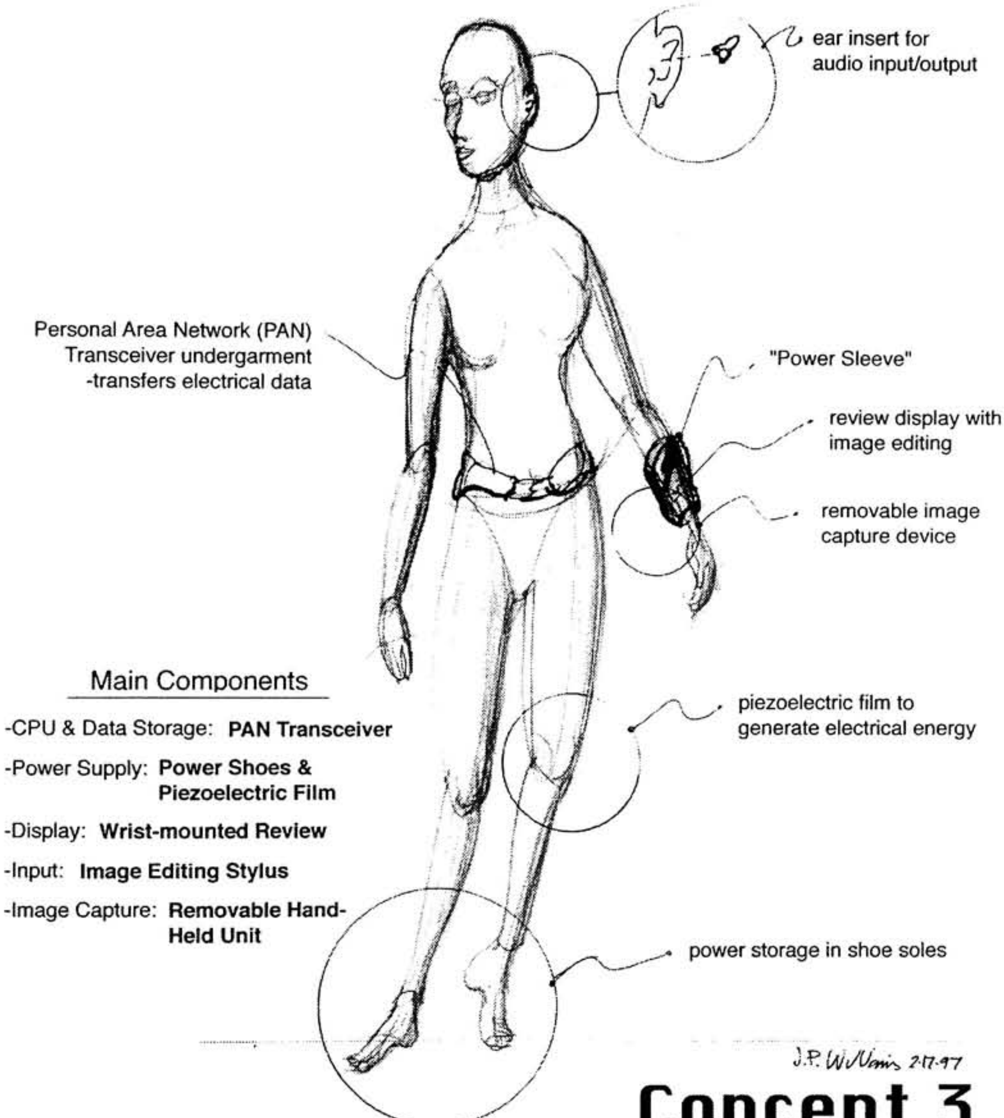


FIGURE 10. CONCEPT 3: COMPONENT CONFIGURATION

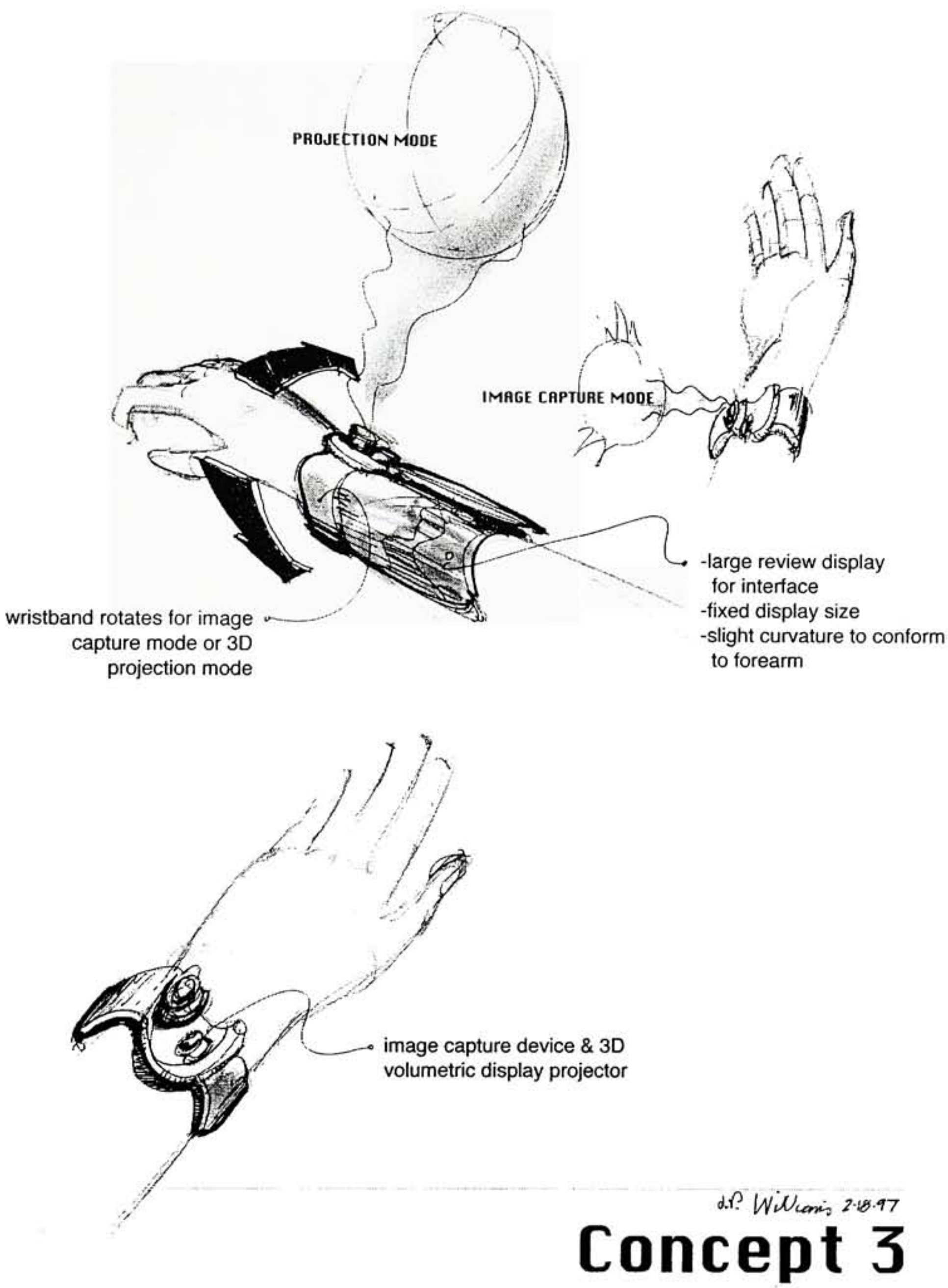


FIGURE 11. CONCEPT 3: 2D & 3D DISPLAY & IMAGE CAPTURE DEVICE

Components

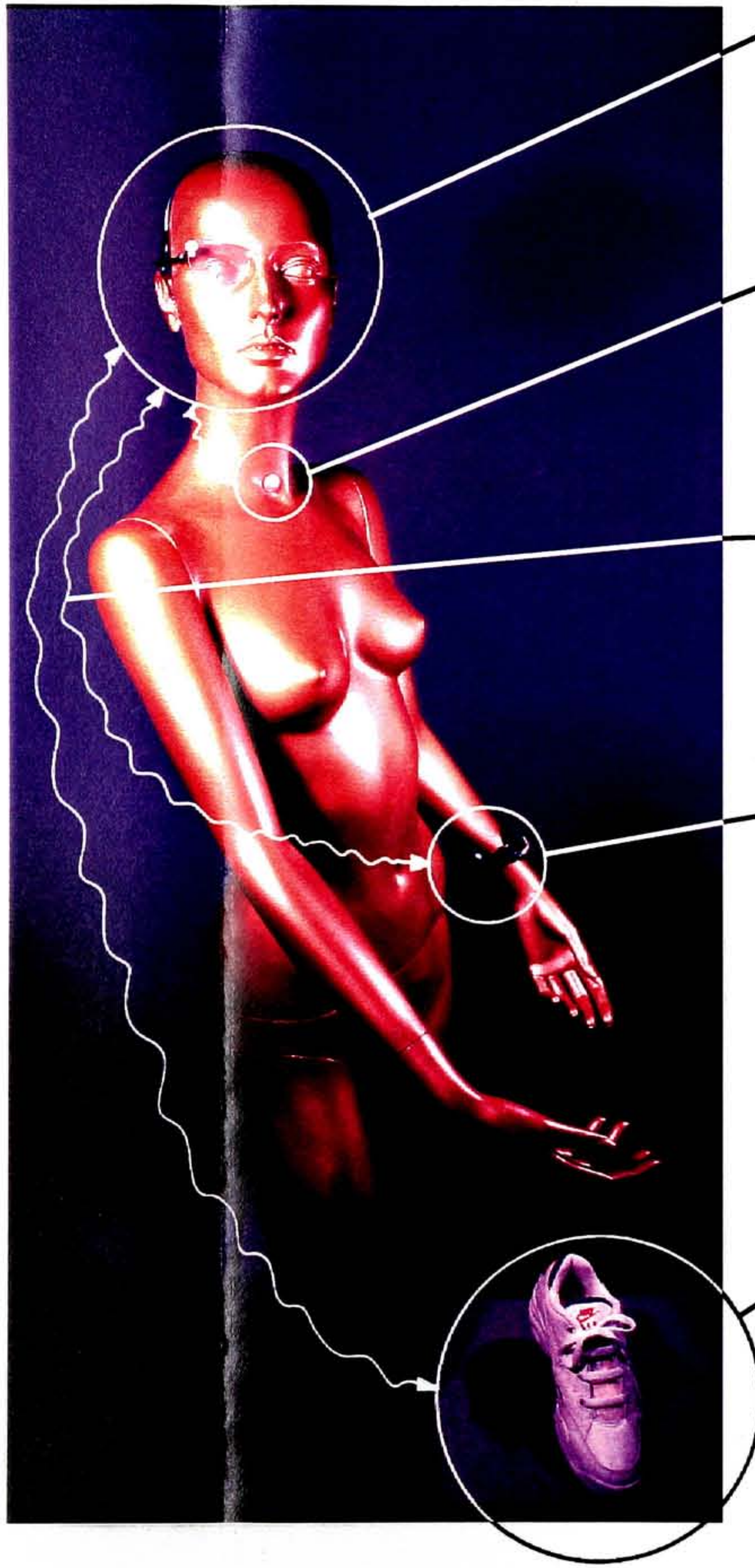


FIGURE 12. COMPONENTS

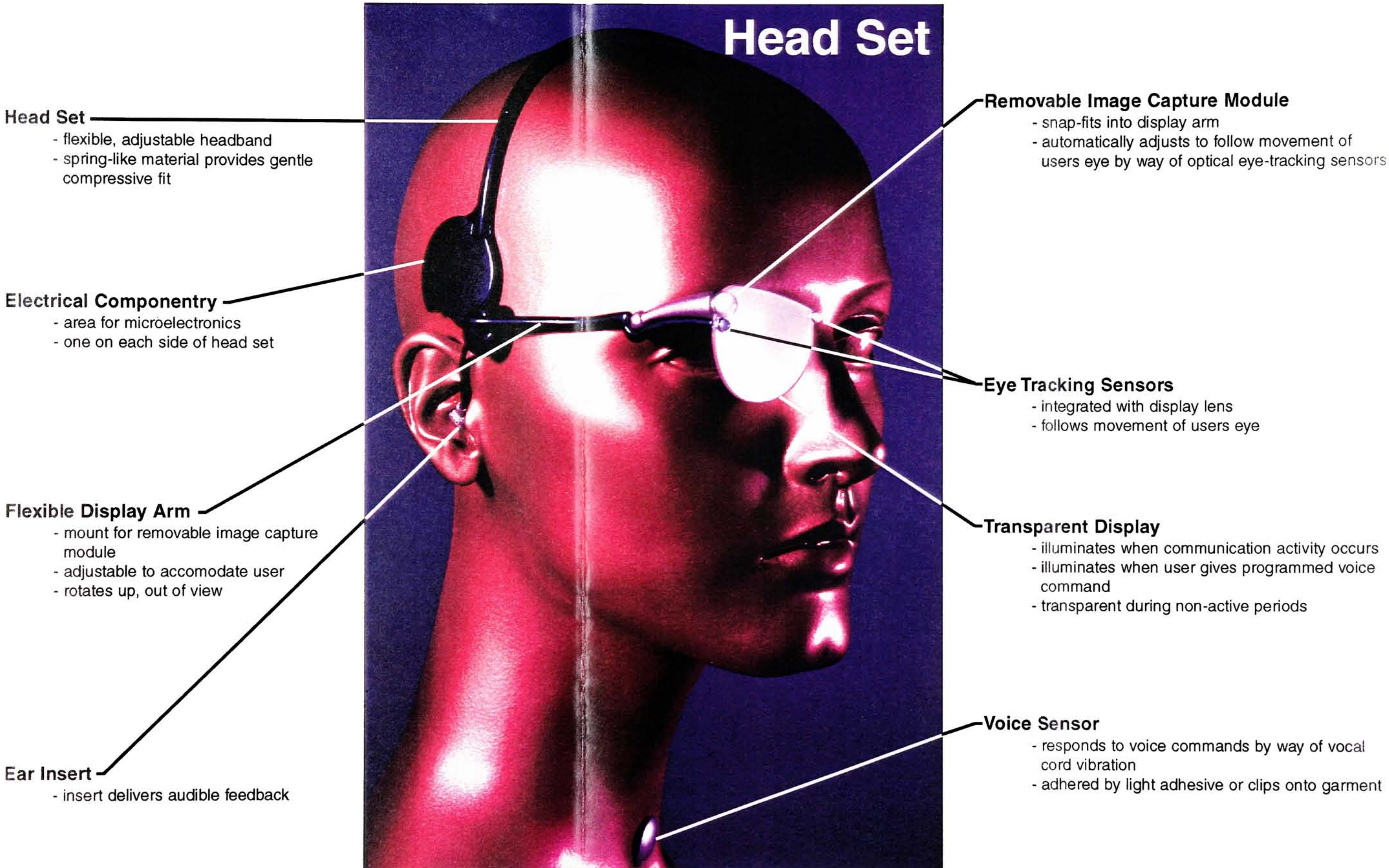


FIGURE 13. HEAD SET

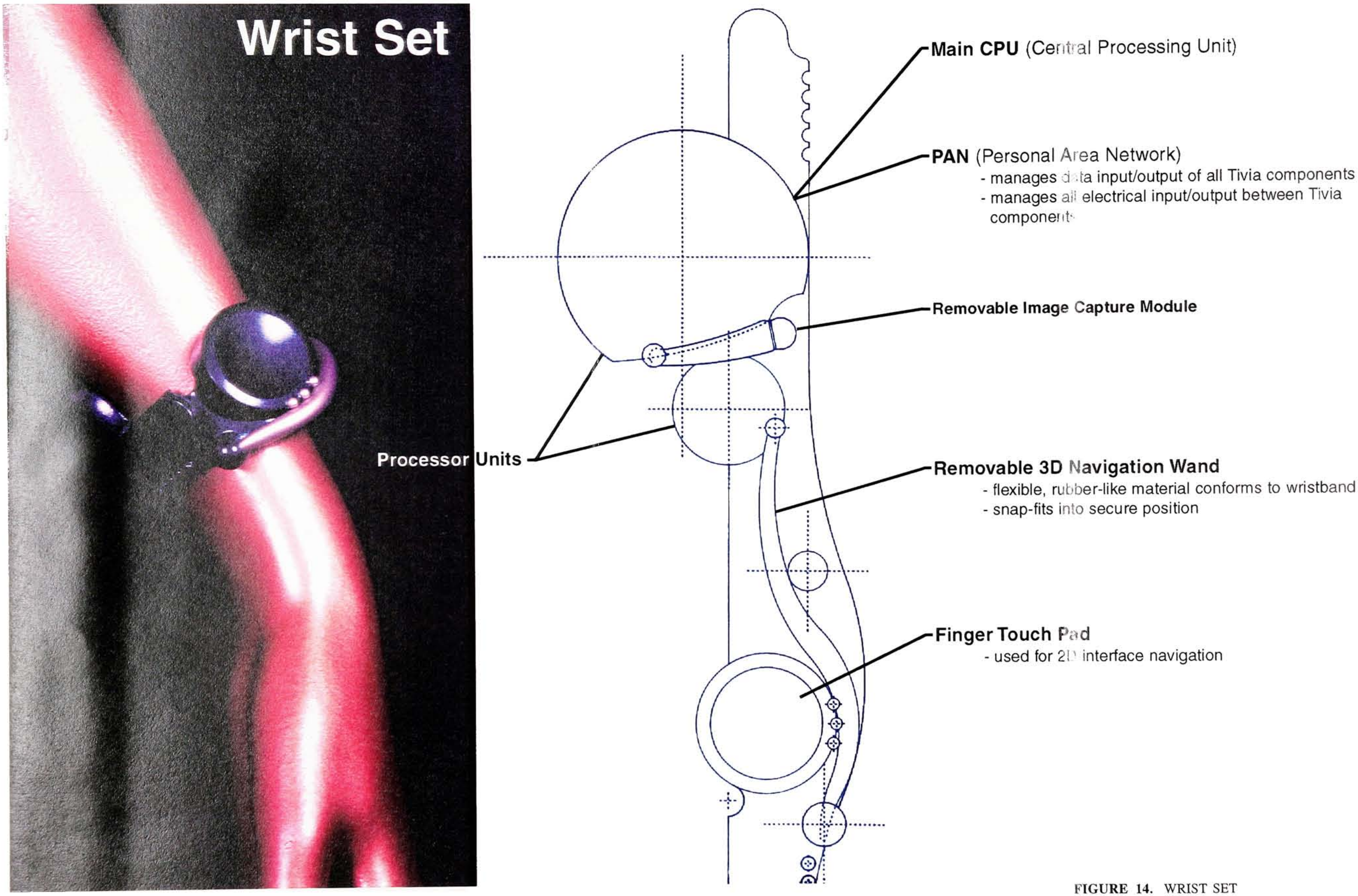
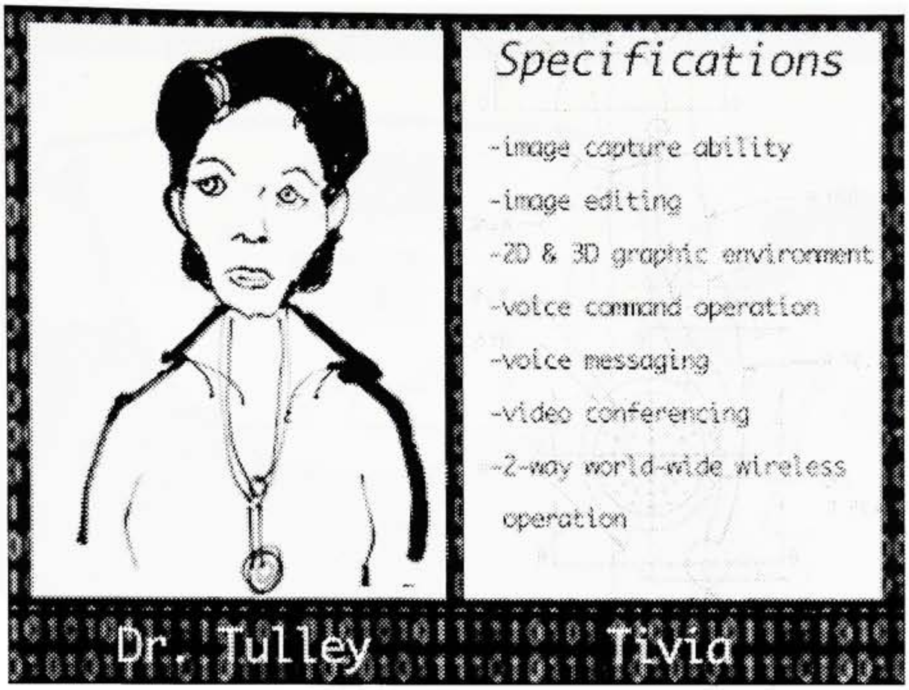
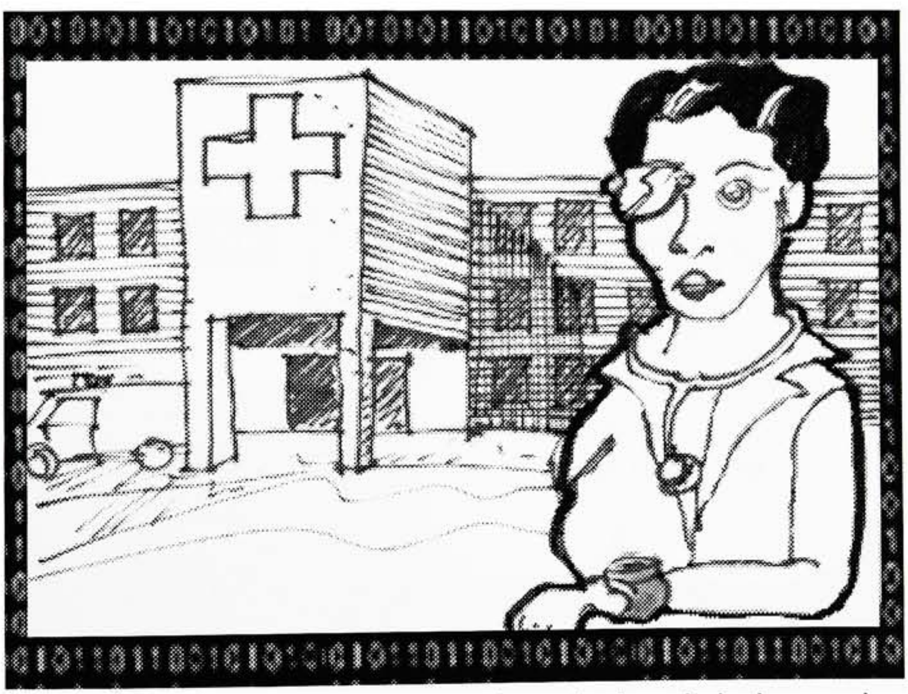


FIGURE 14. WRIST SET



1

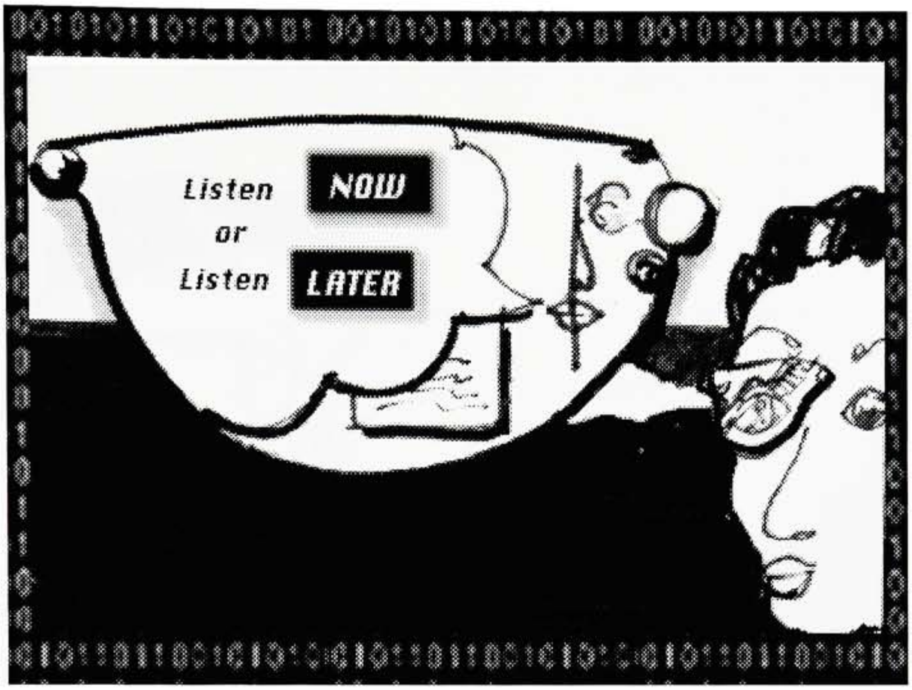
Introducing, Dr. Tulley and Tivia.



2

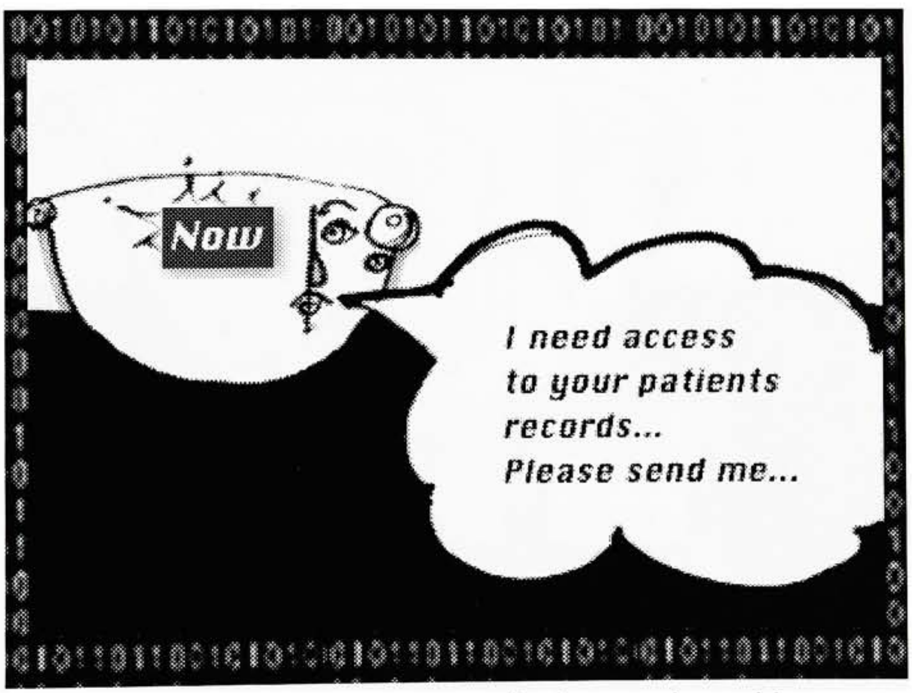
Dr. Tulley is making her daily rounds at the hospital when suddenly, Tivia receives a message.

FIGURE 15. FINAL SCENARIO: FRAMES 1 & 2



3

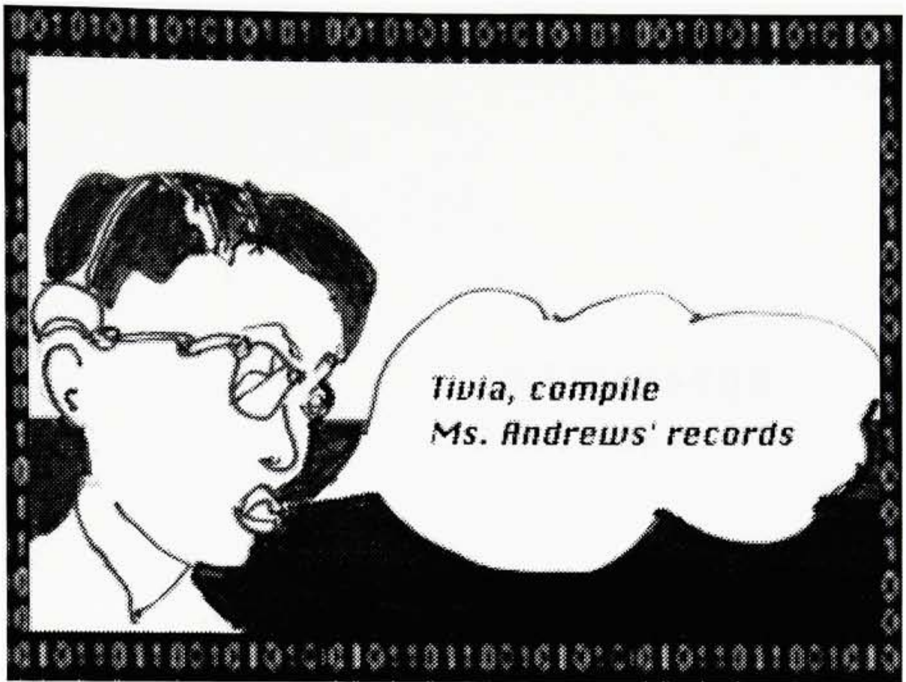
Listen now or listen later?



4

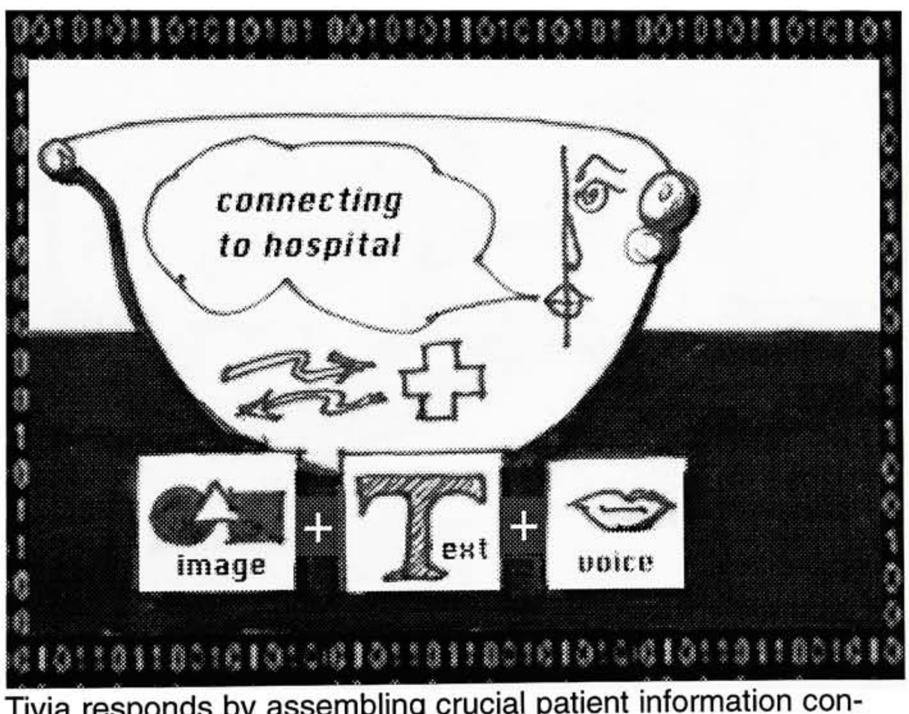
Dr. Tulley, I need access to your patients records-could you send me your recommended treatment for Ms. Andrews?

FIGURE 16. FINAL SCENARIO: FRAMES 3 & 4



5

Sure says Dr. Tulley. She asks Tivia to compile a patient history report from the hospital records. "Tivia, compile Ms. Andrew's records!"

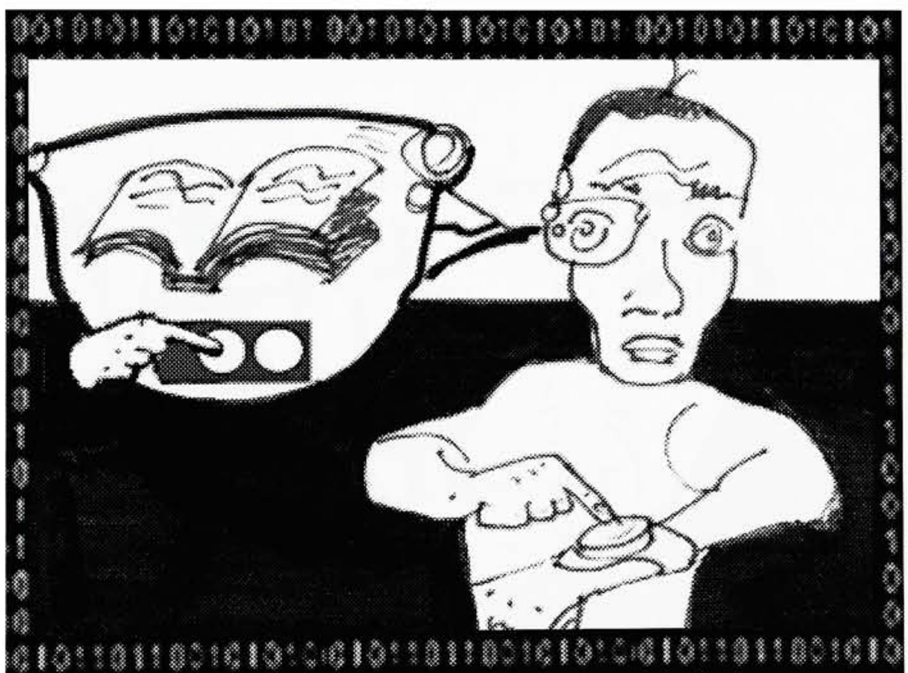


Tivia responds by assembling crucial patient information containing text and images. Finally, Dr. Tulley adds personal remarks regarding her patient... Tivia records her voice as she makes a personal annotation. 6

FIGURE 17. FINAL SCENARIO: FRAMES 5 & 6

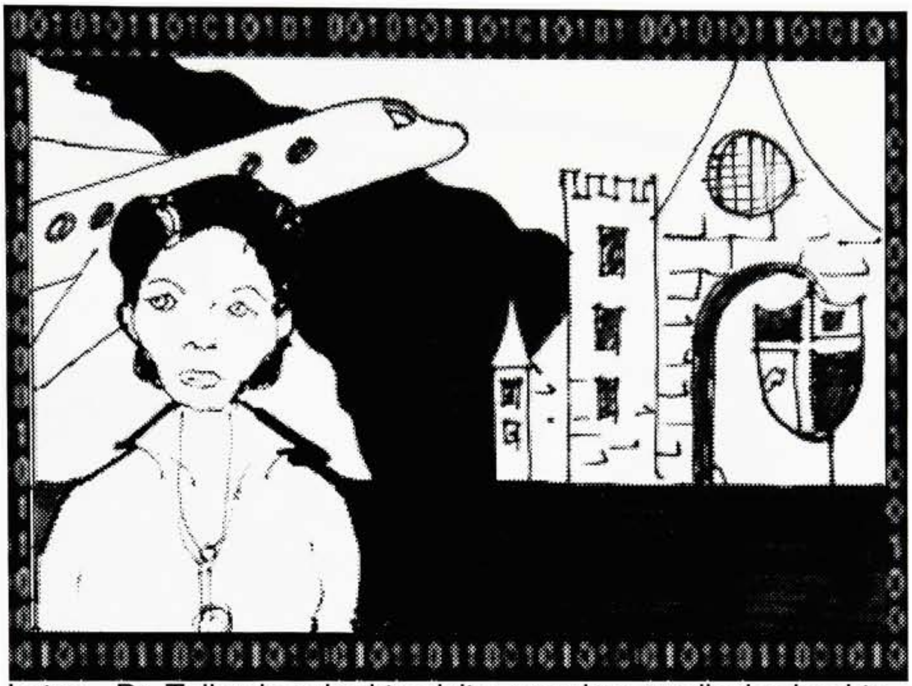
7

Next, Dr. Tulley asks Tivia to send the complete message to Dr. Roper.

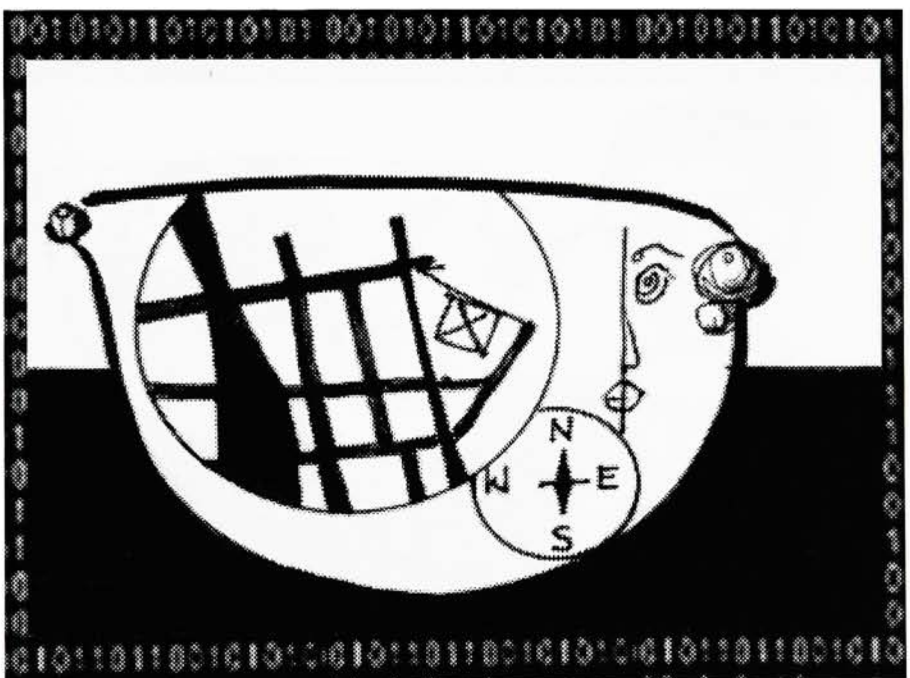


With the use of Tivia, Dr. Roper receives the message instantly. 8
Using the wrist touch pad, Dr. Roper is able to page through the message containing text and images while Dr. Tulleys' voice plays through the headset.

FIGURE 18. FINAL SCENARIO: FRAMES 7 & 8

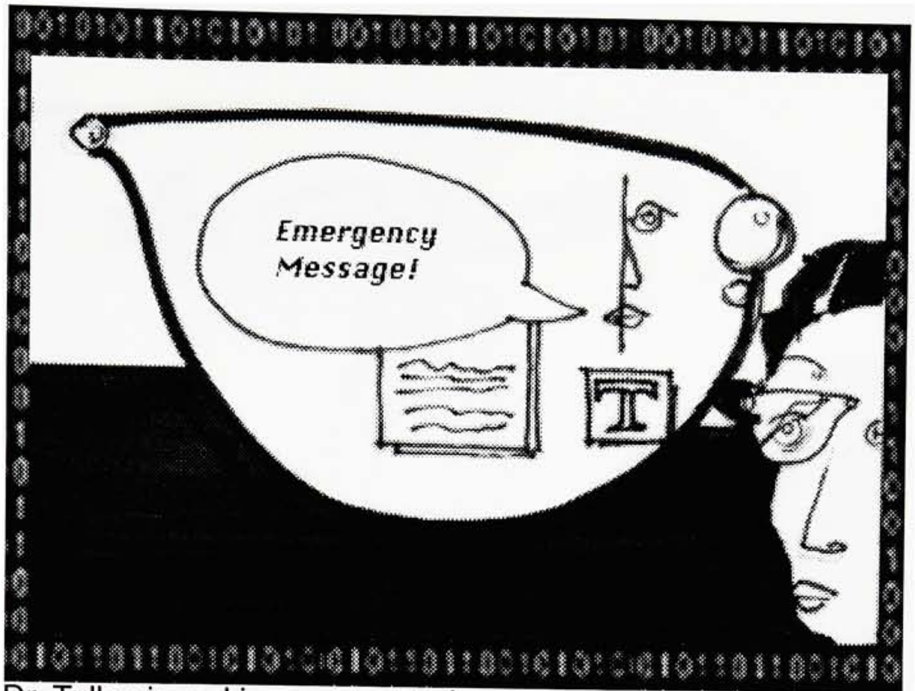


Later... Dr. Tulley is asked to visit a premiere medical school to give a demonstration. While traveling, Tivia maintains contact with her office, colleagues and patients. 9



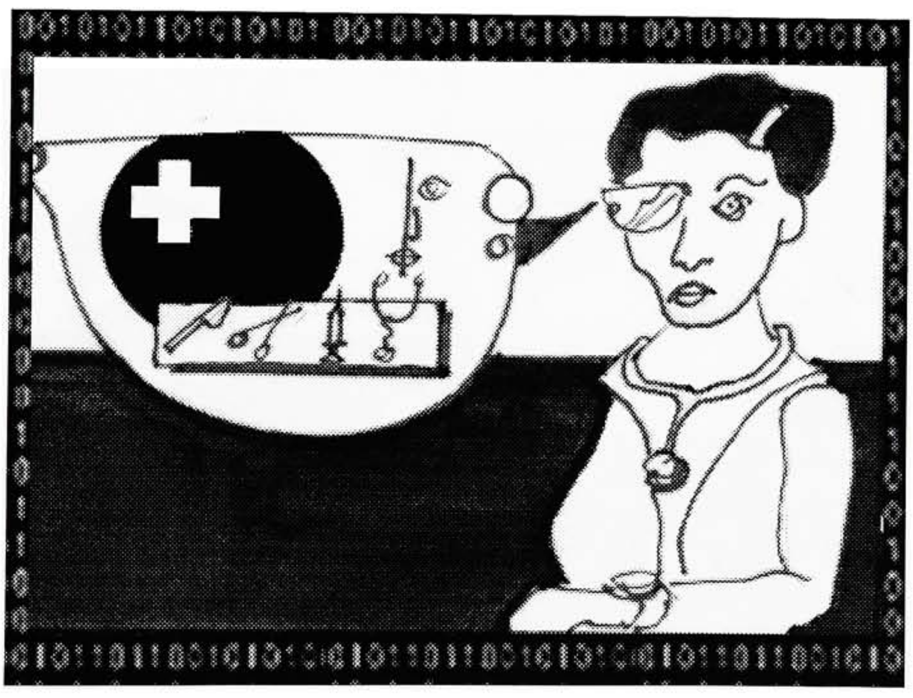
Dr. Tulley arrives at her destination with assistance from Tivia. 10
Tivia's headset displays a map of the local area.

FIGURE 19. FINAL SCENARIO: FRAMES 9 & 10



11

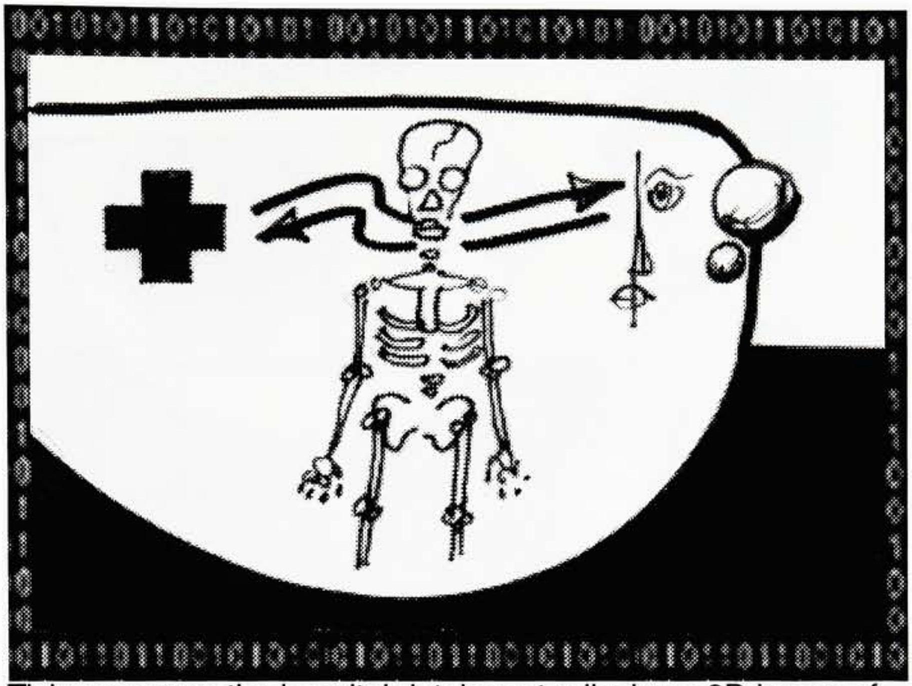
Dr. Tulley is making a presentation to a group of students when suddenly a message is delivered by Tivia. Her patient needs an emergency operation that only Dr. Tulley knows how to perform.



12

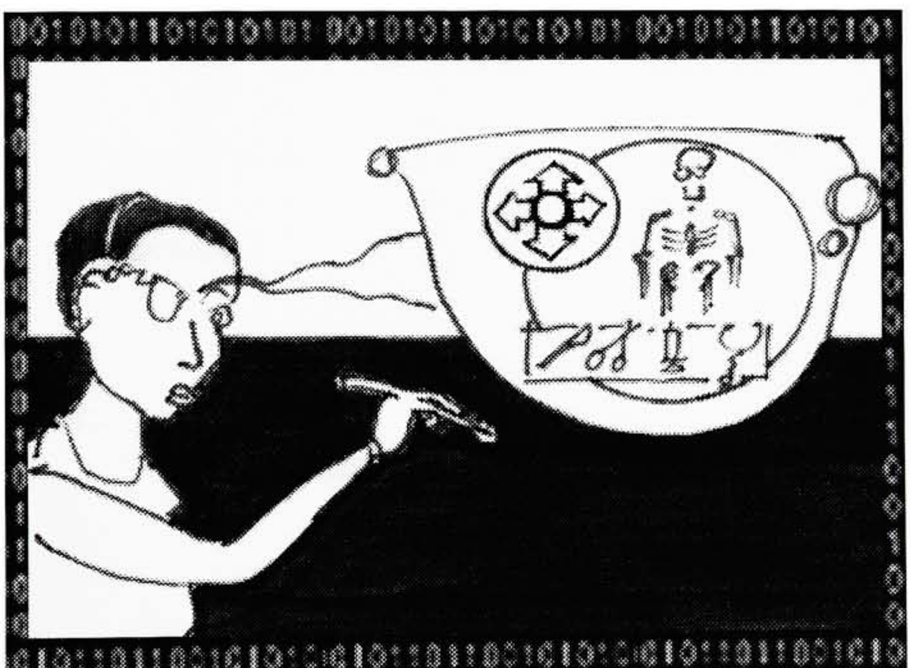
No problem! Dr. Tulley can use Tivia to demonstrate the procedure to her colleagues standing by, much like a virtual operating room environment.

FIGURE 20. FINAL SCENARIO: FRAMES 11 & 12



13

Tivia accesses the hospital database to display a 3D image of the patients anatomy.



14

Using the 3D navigation wand, Dr. Tulley is able to view and manipulate the 3D database representing her patient.

FIGURE 21. FINAL SCENARIO: FRAMES 13 & 14

15

With virtual operating room tools, Dr. Tulley simulates the surgery as her colleagues actually perform the procedure.

FIGURE 22. FINAL SCENARIO: FRAME 15

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