ABSTRACT

The computer has gradually, over the years, become smaller, lighter and more powerful, but the way we use them is still analogous to the large mainframes of past years.

Because of the nature of wearable computers, compared with their static counterparts, we believe that there is an opportunity to explore how humans and computers communicate in this unique and dynamic environment, utilizing speech and vision processing in order to create a more natural interface to the machine. Using agent technologies it should also be possible to aid the user in their search/retrieval of information.

Human-computer interaction is on the brink of radical change. The catalyst for this change will be the computer's ability to sense and recognize its users, to see and reconstruct its environment, and to respond visually and audibly to these stimuli.

I Jimesh Gajera, will be presenting my views and ideas on next powerful generation – Wearable Computers. Our discussions on this topic will surely help us in understanding Bluetooth Technology.
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1. INTRODUCTION

Wearable computers are often viewed as small versions of desk top computers. Wearable computers provide openings to new application areas and provide new design opportunities. Along with this complement of devices are cables that turn a person into a walking network.

Fig 1: Steve Mann is one of his more recent wearable computer prototypes

A wearable computer is a computer, worn and controlled by a user, that is always on and always accessible. That is, the user can always enter and execute commands, even while walking around or doing other activities. Wearable computers with small hidden device with transmission and storage capabilities that is wirelessly connected to an ear-mounted speaker/microphone. This article discusses the status of wearable computers; the challenges faced by software and hardware manufacturers in developing effective and widely accepted wearable devices; and the commencement of a new paradigm for how wearable technology can create value for consumers and enterprises.

Wearable computers are devices that enable a user to conduct computerized tasks with 100% portability and freedom, all nearly transparently.
Wearable computers are integrated within our wardrobe and lifestyle, so as to appear invisible, offering a multitude of input and output mechanisms that allow a user to continue with other tasks even as they interact with the computer and environment around them.

Additionally, while the advanced functionality of today's handheld devices has severe form factor implications, wearable devices of the future will likely function more as thin clients, providing device manufacturers more latitude in absence of the excessive battery and processing power requirements tied to today's devices.

A wearable computer is a computer that is subsumed into the personal space of the user, controlled by the user, and has both operational and interactional constancy, i.e. is always on and always accessible. Most notably, it is a device that is always with the user, and into which the user can always enter commands and execute a set of such entered commands, and in which the user can do so while walking around or doing other activities. This transformation allows it to be worn constantly, with the goal of becoming a seamless extension of body and mind, equipped with various sensors which measure heart rate, respiration, footstep rate etc, and can help in body maintenance. The ‘wearable computer’ apparatus is embedded within nontransparent clothing which provides shielding.

Electronic circuits are built entirely out of textiles to distribute data and power and perform touch sensing. The most salient aspect of computers, in general, (whether wearable or not) is their reconfigurability and their generality, e.g. that their function can be made to vary widely, depending on the instructions provided for program execution. With the wearable computer (Wear Comp), this is no exception, e.g. the wearable computer is more than just a wristwatch or regular eyeglasses: it has the full functionality of a computer system but in addition to being a fully featured computer, it is also inextricably intertwined with the wearer. This is what sets the wearable computer apart from other wearable devices such as wristwatches, regular eyeglasses, wearable radios, etc.

Unlike these other wearable devices that are not programmable (reconfigurable), the wearable computer is as reconfigurable as the familiar desktop or mainframe computer.
2. HISTORY

Several innovations have helped pave the way for wearable computers. These date back to the first mention of eyeglasses in 1268 and the invention of the pocket watch in 1762. However the first actual wearable computer was invented by Ed Thorp and Claude Shannon in 1966 and was used to predict roulette wheels. That same year Sutherland created the first computer-based head-mounted (HMD) display and soon after that Bell Helicopter began experimenting with HMD’s. (Rhodes, B., 1998). Wearable computers have come a long way since these early efforts. This year Stanford University’s Wearable Computing Laboratory managed to fit all of the software required to drive the worldwide web server into a computer the size of a matchbox. (Houlder, V., 1999) This type of technology improvement has made it feasible to produce useful, unobtrusive wearable computers and technology companies are beginning to show an interest.

![Steve Mann's "wearable computer" and "reality mediator" inventions of the 1970s have evolved into what looks like ordinary eyeglasses.](image)

During the period 1991-93, three different wearable computers were constructed as technology feasibility demonstrations by Carnegie Mellon University. They are the VuMan1, VuMan2 and Navigator 1 pictured. They were constructed as class projects and as demonstrations and had no clear intended users. All of them used the Private Eye as a visual output device. The Private Eye is a device with CGA resolution that is suitable for textual output or for very low resolution drawings.
The VuMan1 was used to view blueprints. It had two function buttons (used
to move left, right, up and down depending on mode) and a mode change button.
These buttons were integral to the device. The device, itself, was large and
cumbersome but the reaction to the integral buttons was positive and the
intuitiveness of the device for its intended purpose was very well received.

The VuMan2 was a much smaller device. It was used to provide a campus
tour. A three button selection device was used as the input device. The input device
was separated from the computer as a means of allowing experimentation with
various input devices. The input device could be held in the hand or mounted on
the body. One lesson from this system was the importance of orientation when the
input device was mounted on the body. The fingers were often placed on the
buttons incorrectly.

The Navigator 1 was a larger device with speech input also used for a
campus tour. It had a detachable commercially available trackball as an input
device. We were now entering the realm of mouse surrogates. The trackball we
used had problems with robustness and size - it was too small. Its main problem,
however, was its use during motion. The operator would hold the trackball in their
hand and position the cursor with the thumb. Correctly locating the target turned
out to be very difficult because the screen was moving and that, in turn, was
because the wearer was moving. Furthermore, the device had to be held in the
hand, body mounting was not possible.

The concept of wearable computing was first brought forward by Steve
Mann, who, with his invention of the ‘Wear Comp’ in 1979 created a pioneering
effort in wearable computing. Although the effort was great, one of the major
disadvantages was the fact that it was nothing more than a miniature PC. Absence
of lightweight, rugged and fast processors and display devices was another
drawback.

The 1980s brought forward the development of the consumer camcorder,
miniature CRTs etc. brought forward the development of the eyeglass mounted
multimedia computer. With the advent of the internet and wireless networking
technologies, wearable devices have developed a great deal.

After its invention wearables have gone through 18 generations of
development, with research going on at prestigious institutions like MIT, Georgia
Tech and Carnegie Mellon University.
3. CAPABILITIES

One has only to use her imagination to easily envision a world that is quite different from the one we know today; a world that is changed by the personalization of computers. In his book, "When Things Start To Think", Niel Gershenfeld discusses some of the work being done at MIT Media Laboratory which could have a drastic impact on the way we communicate and essentially redefine the organization of life and the characteristics of what it means to be human. He introduces the concept of a Personal Area Network (PAN) to connect parts of a body. PAN provides a means to get rid of the wires in a wearable computer. It merges the logical and physical components. This works on the same principle of breaking the spectrum into cells except that PAN shrinks the cells down to one body to transmit data through the body. (Gershenfeld, N., 1999) "The trick is to allow "wearable" electronic devices to exchange data by capacitively coupling modulated picoamperes currents through the body. A low frequency carrier (below 1 MHz) is used so very little energy is radiated outside the body itself, minimizing interference and remote eavesdropping. A PAN device electrostatically induces picamp currents into the body which is used as a "wet wire" to conduct the modulated currents." (PAN’s, 1996)

Although the above PAN concept has been prototyped and certainly stretches the mind to think about what could be, actual widely accepted capabilities today are much less developed. The basic package today consists of a Pentium 200 MHZ, 32 MB RAM, 2.1GB HD with a flat panel or head mounted display and a deluxe package would use a Pentium 233/266 MHz with a 128 MB RAM and 4.3 GB HD. This describes the mobile assistant (MA IV) systems currently supplied by Xybernaut, one of the leading corporations in wearable computers. It can be worn on the sleeve, forearm, belt or vest and the monitor/display can hitch to a headset. It responds to voice recognition or one-touch commands, providing wearable, wireless, hands free computing capability. These can be standalone computers or can be connected to a wireless network through an antenna attached to clothing such as a hat. They are powered by small battery packs. (Xybernaut Corporation, 1999)
4. DESIGN OF WEARABLE COMPUTER

A wearable computer needs a user interface which is distinct from that used on desktop systems. This is because the input and output methods are different, because the user attention is different, and because the tasks are different.

What wearable computers have to offer is job-critical information to people whose hands must be free for other work. Assembly line workers, for example, can access a database and look at drawings of what's being worked on and see step-by-step instructions for putting it together. A wearable computer has a minimal input device, an 18-key Twiddler being about the best that can be hoped for, with a nonexistent or minimally functional pointing device. The output device is a heads-up display, competing for attention with the user's surroundings, small color display that hangs before a worker's eye, supported there by a head-mounted boom and rarely better than the equivalent of a 6-inch monitor.

4.1 Interface Devices

The Private Eye (left) provides a tiny monitor display that only one eye can see, and may be mounted on a pair of safety glasses. The JABRA net (right) is an earphone device for listening to auditory output from the system.
The green part of the JABRA fits in the ear; a microphone that sits on the end that is exposed to the outside is for listening to sound that the ear would normally hear without the earpiece. The Twiddler is currently the preferred input device for wearable computer. The PalmPilot (middle) is a PDA that can be used without obscuring the user's vision.

The Private Eye

Instead of an LCD screen monitor attached to the computer (as with a laptop model), the wearable computer uses more robust, personal interfaces for "hands free" operation which allows the user to walk around freely and have the computer operational at all times. Currently, the standard interface for our system is the "Private Eye" (see photo below), a text only interface that is positioned in front of one of the user's eyes. This interface uses a row of LED's (light emitting diodes) and a rapidly spinning mirror to create the illusion of a full screen of text. The Private Eye is a very low power device (one half watt compared to 3.5 watts for typical VGA, head mounted devices) which means a much lighter (and therefore slower) drain on the battery.

JABRA net

The JABRA net is an example of a lightweight, auditory interface, and a candidate output device for the affective wearable computer. This interface paradigm leaves the user's eyes unobscured, and is barely noticeable to the casual observer. An auditory interface like the JABRA would serve well for a variety of applications, including those that are not vision intensive. Using this interface, the computer would use.

Twiddler

It is a lightweight, one-handed, "chordic" keyboard. A chordic keyboard, like those used by court stenographers, produces characters by pressing combinations of buttons. Two handed chordic keyboards are capable of typing speeds that are much faster than traditional QWERTY keyboards; an experienced user of the Twiddler can exceed speeds of 50 wpm while using only one hand. The Twiddler is made by HandyKey, and is friendly to user modifications such as remapping the keys or reconstructing the case. The Twiddler shown here has an attached "orthotic spacer" (the orange lump on the bottom side of the Twiddler in the photo below) which makes operation more comfortable for some users. A chordic keyboard is
very quiet, and offers the user a way to silently (and, in many cases, privately) communicate with their computer, a desirable option even after sophisticated speech recognition systems come of age.

**Palm pilot**

It can be used for both functions simultaneously, or it can be used in conjunction with another de. The **PalmPilot** works as an input device as well as an output device vice.

Computer generated speech to speak with the wearer; the user would be able to communicate with the system via several possible means:

- A PDA style handwriting tablet or miniature keyboard;
- Eventually by speaking directly to the system, with a speech recognition system in tandem with a microphone.

The rest of the system--its central processing unit (CPU), which includes a microprocessor, RAM, and hard drive--is worn in a belt around the waist. The display is a small liquid-crystal chip, whose image is picked up by a silvered mirror, or transmitted through a prism, and reflected or redirected into the user's eye. The display is held at the end of a toothbrush-sized boom, supported by a headboard, say, or by a larger eye-covering mirror or prism arrangement. Thanks to magnifying optics and despite the closeness of the image to the eye, the viewer has the illusion of reading a normal-sized desktop screen at the usual arm's length viewing distance.

Unlike other computers (including laptops and PDAs), a WearComp is inextricably intertwined with its wearer - WearComp's "always ready" characteristic leads to a new form of synergy between human and computer.

Commands are either keyed into a small keyboard worn on the wrist or spoken into a microphone. A video camera is an option, and the computers have standard I/O ports for adding peripherals. In addition, the machines can handle off-the-shelf applications, such as database management and word processing, written for Windows or Linux operating systems.
4.2 Design Boundaries

Wearable computing encompasses a huge range of hardware and applications. Everything from a wristwatch to a complete reality-mediation system is a wearable. Designing a generalized user interface which will scale in a comprehensible manner across this incredible range is a very hard problem and perhaps an impossible one. Thus, to find a task which can actually be tackled, it is necessary to delimit the design arena a little more carefully.

The area of concentration of the Enchantment system is a wearable platform buildable today and optimized for the typical tasks of an experienced user in everyday situations. That is, this project is explicitly ignoring the problems of casual or novice users or users with specialized needs. The reasons for this are twofold: such users would be better served by more targeted interfaces with other design goals, and it makes sense to first design a user interface suitable for the largest fraction of early adopters of wearable technology.
DIGITAL FABRIC

Cotton, polyester or rayon don't have the needed properties to carry the electrical current needed for digital clothing. However, metallic yarns are not new to the clothing industry. We have seen these metallic fabrics worn to make fashion statements for years. Researchers at MIT's Media Lab are using silk organza, a unique fabric that has been used to make clothes in India at least a century.

![Silk Organza](image)

_Silk Organza_  

Silk organza is ideal for computerized clothing because it is made with two fibres that make it conductive to electricity. The first fibre is an ordinary silk thread; running in the opposite direction of the fibre silk thread that is wrapped in a thin copper foil. It's this copper foil that gives the silk organza the ability to conduct electricity. Copper is a very good conductor of electricity and some microprocessor manufactures are beginning to use copper to speed up microprocessors. The metallic yarn is prepared just like cloth core telephone wire, according to the MIT researchers. If you cut open a coiled telephone cable, there's usually a conductor that is made out of a sheet of copper wrapped round a core of nylon or polyester threads. These metallic yarns can withstand high temperatures; the yarn can be sewn or embroidered using industrial machinery. This property makes it very promising for mass producing computerized clothing.
Fig (4) : Copper coil

A strip of the fabric would basically function like a ribbon of cable. Ribbon cables are used in computers to connect disk drives to controllers. One problem with using silk organza would result if the circuits were to touch each other; therefore MIT scientists use an insulating material to coat or support the fabric.

Once the fabric is cut into suitable shape, other components need to be attached to the fabric, like resistors, capacitors and coils. These components are directly sewn to the fabric. Other electronic devices can be snapped into the fabric by using some kind of gripper snaps, which pierce the yarn to create an electrical contact. These devices can then easily removed in order to clean the fabric.

At Georgia Tech, researchers have developed another kind of thread named as plastic optical fibres and other specialty fibres woven into the fabric. These optical and electrical conductive fibres will allow the wear comp to wirelessly communicate with the other devices, transferring data from the sensors embedded in it.
Prior Experience

During the period 1991-93, three different wearable computers were constructed as technology feasibility demonstrations by Carnegie Mellon University. They are the VuMan1, VuMan2 and Navigator 1 pictured in Figure 2. They were constructed as class projects and as demonstrations and had no clear intended users. All of them used the Private Eye as a visual output device. The Private Eye is a device with CGA resolution that is suitable for textual output or for very low resolution drawings.

![Three earlier generations of wearable computers](image)

This type of technology exploration is very common among research organizations. The purpose is to demonstrate that systems of particular types can be constructed, to understand the technology and the difficulties of construction and to gather informal feedback in opportunistic settings with respect to general impressions of the artifacts created. The expense of a formal usability study is typically not justified since the purpose of the effort is to explore technology and not, at that time, produce functioning products. All of the evaluations of the various wearable computers described in this section were of this informal type and were based on student and visitor feedback given to builders of the system.

The VuMan1 was used to view blueprints. It had two function buttons (used to move left, right, up and down depending on mode) and a mode change button.
These buttons were integral to the device. The device, itself, was large and cumbersome but the reaction to the integral buttons was positive and the intuitiveness of the device for its intended purpose was very well received.

The VuMan2 was a much smaller device. It was used to provide a campus tour. A three button selection device was used as the input device. The input device was separated from the computer as a means of allowing experimentation with various input devices. The input device could be held in the hand or mounted on the body. One lesson from this system was the importance of orientation when the input device was mounted on the body. The fingers were often placed on the buttons incorrectly.

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From these systems and the student and visitor feedback we drew the following lessons that represented our technological biases upon beginning to work with the U.S. Marines:

- the hands must be free for a substantial portion of the use of the device to allow the user to perform tasks not associated with the operation of the computer,
- total hands free operation is not necessary since the users rarely required both hands at their tasks at all times,
- operation of the input device without diverting the attention from the non computer task is important, and
- an input device that is integrated with the computational device requires less attention to operate.

**Context for VuMan3 Development**
In the Fall of 1993, we were asked to perform an advanced technology demonstration with the U.S. Marines at Camp Pendleton who perform depot maintenance for various amphibious tracked vehicles. The goal of the demonstration would be to determine whether wearable technology was sufficiently robust to be used in this environment and whether the technology would reduce the time it took to perform maintenance tasks. The measures we would use to determine whether the demonstration was successful would be user satisfaction with the device and task performance times.

We were prepared to perform the demonstration in the context of the 1994 Spring semester of a project class that had constructed the prior wearable systems.

This ``look for a task where your technology can show its worth'' is typical. Not only research organizations but product organizations are often in this situation. Research organizations wish to demonstrate their technology, product organizations wish to sell or create technologies from which they can make a profit. In both cases, the designers are constrained by the business purposes of their organizations. The constraint to use a particular technology such as a particular operating system or hardware in turn constrains the design. Some of our constraints were to use wearable technology in a real task, to do this primarily using student labor and within the time of a semester. Some of these constraints were met but the completion time was not.

First Meeting
With this background, several staff members visited Camp Pendleton in December, 1993 with the following goals:

- to determine if wearable technology was useful in the U.S. Marine maintenance environment,
- to determine a maintenance task for which it was useful,
- to make contact with necessary personnel to give us information about the task, and
- to learn as much as possible about the selected task to carry back to the class.

One aspect of doing design across the continent (we are located in Pittsburgh, Pa and Camp Pendleton is in Oceanside on the California coast) is to capture as much information as possible on each visit. The number of visits we could make was constrained both by the cost of the visit, the fact that the work was going to be performed by students who had other classes and the fact that we were constrained by our labor force (typically seniors) graduating at the end of the semester. We were also constrained by the access that we had to the maintenance personnel. They are all primarily oriented toward completing maintenance and had limited time to invest with us.

Our first goal was to understand the maintenance process. When a vehicle arrives at the depot for maintenance, over 600 of its parts are first inspected to determine which parts are defective. The results of this inspection are recorded on a clipboard, the contents of the clipboard are then entered into the maintenance computer system by a different person from the inspector. Once the results have been entered, the necessary parts that are not in stock are ordered, the parts are taken out of inventory and the vehicle is scheduled for repair. Finally, the defective parts on the vehicle are replaced.

Our initial decision was to construct a device that could be useful in both the inspection and the repair tasks but to initially focus on the inspection. The device would be used to record defects discovered during the inspection. In the jargon, the inspection is named a Limited Technical Inspection (LTI). We chose this task for several reasons:

- it is at the front end of the maintenance process and has the least overhead in terms of learning the language and the context,
- it required a great deal of mobility to move around, under and inside the vehicle,
• it required the inspector to have both hands free for certain portions of the inspection, and finally,
• we liked the challenge of producing a device comparable to a clipboard in ease of use.

The first point about being at the front end of the maintenance process deserves some elaboration. Computer systems, in general, have the goal of improving some business process of the organization using it. The further into a business process one travels, the more baggage one accumulates. This baggage is in terms of language as well as assumptions about what has been done earlier in the process. Therefore, choosing a task from the early portion of the business cycle, simplifies the creation and acceptance of new technology. Of course, there is no guarantee that improving the front end of the business process will improve the whole process but that was not our goal here.

Once we decided to focus on the Limited Technical Inspection task, we made contact with the personnel who performed those tasks. One critical element of doing user centered design is to deal with actual users and not the users' higher level management. We dealt with the actual inspectors as well as their Sergeants. The Sergeants are very experienced at inspections and have the perspective to understand what our technology might do for them. Higher level management has a very abstracted view of the processes being performed and often, these abstractions hide essential details.

We demonstrated VuMan2 to the end users and walked through the vehicle inspection with them. We also walked through the inspection wearing a VuMan2 to determine the constraints that wearing additional equipment might cause. While going through the inspection we made an extensive photographic record - both still and video. We also interviewed the inspectors.

Some of our observations were:
the inspections were performed in both cold and hot weather and, hence, the operator might be wearing gloves,
the inspectors performed some of the inspection on their back, some on their stomach, some while squatting or standing. Some portions of the inspection were performed with measurement tools and some with leveraging tools such as a long pole to test tread flexibility,
the inspectors continually put down the clipboard, performed an inspection and picked up the clipboard to record the result,
copying the data from the clipboard into the computer was a time consuming and error prone process, and
the cables on the VuMan2 tended to snag on obstructions.

The personnel performing the inspection are U.S. Marines, 18-23 years old. We interviewed them and determined they, typically, had very little computer sophistication. They all knew how to operate a computer but several had never used a mouse. They all had over six months experience performing this type of inspection but less than five years.

Besides making contact with the personnel who would actually be performing the inspection, we also began integrating them into our product team. We discussed with them the technology and how it worked and solicited ideas about what would work and what the problems were. We also got their feedback about our initial concept. This was important not only to get their input, which was valuable, but to get their buy in to the demonstration. On subsequent visits, we would be able to show them how their ideas were being incorporated into the system. Thus, they began to assume ownership of the result. This transfer of ownership (at least of the ideas) to the end users tends to make them advocates for the technology and to be more tolerant of the inevitable technological problems when they surface.

This last item is very important. The goal of gaining feedback from the users is not only for the information content but also for the assumption of responsibility and ownership. In our case, since user satisfaction was one of the primary measures, we were very conscious of the side effects of our interactions with the end users.

Requirements
From our interviews we determined that any device to be used in an LTI must be field worthy and rugged, must be able to be operated when the operator is wearing gloves and in a number of different positions.

Finally, the device must be comparable to a clipboard in difficulty of use. We interpreted this to mean that training time for the device should be under five minutes.

**Initial concept**

Our initial concept for a device, discussed with the end users during our visit, was to have multiple buttons (possibly as many as 5) embedded in the device. The initial software concept would use one button for moving up the checklist, one for moving down the checklist and one for selection. The other two would be for various control functions associated with displaying manuals during the other maintenance tasks.

We visualized having the device operable from different locations on the body. Thus, when the operator was lying on the back, the device would be on the front, when the operator was lying on the stomach, the device would be on the back, and so forth.

In general, this is the method that we use to develop the design: we have several loose concepts, these are developed and analyzed against scenarios of use as a method for understanding them and then the concepts are combined, when appropriate, and refined. It is only when concepts are refined and mock ups constructed that any detailed examination of how well the requirements are being met is appropriate.

Ideally, in the user centered process, the user will see and will give feedback to both the concepts and then the refinement. The distance precluded having user involvement at the initial exploration level.

**High Level Design**
When the semester began after the first of the year, the class was divided into three groups. The groups then proceeded in parallel. The three groups were: the industrial design/mechanical engineering group, the electronics group, and the software group. The process that the class uses to rapidly develop the wearable systems has been documented elsewhere [3]. Our interest here is initially the industrial design activities and its interactions with the other groups. We focus on these topics since these are the ones that demonstrate both the user centered focus and the interactions that made the integrated product team contribute to the conceptual integrity of the design.

**Initial concepts**

The industrial design/mechanical engineering group began by doing concept exploration. This is a brainstorming process that involves doing rapid sketches of concepts, putting those sketches up and discussing them. Once the concepts have been elicited, several (two, three, or four) are chosen for more detailed examination. Also, combinations of the concepts are also chosen for more detailed examination.

One suggestion that arose during the concept exploration was that control panels often had dials and that, somehow, the computer system was controlling the inspection. Control panel dials are usually small but this suggestion seemed to have merit. The dial suggestion was not treated as a tremendous breakthrough but merely another concept that was worthy of exploration. The concept exploration phase then focused on two main concepts for the input device: one was the five button and the other a dial. Pure versions and combinations were explored. Input devices that were rejected for various reasons during this phase included a speech recognizer and various exotic input devices.

At this point, the questions about the dial were related to how to make it usable. The discussions revolved around issues such as: how large should a dial be, what was the amount of rotation necessary to move through a screen, and the number of selection points necessary to perform a particular task, and basically, could a dial be used as the input device.

While the industrial design/mechanical engineering group were examining either buttons or a dial as an input device, the software group was verifying that either input device could be used to support the LTI checklist. A dial is logically
equivalent to a tab left and tab right and, thus, if the input could be performed with a dial then it could also be performed with two buttons. The software group proceeded on that basis.

The industrial design/mechanical engineering group during its explorations examined a variety of different sizes and shapes for the dial. Human factors materials [4] were used to get hand measurements. A variety of different possibilities were examined as shown in Figure 3.

![Fig: Various dial concepts that were explored](image)

While the various dial concepts were being explored, the base system input concept was being refined. One of the combinations of the original concepts (a dial, a selection button and a mode button) seemed to offer a solution to the robustness, the mobility and the usability problems.

During the exploration of the dial, the observations were made that if the dial was sufficiently large, then gloves could be worn during operation, and the operation of the dial is the same whether the operator is right or left handed and regardless of the position on the body.

The elements were then in place for the second visit to the end users. The concept of the input device and, a version of the software for the VuMan2 were ready for review and it was clear that many of the requirements could be satisfied with a device with those elements. An overall design theme had not yet emerged and in preparation for the visit, a product mock up was constructed (a blockish shape based on the rectangle) and some sketches were made of a more curved shape.

**Second Visit**
In late Feb, 1994, a second visit was made to Camp Pendleton. For this second visit, as we just mentioned, a software version of the LTI checklist was implemented on the VuMan2, a product mock-up of a squarish device was made and sketches of a more curved product were also made. We also took the variety of dial examples that had been produced to gather feedback from the end users on the dial.

A staff member went through the movements of the LTI wearing the VuMan2 to check for clearances and mobility constraints, especially with the head mounted display.

We held a focus group with the end users. We let them try on the VuMan2 but not operate it to get their reactions to wearing a computer. We then had them look at the storyboard concepts of the VuMan3 and give us feedback. Finally, we had them operate the VuMan2 to get reactions to the software. A screen from the initial software is shown in Figure 4.

![Initial software implementation](image)

One of the concepts we showed them had a knob that kept dirt out of the mechanism and one had a triangular shared grasping portion to facilitate movement of the dial. Both of these were well received by the end users. They liked the finger holes on the dial as a means of orienting their hand.

Note the use we were making of the users at this point. They were a group being used for review of our concepts. We were not using them to generate ideas.
(at this point) but as critics and givers of feedback. It was also important to keep the users engaged and indicate to them that we were making progress, that they could expect to see an actual working system and that their previous input had been taken into account.

**Detailed design**

It was after we returned from the second visit with buy-in from the users that the dial began to assume the elements of centrality of the design. In successive refinements, the dial became a larger and larger portion of the design. Visually it was the largest element of the system.

The detailed design of the dial emphasized elements such as the number and volume of the detents (stops) of commercially available dials, the size, shape and placement of the buttons and, finally the relationship of the dial to the housing.

The key housing decisions had to be made in conjunction with the electronics group. The electronics that were going to be used in the VuMan3 would, essentially, determine the size and weight of the final device. The size and weight was primarily determined by the power requirements of the device and this, in turn, was determined by the electronics that were going to be used. One of the early decisions of the electronics group was to use an Intel 386 processor. This decision was driven primarily because of the unknowns associated with uses of the device other than the LTI. The presentation of manuals and graphics likely would be processor intensive and so a more powerful processor than absolutely required was used. The key decision of the electronics group, however, was the decision on the shape of the mother board.

Standard boards are rectangular. This is the standard shape in which a board can be purchased and it allows the maximum flexibility in the placement of components. Placing a large rectangular board inside a housing, however, tends to make the housing large and rectangular. Interactions and discussions between the electronic team led to a board shape as shown in Figure 5. This shape was compatible with the housing being developed by the industrial/mechanical team who had curved the housing to make it better fit the body.

This decision was not made easily by the electronics group and there were many spirited discussions over the topic.
Although the concept of a dial as the design motif had not yet been articulated, by default, the dial was beginning to drive the decisions made by the other groups. In order to have a curved design, which was compatible with a large dial, the mother board needed to have a non-standard shape.

We finalized these design elements and proceeded to implementation. The users were, at this point, unaware of our final design. If they had been closer we would have reviewed it with them one more time but both because of distance and the looming end of the semester, such a review was not possible.

**Physical implementation**

At this point the central physical design elements had been decided: large integral dial as input device buttons for selection and integral batteries. Figure 6 shows the final physical implementation of the VuMan3.
This design reduced the number of cables to 1 (between the device and the head mounted display). The chosen design had the selection buttons radial around the dial selected by the fingers and the mode button under the thumb. A stop to keep the fingers from coming off the dial was provided by constructing a boot to hold the device. The boot also allowed mounting the device around the belt. It could be shifted from front to back depending on the position of the user and from the left side to the right side depending on whether the user was right or left handed.

**Software revision**

Although the dial had been articulated as the central design theme, the software did not reflect it. Thus, during the summer when the students were completing the physical design, the professional staff revisited the software from the point of view of design integrity.

The software concept that is compatible with the dial is shown in Figure 7. In the middle of the screen is an image or text that need refinement and around the outside are labels that provide links to further screens or final selections. The cursor is initially over one of the labels and each turn of the dial (clockwise) will move the cursor to the next numbered label. Counterclockwise turns of the dial will move the cursor to the prior label. (The numbers around the outside of Figure 7 are just for the purposes of this paper.)

![Example of circular motif possible with dial.](image)
Future uses of the VuMan3 were intended to support other maintenance activities. The image in Figure 7 could be a blow up diagram of an engine or other mechanical part. The movement of the dial corresponds to moving around the selected links in either a clockwise or counter-clockwise direction. That is, what the users do and what they perceive work together.

From a software perspective, anything in which the contents of a single screen can be represented as a circular list of selectable items is suitable for a dial. Each turn of the dial moves the active element to the next element of the list. Each element of the list can be linked to another screen that is invoked when the list element is selected. This covers checklists, as we will see, as well as hyper-text and labelled diagrams. All of these are suitable applications for a dial input.

From a visual perspective, use of the dial suggests placing selectable items on the outside of the screen and to navigate through them in a circular fashion. Thus, the screen look and feel corresponds to the input device being used and the end user feels as if they are dealing with a single, unified device.

The software was then revised to use this motif. The revised software had several elements:

- One broke the checklist up into physically adjacent questions since those are how they are answered. Thus, one section might be the right front, another the right rear, etc. Then on initial entry to the inspection, the user is shown a menu that leads them quickly to the portion of the checklist that is relevant.
- A second placed the selection locations on the outside of the screen. Thus, navigation controls were on the outside as were status selections of the checklist.
- A final element used knowledge of usage patterns to position the cursor rectangle that indicates the current selection of the circular list. There is a common sequence of performing the inspection and for each item, there is a known probability that it is satisfactory. This knowledge was built into the software to provide an initial location for the cursor. Someone performing an inspection, as long as their inspection procedure and the vehicle conformed to the normal probability could sequence through the inspection without moving the dial at all but just performing the selections with the thumb.

Figure 8 shows a screen from the final user interface. The selectable items are: "next", "Sec. Menu", "serviceable" and the three instances of "<none>". Note
how natural this sequence feels when a dial is the input device and consider what is necessary if a mouse were used to move from item to item.

Fig: Final user interface.

Note the evolution of our design decisions. The dial was introduced as a concept in one of the groups of the integrated product team. It gradually grew to the point where it began to dominate the look and feel of the physical device. This required the electronics group to modify their design for the mother board. It caused the software to be modified to reflect the physical design decisions and this final result was a new user interface paradigm: circular input and circular visualization.

Field Test

The final software implementation and hardware design was completed in Aug 1994. It then took about six weeks to fabricate the hardware. We scheduled the field test for October 1994. International events intervened (Somalia) and it was not until Jan of 1995 that the field test was completed.

We observed (video taped) six different inspections. Three with the paper based system and three using the VuMan3. We also interviewed the subjects after they completed the tasks. All of the subjects expressed a high degree of satisfaction with the device and its utility. We met our training time objective by having each subject instruct the next subject in the operation of the device.
Furthermore, a reduction in task time of 40% was achieved. This time does not include the time to actually enter the data into the repair control system because of an incompatibility with the U.S. Marines computer system. The Marines used a 286 based data entry system and the oldest system with which we were able to test was a 386. If this time had been included, the reduction in task time would have been even greater since in other venues we found that data entry takes about an hour with a paper based system and about 2 minutes with a wearable computer.

Descendent of VuMan3

In 1996, we designed another wearable product that utilized the dial. We had multiple applications in mind for this product and so we allow for multiple different input devices. The design, however, is very clearly an evolution of the VuMan3 design and it can be seen to be a descendent of the VuMan3.

Figure 9 shows our latest design. This system has multiple possible input devices. One is the dial shown and the other is designed to be used when the dial is not appropriate and uses a circular touchpad as an input device.
5. RATIONAL DETAILS

How do you operate a wear comp? What sort of software do you use in it? What do you use it as input and output devices? Where do you Store data? How do you store them? All these are common questions that would arise in someone new to wear comp below given are brief answers to such common questions.

5.1 SOFTWARE:
The commonly used operating system on a wearable computer is WOS (wear comp OS). Red hat and GNU Linux can be run in close coordination as an operating system too. Various software mostly GNU freeware such as GIMP (GNU image modulation program) as well as various calendar and planning programs can be run on a wearable computer.

5.2 HARDWARE:

Prices of wearable computers tend to be in "thousands of dollars" whether you buy old or new. An alternative approach is to assemble a low cost system. For example, you can buy an old computer that has NTSC output and connect to small CRT from camera. Some such complete wearable computer systems have been built for as little cost.

5.3 DISPLAY:

A major part of the total cost of the wearable computer system lies in its display unit.

Mainly two types of display are used.

(i) Common portable LCD display
(ii) Head mounted display

**Common portable LCD display**

**FEATURES:**

- High resolution colour video image.
- Image that appears in the person's line of sight.
- Viewing angle comparable to viewing a 26" monitor from 2, meters (6.5 Feet) away.
- Ultra light-weight, no major disturbance in the eyesight.

**Head mounted display**

**FEATURES:**

A typical HMD has either one or two small displays with lenses and semi-transparent mirrors embedded in a helmet, eye-glasses or visor. The display units are miniaturised and may include CRT, LCDs, Liquid Crystal on Silicon (LCos), or OLED.

*FIG (5): Head Mount Display*

**5.4 KEY BOARD**

At the higher end, you can get a "twiddler" from Hand key, or keyboard from info grip. You can connect micro switches that enable you to plug directly into the keyboard port. A combination keyboard that weighs 4 ounces and fits in the palm of your hand. The twiddler 2 is an existing technology of wearable computing.

**5.5 HARD DRIVE**

Many hard drives commonly used in laptop computers can withstand operational shock, it is common to go jogging while editing, and sometimes shoot momentary video while on horseback or riding a mountain bike down the centre of a line bumping over every railway tie, and capturing the experience on a hard drive. It is possible to carry enormous amount of hard drive space on your body. Prof Martin has 36GB hard drive installed in his wear. One of his waist bag systems contains 2GB of hard drive space and 512MB of RAM.
5.6 BATTERIES OF WEARCOMP

Low cost batteries

Early versions of wear comp used lead acid batteries. Lead acid batteries are typically available surplus. For constant application you will want to obtain at least two 12 Volt batteries.

High performance batteries

Li-Ion camcorder batteries are commercially available. A minimum of two batteries is required for constant running 12 Volt batteries.

5.7 VOLTAGE REGULATOR

These are used in order to keep the voltage of Li-Ion batteries constant as output voltage drops significantly, with usage from a full charge. Another reason for constant voltage is that various components of Wear Comp require different voltage

6. OPERATIONAL MODES

There are three operational modes in this new interaction between human and computer.

- Constancy
The computer runs continuously, and is always ready to interact with the user. Unlike a hand-held device, laptop computer, or PDA, it does not need to be opened up and turned on prior to use. The signal flow from human to computer, and computer to human, depicted in Fig a, runs continuously to provide a constant user interface.

![Diagram](image)

**Augmentation**

Traditional computing paradigms are based on the notion that computing is the primary task. Wearable computing, however, is based on the notion that computing is NOT the primary task. The assumption of wearable computing is that the user will be doing something else at the same time as doing the computing. Thus the computer should serve to augment the intellect, or augment the senses. The signal flow between human and computer is depicted in Fig b
Mediation

Unlike hand held devices, laptop computers, and PDAs, the wearable computer can encapsulate us (Fig. c). It doesn't necessarily need to completely enclose us, but the concept allows for a greater degree of encapsulation than traditional portable computers. There are two aspects to this encapsulation:

Solitude:

It can function as an information filter, and allow us to block out material we might not wish to experience, whether it be offensive advertising, or simply a desire to replace existing media with different media. In less severe manifestations, it may simply allow us to alter our perception of reality in a very mild sort of way.

Privacy:
Mediation allows us to block or modify information leaving our encapsulated space. In the same way that ordinary clothing prevents others from seeing our naked bodies, the wearable computer may, for example, serve as an intermediary for interacting with untrusted systems. Wearable computing can be used to create a new level of personal privacy because it can be made much more personal; if it is always worn, except perhaps during showering, it is less likely to fall prey to covert attacks upon the hardware itself. Moreover, the close synergy between the human and computers makes it harder to attack directly, e.g. as one might peek over a person's shoulder while they are typing, or hide a video camera in the ceiling above their keyboard. Furthermore, the wearable computer can take the form of undergarments that are encapsulated in an outer covering or outerwear of fine conductive fabric to protect from an attacker looking at radio frequency emissions. The actual communications between the wearer and other computers (and thus other people) can be done by way of outer garments, which contain conformal antennas, or the like, and convey an encrypted bitstream.

Wearable computing is a framework for enabling various degrees of each of these three fundamental modes of operation.

7. ATTRIBUTES OF WEARABLE COMPUTING
There are six informational flow paths associated with this new human--machine synergy. These signal flow paths are, in fact, attributes of wearable computing, and are described, in what follows, from the human's point of view:

1. **Unmonopolizing of user’s attention**:

   It does not cut you off from the outside world like a virtual reality game or the like. You can attend to other matters while using the apparatus. It is built with the assumption that computing will be a secondary activity, rather than a primary focus of attention. In fact, ideally, it will provide enhanced sensory capabilities. It may, however, mediate (augment, alter, or deliberately diminish) the sensory capabilities.

2. **Unrestrictive to the user**:

   It is ambulatory, mobile, roving; "you can do other things while using it". E.g. you can type while jogging, etc.

3. **Observable by the user**:

   It can get your attention continuously if you want it to; within reasonable limits (e.g. that you might not see the screen while you blink or look away momentarily) the output medium is constantly perceptible by the wearer.

4. **Controllable by the user**:

   Responsive:
   You can grab control of it at any time you wish. Even in automated processes you can manually override to break open and enter the control loop at any time (e.g. a big HALT button, for use when an application mindlessly opens all 50 documents that were highlighted when you accidently pressed Enter, would make a computer more controllable).

   Infinitely-often-controllable:
The constancy of user interface results from almost-always observability and infinitely-often controllability in the sense that there is always a potential for manual override which need not be always exercised.

5. **Attentive to the environment**:

   It is environmentally aware, multimodal, multisensory. (this ultimately increases the user's situational awareness).

6. **Communicative to others**:

   It can be used as a communications medium when you want it to. **Expressive**:

   It allows the wearer to be expressive through the medium, whether as a direct communications medium to others, or as means of assisting the production of expressive media (artistic or otherwise).

**Implied by the above six properties is that it must also be**:
Constant:

Always on, running, and ready. May have ``sleep modes'' but is never ``dead'' (unlike a laptop computer, which must be opened up, switched on, and booted up before use).

Personal:

Human and computer are inextricably intertwined

Prosthetic:

You can adapt to it so that it acts as a true extension of mind and body; after time you forget that you are wearing it.

Assertive:

Resists, if you wish, prohibition or requests by others for removal. This is in contrast to a laptop, in briefcase or bag, that could be separated from you by the ``please leave all bags and briefcases at the counter'' policy of a department store, library, or similar establishment.

Private:

Others can't observe or control it unless you let them. Others can't determine system status unless you want them to, e.g. the clerk at the refund counter in a department store where photography is prohibited can't tell whether or not you are transmitting wireless video to a spouse for remote advice, in contrast to camcorder technology where it is obvious you are taking a picture when you hold the camcorder up to your eye.

Note that a computer mediation device with sufficient bandwidth can synthesize or even heighten the augmentational aspects. For example a sufficiently attentive computer can sustain a sufficient illusion of being unmonopolizing that it could encapsulate the user and still provide the same experience as system running in the augmentational mode of operation.
Similarly, a sufficiently communicative machine, especially if "machine" is broadened to include mechanical mediation devices such as motorized exoskeletons, can synthesize the unrestricted attribute.
8. BENEFITS

❖ Hands-Free Operation

THE WEARABLE uses sophisticated voice recognition technology, with headset-mounted communication and display capabilities, eliminating the need for keyboards or other interface devices. This means that interrelated documents, records and checklists can be accessed by speaking into a tiny microphone and information and images can be presented in a light-weight, heads-up display. Consider the savings in time and productivity. No longer are keystrokes needed to search for records, footsteps required to go back and forth between the aircraft and maintenance shop, or minutes spent flipping through manuals or scanning microfilm data. While remaining at the worksite, users employ voice commands to pull up the relevant information and go about their work uninterrupted.

❖ Flexible by Design

Weighing barely two pounds, with a thin, low-profile shape, THE WEARABLE can be worn around the waist, inside a jacket or mounted in a fixed location. Unlike bulky, power-intensive, hard to use "brick" computers, conventional laptops, or pen computers, THE WEARABLE represents the difference between a toolbox and a tool belt. All the information found at the computer terminal or microfilm reader, such as maintenance records, manuals, parts inventories, etc., can reside in this "belt-on" computer. Users can access vital information as easily as asking for a particular manual reference or record.

❖ Comfort, Convenience, Power

Its light weight and flexible construction allow physical configuration of THE WEARABLE for wear in the most comfortable, efficient manner. All of this as well as full 486-class processing power, powerful memory, disk storage, and communications capabilities are combined with dependable flex circuit technology.
Modular Designs, COTS Components

Use of commercial technology and widely used industry standards such as the PCMCIA form factor standard means THE WEARABLE offers lower cost and easy, cost effective incorporation of new features and options. The modular design provides virtual plug and play capabilities for upgrades and enhancements. The system can also be used with a docking system for ready compatibility with traditional computer peripherals and resources.

Improved efficiency and cost savings

Hands-free operation means reduced data entry and retrieval times. It also allows information processing to occur at the same time - and in the same place - as the task itself. That means faster, more accurate data capture and communication and availability of information when and where it is needed. THE WEARABLE can also dramatically reduce paper. For example, maintenance crews repairing an engine can have thousand of pages of tech manuals immediately available to them electronically by voice command.

Wide-Ranging Applications

This innovative system for truly mobile personal computing can bring major improvements to a variety of military and defense applications including

- Reconnaissance/Special Operations
- Maintenance
- Training
- Operations
- Security
- Documentation/Logistics Support
- Telemedicine

From an infantry recon mission, to traffic control on a carrier flight deck, to maintenance and training functions, THE WEARABLE enhances performance and efficiency.
Conformal Computing

The same physical flexibility that makes this computer wearable also allows it to be shaped to fit easily into fixed locations such as a tank or a submarine. When space and weight are at a premium and the demand for processing and communications capabilities is high, THE WEARABLE can provide a solution.
9. APPLICATIONS

Wearable computer applications are currently being developed for a number of military applications. In the medical field, one research group is exploring the use of wearable computers to support medical personnel in the field. The system allows the medic to enter data concerning the condition of the patient into an electronic record using voice input. This critical data is relayed across a wireless network to a mobile communications center which in turn passes the information to the final treatment facility. In this way, the most current status information is available at all times so that the attending physicians can plot a treatment strategy well in advance of the patient's arrival. This advance information can save lives by reducing the time to diagnosis and subsequent treatment.

Another wearable computer application focuses on minimizing the time and personnel required to conduct a routine inspection of a piece of equipment. The wearable computer is used to guide the personnel through the steps of the inspection procedure while collecting whatever data is required. Advantages include less formal training requirements, enhanced accuracy of data collection, a reduction in inspection time, and a simpler method of updating and maintaining the required procedures.

Closely related to the inspection problem is one of supporting maintenance personnel in the debugging and subsequent repair of malfunctioning equipment. This support can be provided through simple documentation, an expert system assistant, or remote collaboration with an expert. As equipment becomes more and more sophisticated, the knowledge required to repair it typically increases as well. It is often not practical to distribute paper-based documentation to every site the equipment might be sent. Consequently, electronic documentation is becoming more common. Yet, until the advent of the wearable computer there has not been an effective means of delivering this information to a technician in the field.
9.1 Airline application:

- **Line Maintenance**
  While in the cockpit troubleshooting a system, the user realizes the need for a wiring diagram. Instead of returning to the office terminal to find the microfilm reader, he simply consults THE WEARABLE on his belt. With THE WEARABLE, the maintenance manual, illustrated parts catalog, or other reference manuals are with the individual at all times, eliminating time consuming departures from the worksite or mistakes made while rushing to find parts information. THE WEARABLE is capable of hosting any Windows-based application as well as the Airline Maintenance and Operations Support System (AMOSS), jointly developed by Computing Devices and Honeywell.

- **Shop Maintenance**
  A shop technician needs to look up instructions or parts information. And while assembling or disassembling a component, he must access appropriate procedures. With THE WEARABLE, there is no need to interrupt work flow by returning to a terminal or stopping to look up information. He simply buckles on the computer and instantly retrieves the information by voice command.

- **Inspection Review**
  After an aircraft comes into the hangar for maintenance, an inspector can spend as much time on paperwork as he does on inspection - recording findings on clipboards, copying them onto document cards, and then entering them into a computer. Using THE WEARABLE, he can simultaneously inspect aircraft, record the findings, and later download them into a central maintenance system via a standard network connection or wireless RF LAN card. Use of THE WEARABLE can result in time savings of up to 50%!
Navigator 2 is a multimedia wearable computer for a Boeing aircraft inspection application. It is used by US Air Force personnel. An inspector uses the system to examine the skin of a KC 135 aircraft for cracks and corrosion during introduction to depot-level maintenance. The location and type of each defect found is recorded on the Navigator 2 (using a graphical representation of the aircraft as a location indicator). This type of inspection requires crawling over all of the aircraft's skin, typically standing on a "cherry picker" but also attached via safety harness and standing on top of the aircraft. The primary input is a joystick providing general 2-dimensional input that is useful for positioning on the geographic-based input where location is important. The joystick is used in conjunction with speech to mark discrepancies. Field evaluations for aircraft inspection at McClellan Air Force Base indicate not only approximately a 20 percent savings in inspection time but also a dramatically reduced inspection data entry time from hours to minutes.

9.2 Military application:

Combat or other theater personnel can wear it as part of their battle dress or operation uniform. Support personnel, training staff, combat medics, and others can wear the system as they go about their duties - without the time consuming back and forth between the computer workstation and the task site.

❖ Intelligence

Man-machine data collection can generate more precise, accurate and useful data. THE WEARABLE's portability combined with communications networking capabilities makes intelligence data available in real-time while overcoming the distance handicap between the collection sources and the command facility. This provides commanders with greater operational control and flexibility.
Soldier

Warfighters are already burdened with equipment, weapons and supplies. THE WEARABLE gives combatants the advantage of unparalleled computing power and stored data with a negligible increase in weight. Used to improve the situational awareness of mounted or dismounted troops, including the special forces, THE WEARABLE is the next advancement on the digitized battlefield. Troops can use global positioning satellite interfaces to provide themselves and their commanders with their precise locations, report critical data on threats, and keep in close contact with the chain of command to receive orders, make reports, and request supplies.

Voice-activated software could be used, so the user could get any kind of information while they are working.

An electrician could be working on the wiring of a building, could say a few commands and could have the entire floor plan for the building immediately right up on the viewing screen. A lawyer could access necessary case information in a courtroom, he said.
Current applications of wearable computer in normal life:

1. **iPhone head-computer dock patent tips AR and other possibilities**

Apple’s iPhone gaming controller dock isn’t the only new patent application from the company to be published this week; the company is also pushing forward into head-mounted and wearable computer technology. Like the gaming patent, this latest proposition relies on taking an existing portable device – yes, like an iPhone or iPod touch – and combining it with a task-specific dock. Here, the dock is a head-mounted display system, with Apple envisaging an iPhone sliding into the side.

The rest of the patent describes the potential for different mounting designs, different materials from which the headset could be made, and possible applications. The latter includes a voice- and image-recognition system that could spot old acquaintances and flag their identity up, together with overlaying logos and other visual cues – for instance arrows – for GPS directions and the like.
2. *Universal Wrist Charger from ThinkGeek*

ThinkGeek offers a very portable, wearable universal charger they call the Bracer of Battery Life +2. Unlike most charge-as-you-go chargers, this battery-extender doesn’t ruin the sleek lines of your phone, mp3 player, or gaming device, and you don’t need a different one for each of your gadgets. You wear the Bracer on your wrist like a bracelet, and you’ll have a 1500 mAh, 5.5V power source at the ready. The Bracer has a rechargeable lithium ion battery that recharges with the included USB cable. There’s a power button, a power status LED, and a 4-LED power level meter. The Bracer comes with a universal power output cable and nine connectors. You’ll receive connectors for iPhone, Nokia I (3.5 mm), Nokia II (2 mm), LG, Samsung i900, Sony Ericsson, Sony PSP, NDS Lite, Nintendo DSi, and a mini USB connector for Motorola/HTC/Dopod/and many mp3/mp4 devices. It’s $34.99 from ThinkGeek.
3. **Sensors turn skin into gadget control pad**

Tapping your forearm or hand with a finger could soon be the way you interact with gadgets.

US researchers have found a way to work out where the tap touches and use that to control phones and music players. Coupled with a tiny projector the system can use the skin as a surface on which to display menu choices, a number pad or a screen. Early work suggests the system, called Skinput, can be learned with about 20 minutes of training.

4. **Personal Embedded Equalizer**

Here at ThinkGeek we’re constantly amazed at the never-ending evolution of new technology. Hey, it’s our job. Take the lowly T-Shirt for example: In caveman times you had animal pelts… the Medieval era saw rise to the stylish burlap sack… next came lovely soft cotton and then synthetic polyester. Finally the modern space age delivers a fully functioning graphic equalizer in a handy t-shirt format. Party like it’s 2999 with the glowing display on the T-Qualizer that dynamically changes with any ambient sound or music. This has to be the coolest wearable tech we’ve seen since the George Foreman backpack grill.
5. *Vuzix Wrap 3-D glasses promise big screen experience*

Can’t afford a big screen TV or projector but still want to experience that cinema feeling when watching a movie? The Vuzix Wrap 920 video eyewear is a sunglass-style display that delivers a virtual 67-inch screen as seen from 10ft away, displays 2D and 3D video and is claimed to be the most advanced wearable display available. It also features removable noise-isolating earbuds, an adjustable nose bridge and weighs less than 3oz.

The Vuzix Wrap 920 connects to all NTSC or PAL audio/video devices with video-out capabilities and composite video connections. The eyewear comes with a composite A/V adapter for iPod/iPhone for simple plug ‘n’ play connection to your portable media player. There are optional Wrap Adapter connections for HDMI-equipped devices and even desktop PC and laptops for watching movies.
6. Wearable computing research gains support

A project that aims to revolutionise the design of technologies for supporting research has been awarded a grant of about $2.6 million by the UK’s Engineering and Physical Sciences Research Council and the Arts and Humanities Research Council through the RCUK Digital Economy programme.

The multidisciplinary project, entitled PATINA (Personal Architectonics of Interfaces to Artefacts) will be led by the University of Bristol in collaboration with the Universities of Brighton, Greenwich, Newcastle, Southampton and Swansea. The project includes involvement from Microsoft Research, Nokia Research and the Victoria and Albert Museum.

The consortium will build wearable technologies that can identify objects such as books or historical artefacts and use miniature projectors to enhance those objects with related digital information taken from the web.
10. ADVANTAGES

- Enhanced Communication

- Wearable Computers can be used to recognise a person in a high alerted area such as an airport.

- A personal Wearable will facilitate the wearers needs

- Unlikely to be dropped or lost as their are embedded to the clothes as opposed to the handheld devices.

- Able to use wearable computers to complete daily tasks such as a computer which tracks the movements and habits of a person.

- Flexibility
- Freedom

- Work from anywhere

- Convenience

- Makes tasks more easier such as Wearable Computers can be used by Surgeons (a Wearable Computer attached to their arms), which can allow data to be transferred to their computers, this can save time where the surgeons can look at the wearable for information, this will help improve the efficiency of an operation.

Here is a prime example of a great advantage of wearable computing. There is a special shirt developed by VivoMetrics to monitor patients at hospitals, and which can also be used to accelerate new treatment trials.

There are many reasons to use wearable computing. Wearables augment and extend the capabilities of the wearer while preserving personal privacy and functioning over a wide range of situations and contexts. Wearable computing provides a means to leverage the power of personal information while at the same time providing the means to keep it private. Wearables consolidate the functionality of multiple devices into a single, integrated system.

Augmentation

Wearable computing enhances and empowers the wearer

Like any technology, wearable computing extends the reach and capabilities of a person. Wearables can provide enhanced communication, memory, sensing, recognition, and logistical skills. A wearable can filter your calls, provide a reference, monitor your health, remind you of a name, and help you catch a bus.

Agency

Trust and transparency; working for the wearer.

Unlike many technologies which work for someone else, a personal wearable is designed to facilitate, enhance, and work for the wearer. The user trusts the wearable because it belongs to them, because the interaction provides the user with sufficient oversight and understanding, and because the software's operation is understandable and open to evaluation (open source).
Privacy  
Turning Big Brother inside out.

Context awareness requires knowledge of context, which is gained through sensing and interpreting data from the wearer and the wearer's environment. This would be a privacy nightmare if this information were not under the wearer's control. The agency of the wearable turns the potential nightmare into a trusted, valuable resource.

Consolidation  
Gadget creep sucks.

Consolidating applications into an integrated context-aware environment allows for the elimination of redundant batteries, wireless network interfaces, packaging, etc. More importantly, it allows a top-level attention manager to broker all of these applications to make the best possible use of the wearer's personal bandwidth.
11. DISADVANTAGES

There are many disadvantages of using Wearable Computing. Below are a list compiled by the author of this post.

- Equipment can be heavy
- Expensive
- Some Wearable Computers can consist of a lot of wiring
- Can cause irritation in heat
- Side-Effects such as Headaches
- Wearable Computers can invade privacy
- Can be used to gain an unfair advantage over others such as Casinos
- Being tracked wherever you go
- Costly
- It may become easier to get data on an individual if the item is lost/stolen.

Although wearable computers have brought and will bring so much benefits to organizations. They still have some pitfalls. The disadvantages tend to present in following areas.

Firstly, the equipments can be very heavy. This is a considerable issue for the application of wearable computers in the field of army. The actions of soldiers will be slowed down by the heavy equipments, and this can be fatal for not only the soldier himself but also the whole battle. It is a challenge to integrate these piecemeal components into a lightweight package.
Another important problem involved with wearable computers is the cost. It is costly to purchase this type of computers and also to implement. In addition, companies have to invest heavily in training of employees to use the wearable technology most efficiently.

Also, the wearable computers can cause severe side-effects. A wearable computer has the potential to enhance the ability of astronauts to perform their tasks. The abdomen and upper back areas are the best locations to place wearable computers during the inspection. However, there are drawbacks that abdominal placement option suffering from. First, with direct contact with the bladder layer, the user will suffer a risk of damage.

The problems of wearable computers may also include the inconvenience caused by lots of wiring, irritation caused in heat, and data security.
12. LIMITATIONS

Wearable computers acquire all of the attributes and constraints of any wireless network. The gaps include limited bandwidth, seamless communication, and ubiquitous access. Other tough issues fall into four categories – technical, social, economical, and political. The technical issues involve protocols, mobility/disconnected operation, infrastructure maintenance, saturation and ubiquitous access. The social issues are primarily privacy and security. The economical issues are billing and commerce and the political issues involve access rights and spectrum ownership. (Boeing Wearable Computer Workshop, 1996)

The technology limitations associated specifically with wearable computers are primarily with the screen and with the means for controlling the computer. The head-mounted displays are still low resolution and the user may lose vision when moving about. There is not a seamless mechanism for inputting and outputting. (Gartner Group Analyst. Fenn, J. Personal Communication, 1999, July 27) Additionally there are limitations with the power supplies, heat dissipation, and bulkiness. Steve Mann experimented with the first class of Cyborgs this year at the University of Toronto. Students complained that the "Xyberbaut systems were not really all that wearable – at least, not comfortably for more than a few minutes at a time." The battery life was too short to allow online, extended use. Although the system supports a windows operating system, it remains cooler with a more efficient, less user friendly code. To gain wider acceptance, the cyborg outfit must become less cumbersome.
13. DOMINANT CORPORATIONS

There are basically four categories of leading corporations in this market sector. First there are small companies who specialize in wearable computers. These are in their early stages of corporate development and considered high risk. Second there are giant corporations who are targeting a small percentage of their research efforts to this specialty. Third there are large companies that are established in other specialties that would be well served by the growth of the wearable computer. These are viewed as having the best potential to become the leaders of the industry. Fourth, there are vendors who supply components to the wearable computer that see this market opportunity as a ticket to future growth and expansion. I shall provide short profiles of the dominant corporations for each of these categories. Some of the companies are small start up companies, for which I was unable to attain stock quotes or investor analysis but I will include the information that was available on the products, marketing strategies, and company visions.

**Xybernaut Corporation** (NASDAQ:XYBR), which is considered to be the leader in wearable computers today. Xybernaut was founded in 1991 and is located in Fairfax, Virginia. They provide hardware, software and service solutions for the wearable computer. Their customers are leading corporations and government agencies for many mobile knowledge delivery system applications, including maintenance and repair, inspection, inventory control, manufacturing and data collection. Xybernaut’s new MA IV wearable computer is voice activated and allows the user to move hands free while performing his or her work. It consists of a belt-worn computer, a color head-mounted or flat panel display, a one pound long-lasting, hot swappable battery pack, and integrated voice recognition software. (Xybernaut Corporation Homepage, 1999). For the first quarter of 1999 the company recognized its highest revenues which totaled $654,000. This reflected higher sales of the MA IV mobile computer system. The Vector Vest stock analysis gives the stock a relative value, safety, and timing rating of poor. The growth rate is poor. They recommend selling the stock. (PC Quote, 1999). According to Jason Byrne, a technical writer for the Washington Post newspaper, Xybernaut’s Mobile Assistant IV sends a mixed message that the "future is now but suggests there’s a better future ahead." He feels that it is suitable only for people with extreme mobility needs who are willing to cope with the shortcomings of the fledgling product. (Byrne, J., 1999)
Via incorporated in 1993 and is headquartered in Northfield, Mn. Last year Via, Inc. introduced Via 11, a commercially available wearable computer. Via 11 consists of an audio headset and a flexible electronics module worn around the waist. Full-duplex audio allows the processor to recognize verbal commands while delivering audio response. (Dun and Bradstreet, 1999)

Phoenix Group Inc. (PGI) was formed in 1994 and is incorporated in New York State, located on Long Island. Their product line includes Heads-Up Displays (HUD's) for operation in a true "hands free" environment through voice recognition. The products are designed for demanding industrial and military field applications that require high performance under harsh environmental conditions. They are well suited for vehicle, aircraft, shipboard, and outdoor filed applications. PGI's marketing strategy has been to focus on directly targeting potential volume users through an international network of sales representatives. Their customers include Fortune 500 Companies, the U.S Department of Defense, and Foreign Ministries of Defense. (Phoenix Group, Inc., 1999)

Speech Systems Incorporated (SyVox Corporation) develops custom speech recognition applications, specializing in mobile applications that can operate in noisy environments. Founded in 1981, SyVox Corporation supplies mobile information technology solutions to Fortune 500 corporate end users of industrial and professional applications. SyVox offers complete system design, site surveys, installation and support.

Orang-Otang Computers, Inc., headquartered in Sacramento, California, is the leading developer of arm-mounted computer and telephony products. Orang-Otang's intellectual property portfolio includes a wide range of wearable computing and communications devices, which offer user convenience and mobility. The "Peel" line of products, including the "Peel-It" and the "Outrigger" wearable personal digital assistant (PDA) cases are the first wearable computing accessories designed for the consumer market. Orang-Otang also publishes the first commercial periodical devoted to the wearable industry, Wearable Computing Magazine. (Orang-Otang, 1999.) They were founded in 1995 to make "Technology for Primates," a mission which includes liberating those primate-specific features of information technology users known as "hands." The Peel-It has intrigued the media as the least expensive way to own a fully internet-capable, wearable computer. Peel-Its come in all colors, including a new blue jean denim model. When in place on a user's forearm, the patent-pending Peel-It enables a PDA to swivel in place 360 degrees for easy sharing and viewing.
This swiveling feature is particularly useful for bar-code scanning operations where the user must have both hands free.

**IBM Corporation** carries the WorkPad as part of its product line. The WorkPad is a small, portable device that can be worn on the belt or fits into a pocket. It has the same basic computing capabilities as a laptop or notebook computer. The IBM WorkPad provides mobile users the capability of accessing and updating address books, calendars, scheduling, to-do lists, and expense functions. At IBM’s User Systems Ergonomic Research lab in Almaden, California work is being done on a number of variations of wearable computers. A personal digital assistant for grade-school children is one such effort. It looks like a slate that was used before paper was prevalent. It holds assignments, performs calculations, and helps kids manage their homework. It interfaces with other Kids’ Computers to facilitate collaboration, and it can access a teacher’s computer to download assignments or feedback. (IBM, Corp., 1999)

**Nokia** is a global company whose key growth areas are wireless and wireline telecommunications. A pioneer in mobile telephony, Nokia is the world's leading mobile phone supplier as well as a top supplier of mobile and fixed telecom networks and services. Mobile users gain significant benefits from substantially higher transmission speed. It makes possible new mobile applications such as shorter video Connection times. Users will be able send large files over mobile links that they could not send before. The Nokia HSCSD offers a way of satisfying the current demands of users with high mobile data use, while laying the groundwork to capture the lucrative data markets that will open up with the advent of third generation mobile systems. Nokia is also a leader in Wireless Application Protocol (WAP) that brings internet open standards to mobile phones. This will enable mobile phone users to access data.

**CASIO** first entered the digital watch market in 1974. Since then, CASIO has become the world’s leading digital watch manufacturer and continues to redefine the standards of the industry by creating innovative new products with features and functions for sports enthusiasts, business professionals, outdoor adventurers, and others with varied interests from all walks of life. CASIO has a complete line of watches for outdoors including models with direction and relative altitude sensors, plus other features that have made Casio products appealing to sports enthusiasts around the world. Casio first entered the Windows CE Handheld Personal Computer market in 1996. Since then they have produced the smallest palm held PC, a global positioning systems (GPS) wrist watch and several other innovative devices to address the needs of the mobile user. (Casio, Inc., 1999)
14. FUTURE TECHNOLOGY

NASA’s Johnson Space Center is also testing a wearable personal computer to monitor human statistics and speed up astronaut flight-simulator training. They are working with MIT and St. Leo College to determine the effectiveness of the wearable computer to enhance training.

The medical field is another area that is supporting research on wearables because there is such tremendous potential for use. Emergency-medical technicians could have instant access to lifesaving information, procedures and communications with specialists. People with disabilities could have increased mobility and enhanced living conditions.

In addition to these specific service areas, several corporations such as IBM are investing a portion of their research dollars into wearable computers and supporting technologies. For example the telecommunications industry has been adding data transfer capabilities over specialized mobile radio spectrum. Nextel Communications in Mclean, Virginia has expanded its services from data over analog to digital voice. (Dodd, A.Z, 1998) As the market interest in such capabilities expands, continued research in providing these types of services will respond accordingly.

Future Technological Trends

Wearable computer technology is rapidly advancing. Several commercial vendors have entered the market offering commercial off-the-shelf (COTS) technology upon which one can base a custom solution. These products are moving the technology out of the research laboratories and into the hands of real users. This device provides an advanced degree of comfort and ergonomic adjustments due to a flexible bus which conforms to the user as it is worn.

Additionally, we are investigating the use of a networked wearable computer equipped with a video camera and collaboration software to allow people in remote sites to work together. A technician can send live video and audio of a broken piece of equipment or problem to a remote expert. The remote expert can then collaborate through video and audio with the technician working on the problem to find a solution.
Wearable computers and EPSSs are being deployed today. Solutions to real support and training problems for mobile technical personnel are emerging rapidly. In the future we expect wearable computers and electronic documentation to become a standard component of any advanced weapon or surveillance system. Other applications will emerge in the industrial and consumer markets. These commercial applications will reduce the cost of development and deployment in the same way that widespread acceptance of the home computer has benefited businesses.
15. CONCLUSIONS

Continual advances in technology such as the increased processing power available in very small sizes of components and the expanded wireless telecommunications capabilities, have provided the foundation for an infrastructure to support the advancement of the wearable computer industry.

Wearable computing is still largely an emerging technology with considerable interest and potential for future growth and expansion. Today the technology is available and is beginning to be cost effective. These factors make it more than science fiction.

Wearable devices will be a key component in enabling pervasive computing to transform our society into a networked one -- where a digital persona will constantly analyze data and make decisions to provide access to content, services, and entertainment for anyone, at any time, in any place. Indeed, wearable devices will pave the way for gains in mobile computing that entirely transcends our current set of mobile devices and advantages they offer today.
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