

## **INVESTIGATING THE USE OF WEARABLE COMPUTERS IN CONSTRUCTION**

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### **ABSTRACT**

In the last few months a new kind of computer has caught the attention of many industries, a ‘wearable computer’: A computer that can be worn on a human body. Its mobility has made it useful in many places where a computer could not be carried before. Xybernaut introduced the company's ‘MAV-Mobile Assistant’ wearable computer, a device that is a fully functioning, networked computer for mobile business applications. Designed with the combination of Texas Instruments digital signal processor (DSP) and the Intel Mobile Celeron 500 MHz processor, the MA V is produced by IBM Corporation. The unit incorporates a belt-worn computer, color head-mounted display, 1-pound swappable battery pack and integrated voice-recognition software. Its potential in the construction industry is investigated, to establish its usefulness for the industry. This paper will discuss the wearable computer’s design, potential and the authors’ experience using this technology. A discussion with industry partners about the potential uses of this technology is also included in this paper.

### **KEYWORDS**

Xybernaut, Wearable computers, Mobile Computers

## **1. INTRODUCTION**

Today the latest technology is being used in the construction industry to save valuable time and money. Some of the new software and hardware is being developed specifically for the construction industry. Some of the more radical changes are occurring in the drafting, estimating, scheduling, and project management areas of the construction industry through the use of new software and hardware.

AutoCAD and SoftPlan are two drawing programs on the market today. Both are exceptionally good at helping the designer draw plans for a building. Plans can be generated in a fraction of the time that it would take a draftsman to draw the construction documents manually. Computers have also made the estimating process quicker and more efficient. Advances in software management programs like Timberline have allowed builders to manage data and price a product at the same time. Variables can be changed to fit ones’ specific needs, and there are multiple presentation styles available. Scheduling software provides contractors with an organized and efficient way to plan and keep track of their projects. Programs like Virtual Boss and Suretrack are so easy to use that one can update project schedules daily while on the project. The scheduling software also provides features to maintain to-do lists and contact information regarding the project. One such recent software, Constructware, allows contractors to track items and view secure documents such as purchase orders, contracts, and requests for information, etc., from any

location with online availability. Constructware also reduces cost through fewer personnel expenses, by keeping a project organized and by increasing communication.

Now that the construction industry has this technology, it just needs to learn how to use the technology it has, right? Wrong. The construction industry is on the edge of something that could drastically improve the entire construction process. That something is a 'wearable computer'. What if one could have all this technology, software, hardware, etc. and carry it around the jobsite? What if one could do a virtual site visit? This "...has the ability to bridge time/distance constraints imposed by working at remote construction projects...the opportunity for real-time decision making in construction is improved." (Mills and Beliveau, 1998) In a few years communication on projects might improve to the point one might wonder how this was accomplished before the wearable computer. Perhaps the attitude could be as David Mizell, who is in research and development at Boeing said, "John Q. Consumer has already voted—he wants a cell phone and a Palm, not some geek gear hanging down his nose." (Miller, 2001) Individual consumers might find this gear unfashionable, but yet, some might find it attractive.

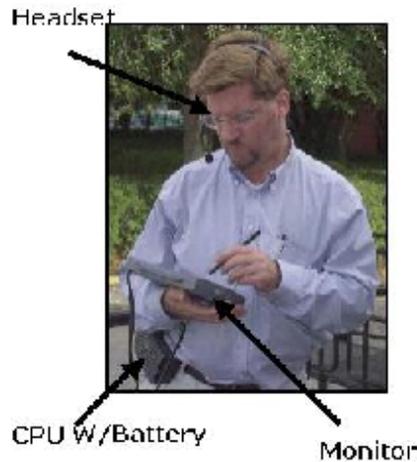
This paper is organized into two main parts. The first part describes the wearable computer technology, some recent research and a few general applications for this technology. The second part describes the potential uses in construction and includes information received from professionals in the construction industry as to their thoughts on the application of the wearable computer in the industry.

## **2. THE WEARABLE COMPUTER**

Construction has changed radically since the information age began. Historically, processing and storing information required a great deal of time and money. Communication was slow and in some cases just not even attempted because of the difficulties involved. Technology has been implemented in the construction industry in every phase. A project can be managed over the internet. Design drawings can be changed in an instant, on-site and large amounts of data can be stored for an estimate. A schedule can be altered and updated with the click of a mouse. All of these new processes and advances have the same purpose: to save time and money.

Construction has evolved into a very technologically minded business and will, most likely, only become more advanced in this area. A great example of this is the wearable computer. Most people have a somewhat simple notion of a wearable computer. A wireless phone with an endless array of features, or a wristwatch for some two-way communication and global-positioning system, maybe even a digital camera. (Makulowich, 2001) The notebook is not a mobile computer; it's a stationary computer that's easy to move. Some wearable computers can withstand a three-foot drop and are even water-resistant, and can withstand exposure to the elements. (AP, 2001) The general public was exposed to wearable computers in 2000 when IBM ran the commercial showing a young person on a bench in the park watching stock prices via his head-mounted display. He then startles all the pigeons around him as he shouts trades into his speech-recognition microphone. (Maney, 2001)

However, wearable computers typically include a microprocessor, memory, voice recognition, hard-drive, head-mounted display with microphone, video-output adapter, handheld mouse and wrist-worn keyboard. Currently the pieces of the wearable computer are a belt consisting of about two pounds of computer with battery and one pound of back-up battery on one side and a handheld touch-screen monitor in a pouch on the other side. A head-mount display screen of the width of a quarter is in front of the user's eye. The computer itself is a 500 MHz machine with 128 MB RAM and has an expandable 1GB hard-drive. Any operating system could be used with the system, such as Windows 98, Windows 2000 or Windows XP. The wearable computer currently costs \$9000 inclusive of all the accessories but as evidenced with any new technology, the prices will most likely decrease as practical uses increase.



**Figure 1: Wearable Computer being Worn**

In 1979, when Sony created the Walkman, its inventors felt that most people would be reluctant using the headphones in public because they would consider it unfashionable. They proceeded to put two headphone jacks in the device thinking it would be used by two people listening to music together. Obviously, they were wrong about these headphones. The lesson here is to never underestimate how far people are willing to go to accommodate new technology. (Maney, 2001)

Past experience with technology indicates that in a matter of few years, the wearable computer, will be smaller in size and better in performance. Hence the current design is in a way irrelevant as it relates to the possible long term uses of this device in construction and other industries, which will be discussed later. Already companies are working on building these computers into wristwatches. (Maney, 2001) As the designs become smaller, sleeker, and lighter, the fashion issue will most likely not be as significant.

### **3. GENERAL APPLICATIONS FOR WEARABLE COMPUTERS**

Before exploring the construction industry uses and benefits, let us examine the current or potential uses in other areas/industries. Currently, there are many companies using the wearable computer in their everyday business operations. Bell Canada is using the wearable computers on a daily basis. Their workers who climb telephone poles and go down in manholes are able to have their computer right on their body. This greatly reduces the number of trips they must make to their vehicle to, use their laptop. (Maney, 2001) The military uses wearable computers for repairs and maintenance. For example this allows personnel to crawl under an artillery tank and have all their technical manuals on-hand. (AP, 2001)

This technology also enables broadcast journalists and TV correspondents to write, shoot and edit stories from the field unassisted. People with disabilities can wirelessly control a computer. The wearable computer could be used as a universal language translator or a multi-diagnostic workstation for doctors. (Miller, 2001) A related item that has a great deal of potential is the Eyetap device. It is a digital video camera that is placed behind the head mount display. The Eyetap will make one's eye both a camera and a digital display. This way, whatever one's eye sees, the computer will see and can be broadcast anywhere to anyone at anytime. (Makulowich, 2001) Soldiers will be able to use satellite imagery of the battlefield, access global positioning and ballistic accuracy calculations with instant communications a click away using computers embedded in their uniforms. NASA plans to use wearable computers in the Mars space suits. (AP, 2001) Boeing and a few reporters are putting them to use. (Daragahi, 2001) In fact, Federal Express recently ordered \$1 million worth of wearable computers and plans to give these to their aircraft maintenance workers. (Maney, 2001) There are many more applications for these computers, that are either already being implemented, being developed or discovered. Obviously, they all cannot be mentioned here.

For the fashion conscious, current research is being conducted through the Defense Advanced Research Projects Agency. They are currently trying to bring together people and technologies in the textile and electronics industries.

They want to create a class of wearable systems made of fabric and woven into fabric. The program will enable systems where the electronics are integral with clothing. They can be rolled and crumpled up, and remain fully functional. (Merritt, 2001)

In addition to the companies currently using this device, some who are now experimenting with this technology are General Electric, Northwest Airlines and Ford Motor Company, to see if it will improve efficiency. (AP, 2001) Currently, one of the leading companies that produce the wearable computers is Xybernaut. Xybernaut indicated that at their first conference four years ago there were 80 people, and last year there were 700 people from 34 different countries. (Miller, 2001) Part of the reason for the increase in interest is the unlimited number of beneficial capabilities that people envision with wearable computer technology. According to some authors (Westling, 2001), by 2007, more than 60 percent of the United States population ages 15 to 50 will carry or wear a wireless computing and communications device at least six hours a day.

### 3.1 Construction Applications for Wearable Computers

A five-question preliminary survey was conducted with a few construction firms. The purpose of the survey was to investigate the potential uses for the wearable computer technology and the interest in the industry. The questions and their responses are presented in table one below. Executives from upper level management answered the survey. The survey was sent to 27 companies and 8 companies responded to it.

**Table 1: Survey questions and their responses.**

<p>Questions 1: Please select which of the following mobile computing / communicating devices you use in your firm? A. Cell Phone                      B. Laptop                              C. PDA (Palm Pilot) D. Wearable Computer      E. Job Site Video Camera      F. Others (Please Specify)</p>
<p>Answer 1: All firms responded they were using cellular phones and laptop computers on the job site. Some firms indicated that they were using PDAs', job site video cameras, two-way phones and digital cameras.</p>
<p>Questions 2: What data do you record on the job site? (all information that you write down in a form or record in a device such as number of cubic yards of concrete poured, slump of concrete, temperature etc.,)</p>
<p>Answer 2: While each firm had a unique response to this question, it was concluded that all firms were gathering similar information. This information includes equipment log, material log, employee log, sub contractor log, weather log, safety log, daily progress, change order and submittal log, progress photos, meeting minutes, visitor log and general remarks.</p>
<p>Questions 3: What data is needed by your staff, on the job site to perform their duties? (all information such as a set of plans for the superintendent, a copy of the schedule for the project manager etc.,)</p>
<p>Answer 3: The respondents indicated that the information required by the personnel on the job site to complete their duties includes plans, specs, shop drawings, contract document, schedule, estimate, list of subcontractors and vendors, cost code list and owner billing information.</p>
<p>Questions 4: If you had a computer that was smaller than a laptop and was more ergonomically built with all the software of a laptop/desktop, connected to the internet, what applications do you foresee for it on a construction job site?</p>
<p>Answer 4: All respondents indicated that the convenience of being on-line on the job site would enable them to contact the home office, architects, engineers, owners and sub-contractors instantly and therefore reduce time for communication. They also indicated that they would be able to keep daily task lists, update schedule, use e-mail and other software while they are on the job site.</p>

Questions 5:

Would your firm be interested in testing the applicability of wearable computers on a construction job site? (free of charge to your firm)

Answer 5:

All respondents indicated they would be willing to experiment with the wearable computer in their job sites.

The survey indicates that the construction industry is already using digital technology to improve performance on projects. It is also evident that an enormous amount of data is recorded on the job site by construction personnel. Also a lot of information is required to complete a project successfully. The respondents were encouraged by the prospect of communicating using a computer while on the job site, instead of going to the job trailer. All respondents indicated that they would be willing to experiment with this technology, thus indicating that there is a tremendous potential for the success of wearable computer technology.

The next step in the process must be to actually put the wearable computer to test in the field. Based on the preliminary survey above, an experiment must be designed to investigate the use of this technology on the job site to perform the tasks mentioned by the respondents in question four of the survey. A cost-benefit analysis must also be performed as a part of the investigation.

In the construction industry specifically there seems to be some excitement. Heckman (2001), says the wearable computers first buyers would likely be professionals in the construction industry. Also, FIATECH, a research and development group of owners, operators and suppliers have a two-year goal to introduce wearable computers to the construction industry. Their idea is simply to seamlessly integrate hardware and software into lightweight, portable, secure, safe and effective wearable computer systems for construction, operations and maintenance field personnel. (Newland and Owings, 2001) Jim Porter, with Dupont says, "In today's competitive environment, we need to be able to access data, drawings, and other information on demand remotely at the construction site. Wearable computers will allow us to do this." (Newland and Owings, 2001) FIATECH will record the activities of people in the field to understand how their work is done and how it can best be improved through the use of a wearable computer. (Newland and Owings, 2001)

As mentioned previously, the construction industry already uses a great deal of existing technologies. Most are separate devices and/or located at some fixed location. One of the major issues with the construction industry is that the production activity is dispersed and the site locations frequently change. This is a disadvantage for the construction industry that most other industries do not have. This makes IT support and integration for the construction industry more difficult. (Rebolj, et al 2000) This in turn makes it a great candidate for the wearable computer or mobile computing. In addition, effective communications is the most important component for successful projects. Communication between the participants on a job site is difficult due to the large number of participants, their remote locations, the visual nature of many issues/solutions, the use of diagrams/pictures, the number of problems that arise at the site and the need for them to be solved on-site. However, it is also exactly these kinds of issues that might make the wearable computer a very effective, efficient, useful and beneficial tool for construction. Since the construction industry is so heavily dependant on information flow and communication, it is sometimes frustrating when one wishes to communicate from the construction site. Being on a remote location and having insufficient technology infrastructure quite frequently limits the frequency and effectiveness of the communications. Wearable computers offer a way to improve this situation, especially if a visual link is provided by some mobile video transmission system. (Miah, et al 1998)

Although this may be true for many industries, certainly for the construction industry the wearable computers and all attached devices must be accessible, lightweight, and easy to use. They must be able to withstand all types of weather and environmental conditions. For example, the screen should be readable in all types of lighting, the computer should be impact resistant, have rechargeable batteries and a host of other functions and ergonomic features. (Newland and Owings, 2001) The ability to have hands free operation of the computer is a critical benefit for the construction industry. It would be a tremendous benefit if a construction worker had electronic access to project documents such as, specifications, drawings, shop drawings, and catalog cut sheets, while on the site and hands free. In this situation, the wearable computer would be invaluable. Consider inspectors looking over a new building before giving the certificate of occupancy. They use wearable computers to review suggestions and pull up site drawings and other related documents for the final report, which they could then email back to the construction firm via wireless wearable computer devices. Other applications are numerous and impossible to number. Access

data instantly, check drawings on the fly, review critical safety information, standards, codes, update documentation and diagrams, decrease work-cycle time, more up time and less redundancy are all potential advantages of this emerging technology. Wearable computers will change the way work is done in the field. (Newland and Owings, 2001)

A company in Japan called Daito Trust Construction Company used a version of the mobile computer and made the process of construction easier and greatly increased productivity. They reported four main benefits of the system: redundancy of tasks was eliminated, reduced response waiting time, limited revision of job tasks, and access to new construction standards. (Rebolj, et al, 2000). Research done by Rebolj, et al (2000), shows that the efficiency of communication between the participants with current mobile computing components at a construction project site can be significantly improved. For example, PDA's currently available, mobile phones and web services are such components. However most of these items, although performing well, did not hold up well to dust, strong light, rain, and handling by workers.

The question of whether it can be used or not, is yes. How it can best be used remains to be seen. However, the application most likely will be a combination of all examples presented. It does seem likely that for things such as, requests for information, equipment management, schedules, means and methods, submittals, materials management, cost management, jobsite record-keeping, quality assurance, quality control, access to standards/codes, access to plans/specifications, virtual site visits, live voice, live video, and live data transfer, the wearable computer does offer a great deal of improved efficiency; saving time and money.

Like most other industries, the construction industry is interested in using this technology to improve their performance. While there is really no way to completely answer how this would be accomplished at the present time, the responses to the survey and the literature search indicate that this topic is worth further research and investigation.

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