

**The Issues Involving the  
Implementation of a “Virtual Visit”  
on a Construction Site**

by

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(ABSTRACT)

During the construction phase of a project it is vital to have good communication between all of the parties involved in the construction process. A construction project is dynamic in nature, and is constantly being changed due to issues involving design and structural improvements, constructability issues, or simply an altering of the original design intent. All of the parties must act together to maintain a high quality of work and initiate any changes, as they are needed, so that the whole project does not suffer from lost time and inefficiency.

When changes are initiated on a construction site, it is not always possible for the desired personnel to be on-site. In these instances a decision must be made whether to travel to the site, or to allow the decision to be made sight unseen. This thesis offers an alternative solution to this dilemma, a “Virtual Visit” system. The idea of a “Virtual Visit” system is to allow personnel to view, evaluate, or to clarify in their own minds what is occurring on

the construction site. This is accomplished by augmenting typical telephone conversations with video, combined with the data storage and retrieval capabilities of a computer.

This research conceptualizes a “Virtual Visit” system, and models aspects of the system in order to test it’s potential on a construction site. The “Virtual Visit” system is designed to store and retrieve data collected on the construction site and permanently stored it in an archival network. The data collected on the site can take the form of video, audio, and text. The combination of these three formats allows for the documentation of construction activities in a clearer, more readable format than traditional methods.

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# ***Chapter 1***

## ***Introduction***

This chapter summarizes the background associated with the “Virtual Visit”. The chapter further discusses the objectives of the thesis, the scope and limitations of the thesis, and the methodology used during the research.

## ***1.1 Background***

During a construction project three primary parties dictate how a project will be built: (1) the owner, (2) the architect and design engineer (A/E) and, (3) the general contractor. Although every construction project and the interaction of the three primary parties is different, it can be said that generally the owner dictates what is to be built, the A/E takes the vision of the owner and creates the design and specifications for the project, and the contractor then builds the project to those design and specifications.

During the construction phase of a project it is vital to have good communication between all three parties. A construction project is dynamic in nature, and is constantly being changed due to issues involving design and structural improvements, constructability issues, or simply an altering of the original design intent. In any case, the three parties must act together to maintain a high quality of work and initiate any changes as they are needed so that the whole project does not suffer from lost time and inefficiency.

Evaluating the quality of work as well as any proposal to change the original specifications can be the responsibilities of either full-time on-site personnel (ONP) acting as inspectors, or visiting off-site personnel (OFP) overseeing the work periodically. When the persons responsible for making changes are present on the construction site communication problems are minimized. Any necessary decisions can be made quickly and documented immediately. Unfortunately, the proper personnel are not always on-site, and while some

issues can be handled through telephone conversations, other issues may require an on-site visit. These visits are not always possible, however, forcing the resolution of the issues to be delayed or handled by less experienced personnel. Even when these visits are possible, the OFP sometimes comes to the site only to realize that the visit was unnecessary. At this point the OFP's time has been wasted on an unnecessary trip that might have been avoided with better communication.

An alternative to an actual on-site visit is a "Virtual Visit." A "Virtual Visit" is defined as a visit to any location, in this case a construction site, that occurs without an individual actually being there. The idea of a "Virtual Visit" is to allow personnel to view, evaluate, or to clarify in their own minds what is occurring on the construction site. The "Virtual Visit" is designed to give off-site personnel a better option when visiting a site is inconvenient or impossible, or when the determination of whether or not to visit a site must be made.

The concept of the "Virtual Visit" is to improve communication between the ONP's and the OFP's by augmenting typical telephone conversations with video combined with the capabilities of a computer. The video allows the OFP's to better understand what is occurring on the site, while the computer allows for data storage and retrieval of still frame images from the video as well as any other information gathered during the "Virtual



Visit.” This allows the “Virtual Visit” to become a documented record that can be easily retrieved for later viewing by any of the parties involved.

The goal of this research is to conceptualize the necessary components of a “Virtual Visit” system, and test aspects of the system on actual construction sites.

## ***1.2 Research Objectives***

Determining the possibilities of a “Virtual Visit” system first requires that the system be modeled and that the system’s capabilities be tested. Specifically, the objectives of this research are:

1. To conceptualize the “Virtual Visit” system as it relates to evaluation and clarification of activities occurring on a construction job site.
2. To develop a working model and test the limits of a potential “Virtual Visit” system as they relate to the users and data transfer.
3. To introduce a proposed format for a data storage and retrieval system to be used with a “Virtual Visit” system.
4. To develop security issues involved in data storage and retrieval particular to a permanent archive and conceptualize a process for addressing the issues.
5. To discuss the potential of future technology and recommend future action related to the “Virtual Visit” system.

### ***1.3 Research Scope & Limitations***

The goal of this research is to provide a conceptual framework to allow for a “Virtual Visit.” This conceptual framework includes issues of the users, data transfer, and data archiving and security. The research (1) addresses existing technology related to the “Virtual Visit”, (2) uses the existing technology to conceptualize a “Virtual Visit” system; and, (3) discusses future technology and how it relates to a “Virtual Visit” system.

Due to the time and money constraints associated with a thesis, limitations had to be placed related to the development and actual testing of the discussed issues. The research limitations are:

1. This research does not attempt to develop a complete working system. The research instead looks into the specific issues that, given that a “Virtual Visit” system existed, would occur while attempting to implement it on a construction site.
2. This research will not construct an actual archive. The research does, however, look into the security issues associated with archiving information electronically and creates a basic structure.

## ***1.4 Research Methodology***

There are two tasks related to this research: (1) the literature review of existing technology that is used to define a conceptually possible “Virtual Visit” system and, (2) the field research, using a model system, to test specific aspects of the “Virtual Visit” system.

### **1.4.1 Conceptual “Virtual Visit” System**

Research has been done on existing technology, covering issues such as data transfer, data storage, CPU's, teleconferencing, etc. The goal of this research has been to conceptualize a “Virtual Visit” system. The research on the existing technology has occurred primarily through pamphlets and discussions with personnel from research and development firms. This has been necessary due to the level of technology required to create a working “Virtual Visit” system. It has in fact been found that some of the technology discussed was in the prototypical stage at the time of this writing. The specifications and parameters associated with the conceptual system were current at the time of this writing; however, due to the improvements and public interest in this technology it can readily be assumed that the parameters are being improved rapidly. It is for this reason that future technology is discussed in the final chapter that may further improve the “Virtual Visit” system.

### **1.4.2 Field Research**

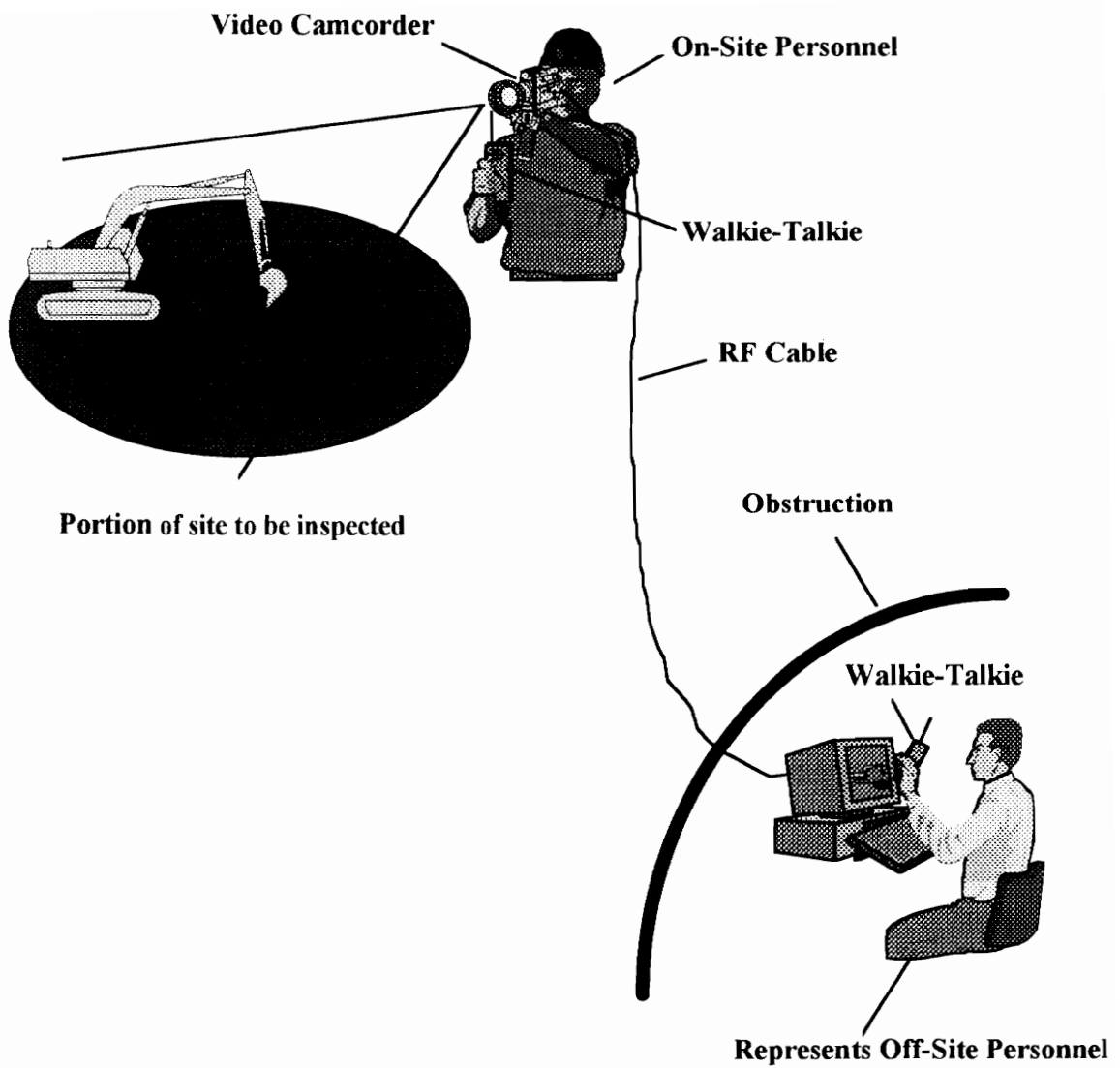
There are several issues involved in the field research. These issues are broken down into three phases consisting of: (1) the development of a data storage and retrieval system

(DSR) that is used in phases two and three which are, (2) the construction of a model system that is used to determine the limitations of examining a construction site virtually, and, (3) the testing of the effects that the transfer of data has on the efficiency of the “Virtual Visit” system. These phases are discussed in Chapter Five, “Validation of the Virtual Visit System.”

In Phase One, the data storage and retrieval system, or DSR, was developed using a customized database. It is capable of storing audio, video snapshots, as well as standard information deemed necessary for future retrieval and analysis. The decision as to which fields appear as standard information was based on studies of similar databases. The goal was to store as much relevant information as possible, while still allowing for good organization of the data, and thereby efficient retrieval.

In Phase Two, a teleconferencing system was used to simulate a “Virtual Visit” (see Figure 1-1). Instead of the teleconferencing camera being stationary, it was moved by an ONP throughout the site relaying video information to the OFP. The OFP sat at a computer terminal at the construction site and attempted to run evaluations of the construction site using only the information on the computer screen and an audio conversation facilitated by walkie talkies held by both personnel. The information that was collected in this simulated “Virtual Visit” was stored in DSR for later retrieval. The effectiveness of the system, both the visit and DSR, was evaluated by the OFP and used

to determine how much an actual “Virtual Visit” system can accomplish on a construction site. It also determined the reaction of construction personnel to the technology and the level of experience in construction and in computers necessary to operate the system effectively.



**Figure 1-1 Model Set-up**

In Phase Three, DSR was placed in a teleconferencing environment in order to test the effect that data transfer has on the efficiency of the system. This phase had two primary goals: (1) to determine how effective a large transfer of data can be when run over ISDN lines<sup>1</sup> and, (2) to determine how the development of the software (DSR) and hardware must be altered in order to compensate for any data transfer deficiencies.

## ***1.5 Thesis Organization***

The thesis is divided into six chapters:

The first chapter summarizes the background associated with the “Virtual Visit”. The chapter further discusses the objectives of the thesis, the scope and limitations of the thesis, and the methodology used during the research.

The second chapter reviews the three primary parties involved in the construction process as well as two organizations in which the parties interrelate. The communication problems associated with the parties are discussed as well as problems occurring from inefficient data storage and retrieval.

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<sup>1</sup> ISDN stands for Integrated Services Digital Network. ISDN lines are high speed lines in which information is passed in a digital format. ISDN lines are discussed in Chapter Three “Existing Technology.”

The third chapter reviews the existing technology that was used as “building blocks” for creating the conceptual model introduced in Chapter Four.

The fourth chapter proposes a conceptual model for a “Virtual Visit” system. The model is based upon the technology introduced in Chapter Three. The model is broken down into four categories: (1) the mobile on-site computer unit (MOCU), (2) the data transfer from MOCU to the OFP’s, (3) the data storage and security issues associated with a permanent archive, and, (4) the software parameters.

The fifth chapter attempts to validate the “Virtual Visit” model. This chapter includes research done on three aspects of the model: (1) the development of the Data Storage and Retrieval System (DSR), (2) the determination of the limitations of examining a construction site virtually, and, (3) the effects of data transfer rates.

The sixth chapter discusses future technology as it relates to the “Virtual Visit” system, and presents conclusions and recommendations for further research related to the “Virtual Visit” system.



## ***Chapter 2***

### ***Background Information***

This chapter reviews the three primary parties and their traditional roles within the construction management process. The interrelationships of the three parties are discussed as they relate to two organizational structures - the traditional designer/constructor organization and the owner/builder organization. The roles and interrelationships of the parties are used to illustrate common communication problems that occur between the three parties. The issue of data storage and retrieval on a construction site is also introduced.

## ***2.1 The Primary Parties Associated With the Construction Management Process***

In the management of a construction project, three parties are primarily responsible for the successful completion of the project. The three parties are: (1) the owner, (2) the architect/ engineer (A/E), and, (3) the general contractor. Each of these parties has a distinct role that must be played in the construction process in order for a project to be constructed successfully. These three parties must come together as a team with the goal of completing the project at a high level of quality, within budget, and within the required timetable (Oberlender, 1993). The roles defined in the following sections are the roles traditionally given to each of these parties.

### **2.1.1 The Owner**

The owner is the party that finances the project and therefore dictates what is to be built. It is the owner's vision or design intent of the project that the A/E attempts to design and the general contractor attempts to build. During the course of a project the owner sets the overall policy and selects the appropriate party to take charge of the project (Hendrickson, 1991). The owner can either be private, ranging in size from one person to a corporation, or public such as a state or federal government. In either case the owner has the final say on all issues, though he/ she may choose to delegate that authority to the party (such as the A/E) that has been placed in charge of the project (Clough, 1989).

### **2.1.2 The Architect/ Engineer (A/E)**

The A/E is the designer of the project. He/ she attempts to take the vision of the owner and create it in the form of specifications and designs. During the course of a construction project the A/E is responsible for clarifying the design as well as making any changes requested by the owner or required due to constructability issues. An A/E firm can be either publicly or privately owned.

An example of a publicly owned A/E firm is as a division of a state agency such as a state Department of Transportation (DOT). In this case the A/E is considered to be an in-house designer and designs work specifically for the public entity. On the other hand a privately owned A/E firm is sought out by an owner and contracted to design the owner's project. In either case the designer is responsible for designing a project within specifications that meets with the approval of the owner (Clough, 1989).

### **2.1.3 The General Contractor**

The general contractor is chosen by the A/E or the owner and given the responsibility for completing the construction project as per design and specifications unless a change is issued by the A/E (Clough, 1991). Typically the general contractor will subcontract out portions of the project to other contractors. These subcontracts are given: (1) to help minimize the risk taken by the general contractor, (2) to comply with a state or federal requirement or, (3) because the subcontractor has developed an expertise in his/ her

specific area. Throughout the project the general contractor acts as the on-site administrator and coordinator of all of the work. The general contractor also acts as the liaison between the construction site and the A/E and owner.

## ***2.2 Organizations of the Parties***

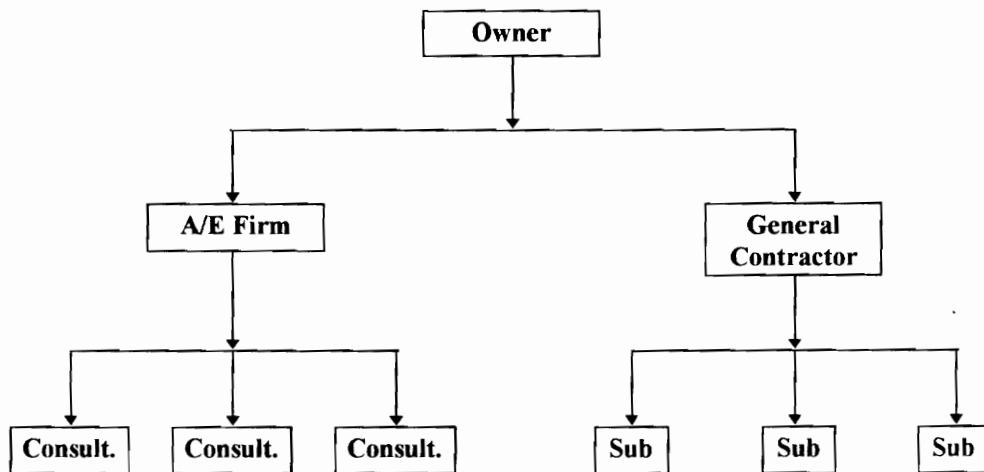
In construction there are numerous ways to organize the construction parties and to develop the responsibilities of each party. For the purposes of this research, two organizations are used - the traditional designer/ constructor organization and the owner/ constructor organization. These organizations are illustrated so that the issue of communication between the parties can be better understood.

### **2.2.1 Traditional Designer/ Constructor Organization**

In the traditional designer/ constructor organization the A/E acts on behalf of the owner to oversee the project implementation during construction (Hendrickson, 1989). The A/E observes the work of the contractors to generally insure that the work is within specifications. Any changes or deviations to the specifications by the contractors must either be approved by the A/E, or brought to the attention of the owner by the A/E.

The construction of the project remains the responsibility of the general contractor. The general contractor usually will place a project manager (PM) and/ or superintendent in charge of the project and its day to day operations. The PM may or may not be present on the site full-time, while the superintendent generally remains on the site. Project engineers

may also work under the PM and superintendent on larger projects. Figure 2-1 shows an organizational chart of a traditional design/ constructor organization.



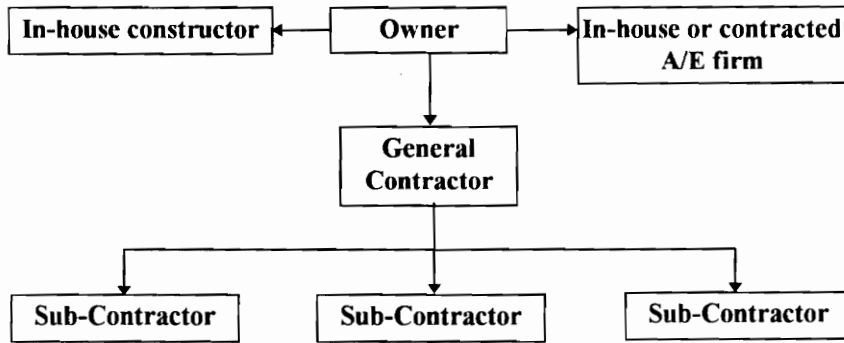
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**Figure 2-1 Traditional Design/ Constructor Organization**

### **2.2.2 Owner/ Constructor Organization**

The owner/ constructor organization is similar to the traditional design/ constructor organization. The difference is primarily that the owner is more involved in the construction process. Unlike the traditional design/ constructor organization, the owner may have access to in-house designers (A/E's) or in-house builders in addition to the body of private A/E's and contractors. This allows the owner more flexibility in delegating work. The owner makes most of the decisions on the job regarding changes or interpretations of the design and specifications, and may retain the responsibility for the

inspection of the work as well (Hendrickson, 1989). Figure 2-2 shows an organizational chart of the owner/ constructor organization.



**Figure 2-2 Owner/ Constructor Organization**

### ***2.3 Inspection of the Project***

During a construction project it is necessary to be sure that the job is being completed at a high level of quality and to design and specifications. It is also necessary to maintain records for the work concerning productivity, quality, and cost. The process by which this is accomplished is generally known as inspection of the project. Inspection of the project can be as precise as a soil sample or slump test, or as inexact as a 15 minute viewing of the site. The level of inspection is in part determined by the activities being completed on the site, the requirements of the owner, and the competence of the people performing the work.

Inspection of a site can be accomplished primarily in two different ways. A full-time site inspector(s) can be on hand to evaluate and report on every aspect of the work as it is accomplished. The inspector generally can work with the constructor and solve most minor problems without the use of outside help. The on-site inspector usually reports to a supervisor that visits the site periodically. It is this superior that must sometimes be present in order to avoid and/ or make changes on the site. This form of inspection is called total inspection (Brock, 1986).

The second form of inspection is called phase inspection. Phase inspection is a methodology that recognizes that adequate quality control can be obtained on most contract items by inspection at predetermined stages of completion of the various work activities. Generally, the stages are identified as the point at which contractors can proceed no further without eliminating the opportunity for the inspector to verify that the construction is in conformance with the contract plans and specifications (Brock, 1986). At these stages a representative from the supervising party comes out to the site at predetermined inspection dates to check on aspects of the job and determine whether the job is being constructed correctly. An example of phase inspection is shown in Figure 1-3 (Virginia, 1983).

STAGE	INSPECTOR ACTIVITY	OPERATION PHASE RELATION	MAJOR OBJECTIVE OF INSPECTOR ACTIVITY
<b><u>PIPE CULVERTS &amp; STORM DRAINS</u></b>			
(1)	Check pipe layout & cross-section areas involving minor structure excavation	This phase is critical & must be performed prior to contractor beginning excavation operation or disturbing original ground elevations.	To insure placement of pipe in proper position relative to stream, topography, entrances, & outfall conditions. Provide quantitative data to determine minor structure excavation.
(2)	Cross-section completed area of excavation if minor structure excavation is involved. Explore foundation, check line, grade, termini, source of pipe bedding (local, commercial, etc.).	This phase is critical & must be performed prior to actual placement of the pipe bedding material.	Ascertain uniform foundation, proper line & grade. Complete the gathering of quantitative data to compute minor structure excavation. At this point all inspector activities have been performed to permit Contractor to commence placement of pipe bedding material.
(3)	Inspect placement of pipe bedding material over normal earth foundation	This phase is critical & must be performed prior to placement of the pipe.	To insure placement & depth of bedding material to give a lightly & uniformly compacted bed shaped by means of a template cut to match the lower sector of pipe as outlined in the specifications.
(4)	Check pipe, test data, material for sealing joints, bolts, bands, etc.	This phase is critical & must be performed prior to placement of pipe.	To verify material quality.

**Figure 2-3 Phase Inspection Guidelines (Virginia, 1983)**



It should be noted that no matter which form of inspection or contracting is occurring on a site, site visits by party representatives that serve other functions than inspection occur on every job site. A project manager or A/E may make site visits in order to be kept abreast of the situations occurring on the job site.

## ***2.4 Communication Problems Associated With A Construction Project***

Numerous articles have been written involving the importance of communication to a construction project. Good communication can help to ease issues such as design changes by allowing all parties to explore the implications of the changes (Rwelamila, 1994). With the increase in size and complexity of today's large projects, the communication channels on a project have increased drastically and have contributed to a steady decline in construction productivity over the last few decades (Tucker, 1986).

During the course of a construction project, problems develop involving design changes, constructibility issues, etc. The minor problems can generally be handled immediately by on-site personnel, such as a full-time inspector. The more complex or complicated problems, however, sometimes exceed the expertise of the on-site inspector. In a study conducted by (Hanna, 1994) it was found that many inspectors were not knowledgeable about the plans and codes, and were not qualified and competent. In the case when off-site help is required, good communication is essential. Sometimes a phone discussion with

an expert OFP will suffice and the situation can be resolved. Other times, however; a phone discussion will not suffice and the best alternative is a site visit by the OFP.

A site visit has the advantage of allowing the OFP to see firsthand the issues that are affecting the project. When a site visit is not possible, however; resolution of the issues becomes more difficult. The OFP may elect to allow less qualified personnel to make the decision in lieu of his/ her site visit. This option has the disadvantage of putting the project out of the hands of more experienced personnel. The OFP may alternatively elect to delay the decision until he/ she arrives at the site. This option has the disadvantage of delaying the project and possibly disrupting the plans of one of the other parties.

In an effort to reduce the above scenario and improve communication between the parties, site meetings with all of the parties present have become endemic in project life. The meetings have been used to share information, monitor and control the project, and coordinate among themselves (Rwelamila, 1994). The limitation of site meetings is, however; that they occur generally about once a month, and with the fast track pace of today's construction projects this is not always enough.

Lack of familiarity with the project by the primary parties can result in poor communication and can inflame relations. The ability to communicate effectively from the site to the OFP's improves the OFP's understanding of day to day activities, and also

allows the OFP's to react to current situations before they become problems. The ideal scenario is more site visits by the OFP's. Unfortunately most OFP's, such as the owner, A/E, or PM, have other responsibilities that do not lend themselves to spending time traveling between sites.

### ***2.5 Problems Associated with Current Methods of Data Storage and Retrieval***

The process used for the construction of most projects is characterized by fragmentation and paper-based exchange of data. This leads to inefficiencies in and lower quality of the construction process (Teicholz, 1994). The construction process deals in a large amount of data. This data includes but is not limited to: the specifications and designs, inspection and change order approvals, daily and monthly progress reports, accident reports, test reports, billing information, and notice to claims (Brock, 1986). The amount of data that the construction industry deals with makes storing it in a manner that allows for easy retrieval vital. Unfortunately this job data often finds itself in a box with a hundred other pieces of data just like it where it becomes difficult to retrieve.

A paper written by Sanvido (1992) describes a process for developing a site-level construction information system. The goal of the system is to support decision-making. One of the key elements in the development of productive, on-time solutions, is data collection and data analysis. On a construction site quick decision making is often vital to a project and the analysis of this data is the key to that decision making. If the data is not

organized efficiently then an excessive amount of information might overload the decision makers. Galbraith (1974) stated that decisions are slowed or become ineffective when decision makers are faced with more information than they can process.

The construction industry is in need of improved methods for the storage and retrieval of data as well as improved methods of communication. This is illustrated by research that is currently being conducted in the United States. Three excellent examples are the research by Caywood (1995), Thorpe (1995), and Liu (1995).

Caywood (1995) proposed and tested a pen computing system as a way of documenting inspections occurring on Virginia Department of Transportation (VDOT) jobs. He also proposed a mobile inspector van that could travel between jobs. This van would be kept well informed by advanced communication systems located in the van and could either download or upload data to the pen computers, which in turn could be used for on-site inspections. In this way permanent on-site inspectors would be replaced by mobile inspectors. This movement towards mobile communication on a construction site demonstrates the construction industry's commitment towards better communication as discussed in this paper.

Thorpe's (1995) research focused on enhancing construction communication using multimedia, and was tested on a design-build contract known as the Barking Power

Station project. The enhanced communication included a video diary, which was used to allow the shift labor to better communicate from one shift to the next. The footage was also used to illustrate problems and progress, as well as daytime site conditions for the night shift. In addition to the video diary, a teleconferencing link was created between the site and the designers in order to allow for real-time communication and better interaction between the designers and the constructors. Finally, Thorpe proposed a remote teleconferencing system for the evaluation of a project. Both the improved communication as well as the proposed remote teleconferencing illustrates a recognized need by the construction industry for improvements in these areas.

The third example is the electronic hard-hat that is proposed by Liu (1995). The hard-hat would have a notepad computer, microphone, head sets, video camera, and a heads up display to store/ transmit/ receive text, audio, images, and videos. The hard-hat would also use voice recognition to allow for hands-free application by the user. The system would allow for improved storage of project data. This electronic hard hat system relates to this research by demonstrating a hands-free concept for communicating from the site to the office using a remote teleconferencing system.

Today the construction industry is said to be “data rich and information poor.” This saying illustrates the fact that although the construction industry has learned to save paper, it unfortunately has not learned to store it in a way that makes it accessible, and a good

source of information. The importance of access to good information can further be illustrated both in change orders and in claims.

### **2.5.1 Change Orders**

A common occurrence on the job site is a change order. A change order results from a directed change from the owner or the owner's representative. A change order is necessary if the time, cost, or method of construction deviates from the original design and specifications (Bramble, 1990). A contractor will submit a proposal for a change order to either the on-site inspection team or the A/E.

In order to process the change order before an activity begins efficient access to previously stored data is vital. Often times; however, the change order is submitted at the point that the work is affected. At these times the contractor is sometimes permitted to start work without an official change order. When this occurs data must be available to resolve the change order as quickly as possible and a system must be available to allow the inspectors to record all data as the actual work incurred is recorded (Brock, 1986). In either case efficient access to good information is vital.

### **2.5.2 Issue of Claims**

When a problem occurs on a construction site and the parties involved cannot resolve the problem, a claim can result. A claim occurs when someone asks for money, additional performance time, or a change in the method of performance. While in this way a claim is like a change order the difference is that the owner receives no obvious benefit from the

requester. This can be a source of conflict as the owner cannot visualize or value the change. The party asks, “What am I paying for? Show me.” (Bramble, 1990)

A claim can be resolved between the parties by negotiation, mediation, or litigation. While a claim may be expensive, it becomes much more expensive if it ever goes to court. The cost of attempting to organize the data, bring in experts, and rebuild the job on paper can be extraordinary. The goal of all parties involved, therefore is to avoid litigation (Brock, 1986). This can best be done by keeping all parties informed on the progress of the job as well as any changes that have occurred.

On-site inspection is the front line of claims avoidance. The inspector’s daily report, coupled with the resident engineer’s diary and report, must record what work actually occurred or did not occur. The report must be complete, factual, and objective. Properly prepared, daily reports can provide an irrefutable record of actual events and the time of events. (Brock, 1986) The importance of maintaining good data in these reports is obvious; but in order to use that data efficiently, the data needs to be immediately accessible. Brock (1986) states regardless of who is right and who is wrong, timely and factually complete documentation by both sides will greatly expedite dispute resolution.

The determination of who pays a claims can cause misgivings between the parties, however; good information justifying a claim can go a long way to quelling those

misgivings. The more informed all of the parties are about what is occurring on the site the more likely the parties are to resolve claims amicably.

## ***2.6 Summation***

Construction is a dynamic business that is constantly changing during the life of a project. This tendency for change makes good communication between all of the primary parties and efficient data storage and retrieval imperative.

Good communication is necessary to allow for quick and efficient solutions of both major and minor problems, as well as enabling all parties involved in the construction process to coordinate their activities around one another. One possibility for improved communication is more site visits. More site visits would allow the parties to educate themselves on issues occurring on-site and thereby interact more efficiently with one another. Unfortunately more site visits are unlikely due to the travel time required to reach construction projects, combined with the other duties typically associated with OFP's.

Efficient data storage and retrieval is necessary within the construction industry due to the large amount of data that is exchanged during a construction project. The construction industry is notorious for collecting data and obtaining very little information from that data. In the case of change orders and claims, the ability to retrieve good information and



resolve issues quickly can help to maintain amicable relations between the parties and maintain a sense of teamwork as the construction project progresses.

## ***Chapter 3***

### ***Existing Technology***

This chapter introduces technology relevant to the “Virtual Visit” system. The technology discussed in this chapter functions as building blocks for conceptualizing a “Virtual Visit” system as discussed in Chapter Four. The primary goal of this chapter is to introduce the reader to the functionality of the technology. Often manufactured hardware is identified. If more information is required on the hardware, Appendix B contains relevant specifications. The topics discussed in this chapter include: (1) Long Range Data Transfer, (2) Teleconferencing Technology, (3) Methods of Data Storage and Retrieval, (4) Portable Computer and Video Components, (5) Wireless Data Transfer, and, (6) Related Technology.

### ***3.1 Long Distance Data Transfer***

In 1835, Samuel Morse launched the age of long distance communications with the electric telegraph. Since then, the ability to communicate with anyone, anywhere in the world is taken for granted. Today communication can occur using telephones, modems, etc. The key to using these devices, however, lies in the ability to transfer data over long distances. There are many methods for long distance data transfer, and four are discussed below: (1) POTS, (2) ISDN, (3) Fiber Optics; and, (4) VSATs. The discussion is based on Nellist (1992), unless otherwise noted. The reason for using Nellist is his ability to communicate the complexity of telecommunications in a manner understandable by the layman.

#### **3.1.1 Plain Old Telephone Lines (POTS) -- Analog vs. Digital**

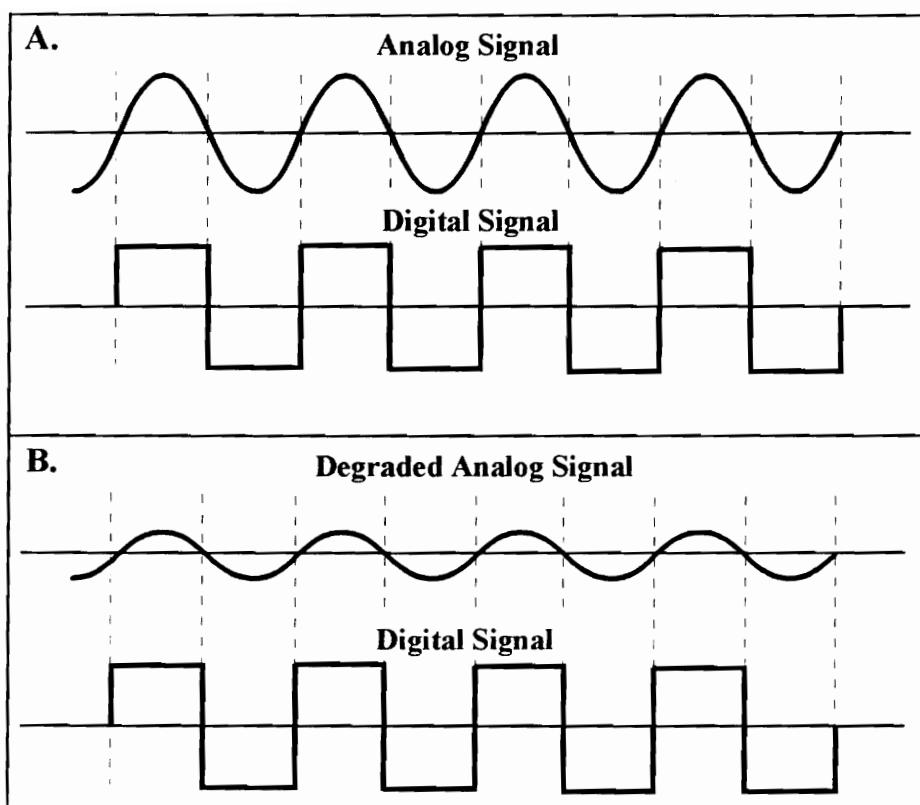
Plain Old Telephone Lines (POTS) are the current telephone lines that exist in the homes and business of millions of people all over the world. Audio, data, and even some limited video information is passed along these lines using the phone, the modem and the computer. There are two methods for communicating using POTs - analog and digital.

Analog was the original form of all voice telecommunication. When a person speaks into the telephone, the sound waves that are normally received through the air and interpreted by the human eardrum, are transferred to a thin diaphragm which vibrates. This vibration causes an electric current to flow by forcing electrons to bump against each other, sending

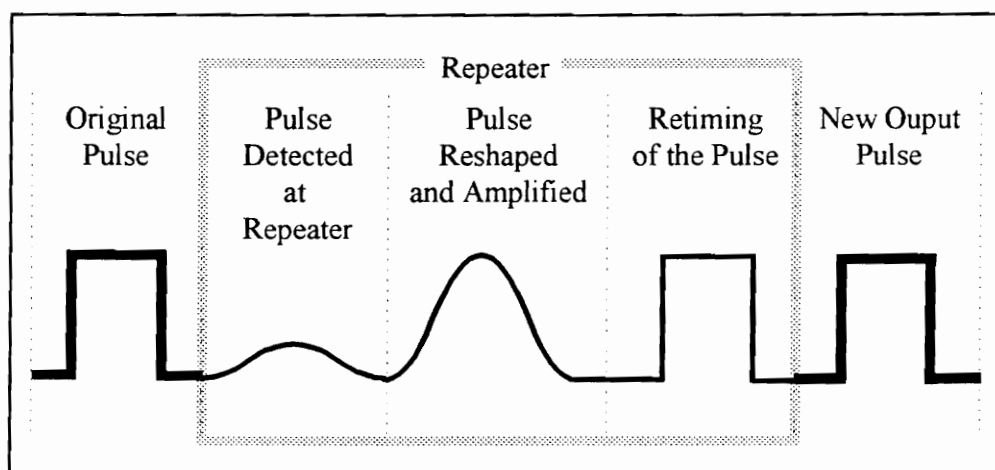
energy from one end of the wire to another. At the receiving end, an electromagnet drives a second diaphragm, which in turn recreates the sound originally made at the first diaphragm.

The second form of POTs communication is digital. Digital transmission means that voice, data, and video signals can be sent in digital form as a stream of on/ off pulses. Digital transmission is well suited for computer data since it has the advantage of being more accurate over long distances, however; in order for an analog signal, such as the human voice, to be transmitted it must be converted to digital. A digital signal conveys information in the form of symbols called bits. A bit is always one of two things, on or off and conveys nothing else. This differs from the analog signal that comes in the form of a wave (see Figure 3-1a). The advantage of a digital signal is that unless a digital signal degrades to the point that an on pulse appears to be off, or an off pulse appears to be on, the signal remains very clear. This is in contrast to the analog wave that degrades over time and distance (see Figure 3-1b).

With either the analog or digital signal, degradation over time and distance is an issue. In order to limit this degradation, repeaters are used to strengthen the signal. Figure 3-2 shows an example of a digital signal being regenerated.



**Figure 3-1 Comparison of Analog vs. Digital Signals**



**Figure 3-2 Pulse Regeneration (Nellist, 1992)**

The telephone system is currently evolving from an analog network to an integrated services digital network (ISDN) where simultaneous transmission of voice, data, and video is possible.

### 3.1.2 Integrated Services Digital Network (ISDN)

Integrated services digital networks (ISDN) are the next major step in wire communication. ISDN will provide direct digital services to the business or residential customer through a basic 144 Kbps interface with three channels. These consist of two B channels carrying 64 Kbps transmissions of voice, high-speed data, graphics, facsimile and highly compressed video. The third channel is a 16 Kbps D channel which carries control information and data.

There are four basic categories of ISDN interfaces. These are:

1. **2B + D** B1: 64 Kbps B2: 64 Kbps D: 16 Kbps

(This represents two B channels and one D channel)

2. **23B + D** B1: 64 Kbps ... B23: 64 Kbps D: 64 Kbps

(The represents 23 B channels at 64 Kbps and one D channel at 64 Kbps)

3. **3HO + D** HO1: 384 Kbps HO2: 384 Kbps HO3: 384 Kbps D: 64 Kbps

(This represents 3 HO1 channels at 384 Kbps and one D channel at 64 Kbps)

4. **Nonchannelized** H1: 1.536 Mbps

(This represents one H1 channel at 1.536 Mbps)

ISDN is the result of more than ten years of effort to develop standards for a worldwide digital system. The goal of this system is to enable customers to have accessibility ranging from low rate telemetry readings (requiring a lower data rate) to high-speed data and compressed video. ISDN is currently being used in teleconferencing technology due to its ability to transmit compressed video and audio.

Currently ISDN is not being used to its potential. The system has not reached a high level of standardization, although the effort towards standardization is resulting in improvements. ISDN in it's current form is capable of carrying relatively high-quality video, however; fiber optics can greatly improve on the technology once it is provided directly to the home or business.

### **3.1.3 Fiber Optics -- Lightwave Systems**

In the early 1980s, especially after the divestiture of AT&T, long distance telephone companies began to use fiber optic cable instead of the traditional copper cable used to that point. Fiber optics takes the electrical signal and converts it into light energy in the form of a laser. The laser is then projected through a fiber cable which transmits it with very little loss. The signal is then received by a detector that converts the light energy back into electrical information. Note that repeater stations are still necessary to limit the degradation of the signal.

In 1981, the first operational system operated at a bit rate of 45 Mb/s which provided a maximum capacity of 672 voice circuits over two fibers. The current third generation fiber optics system that is in use operates at a bit rate of 565 Mb/s providing 8064 voice circuits per pair. The systems that follow are expected to operate at 1.2 or 2.4 Gbps, with an error rate of five bit errors per 10 billion bits.

The key to the implementation of fiber optics is its implementation to the home. This implementation will create broadband integrated services digital network (BISDN) and will represent a major break from POTS. While the installation costs of this technology will be more, the improvement in data transfer rates is amazing. These improvements can lead to a blending of computers, desktop publishing, and entertainment systems. Together these technologies could create a sophisticated home and office communication network.

#### **3.1.4 Very Small Aperture Terminals (VSATs)**

VSAT's are a category of satellite earth stations, with antennas ranging from 1.4 meters to about 3.0 meters that are capable of two-way interactive transmission (Artz, 1992). VSAT's typically use hub stations, or satellite uplink stations, to send information to satellites from earth stations and then downlink to the desired receiver(s).

Satellite technology offers a number of advantages over land-based systems such as POTs or fiber optics. The most obvious advantage is the ability of satellites to reach difficult



terrain and to work at relatively high data rates (from 56 kbps to 2048 kbps). Satellite's costs also do not rise as distance increases (Comsearch, 1991). These characteristics make satellites suitable for 2-way interactive teleconferencing (Kamal, 1993).

There are disadvantages to satellite technology, however; the most glaring being cost. A VSAT system can cost over \$100,000 for the system and the use of a transponder. The accessibility of the hub stations can also be an issue related to connecting two sites. New VSAT systems such as TDMA (time division multiple access); however, try to overcome these disadvantages. The TDMA system does away with the hub station. The requirements of the hub station are fulfilled by equipment that fits into a suitcase-sized enclosure. The connection time is replaced by "service on demand" software, which allows immediate reconfigurations for scheduled and unscheduled video conferences (Kamal, 1993).

VSATs are being scrutinized as a possible contender in the blossoming multimedia and teleconferencing age (Artz, 1992). The global advantages offered by VSATs could open up a new door in teleconferencing.

### ***3.2 Teleconferencing Technology***

In the past two decades, computers have grown in importance in the office as well as in the personal lives of the consumers. One potential use of the computer as it increases in power is as a communications center. Using modems and telephone lines to link computer stations; audio, video and data may now be transmitted between these stations. This ability to transfer data opens the door for teleconferencing and other forms of communication via computers. It should be noted that Local Area Networks (LAN) and Wide Area Networks (WAN) are also an effective medium for teleconferencing, however, due to the nature of this research they cannot be used for this research.

#### **3.2.1 Introduction to Teleconferencing**

Teleconferencing is a direct connection, usually between two or more computers in which documents and video are shared, along with the audio that is a part of everyday normal conversation. Teleconferencing can be done in a number of ways (1) using POTS, although the data rates are generally too slow to be effective, (2) by ISDN, which is the norm, (3) by use of a local area network (LAN), although the distance is limited; and, (4) by satellite, which allows for high rate data transfer but has high costs and scheduling difficulties for the average user. Teleconferencing has many uses, however; two areas have been in use significantly in the past decade: remote corporate offices and remote education.

### **3.2.2 Linking Corporate Offices**

Currently a large number of corporations have begun to link offices using teleconferencing. Apple is using the technology to link all levels of its executives to its French office (Kaminski, 1990). Citibank has attempted to reduce costs in one of its marketing centers using teleconferencing (Teleconference, 1991), and DEC software engineers communicate with each other on a daily basis and have been able to improve communication and maintain low travel costs (DEC's, 1992).

An excellent example of using teleconferencing to allow offices separated by large distances to communicate effectively is HAL computer systems. HAL is located in Campbell, CA, but in 1992 decided to begin to develop its software in Austin, TX, while still developing its hardware in California. In order to compensate for potential problems in communication, HAL linked the two offices with a \$150,000 teleconferencing system. This enabled the two offices to remain in contact with each other during the development of their products (Kaufman, 1992).

### **3.2.3 Teleconferencing in Education**

Going to a classroom and being taught by an instructor is a familiar scenario for most students. In most cases, especially in the United States, students have access to schools. In Australia, however, the problem of educating a sparsely spread out populace is being attacked using teleconferencing technology. In 1991, Australia began to use the

Australian VDA. The VDA allowed up to six students to be connected to a teacher's computer. The students could see whatever the teacher wished them to see. Later in 1994, technology was developed by Apple that allowed full color video and CD images to be sent to students.

In the United States, businesses and universities have formed the Collaboration for Interactive Visual Distance Learning to implement a video conferencing program to allow engineers to take university classes from their offices. The system will be two way video and audio (Schwanhausser, 1993). Finally, plans for a Global Classroom to be run around the globe using CDs, multimedia, and teleconferencing are being considered (Kurshan, 1991).

### ***3.3 Methods of Data Storage and Retrieval***

There are many ways to store and access data. One of the most popular forms is that of a database. This section discusses a widely used type of database known as a relational database. There are other forms of databases, such as object-oriented (Grieshaber, 1995), however, it is not discussed since the relational database is the database represented throughout this research. This section also discusses the World Wide Web and its method of storage and retrieval in order to illustrate an example of a large quantity of data that is accessible to a large group.

### **3.3.1 Relational Databases**

A relational database offers the ability to store and organize data by “relations”. Each relational file is a table where the attributes (the columns) are named individually and represent ordered fields within a record, and the rows correspond to unordered records. Each record field contains a value and key field that are used to identify records within a table (Grieshaber, 1995).

A typical relational database, such as dBase and Oracle, offers the ability to customize the database to the user’s preferences. This includes defining the fields, the relationship that each field has with each other and with the database as a whole, and creating an environment for the user that is appropriate for the display of data.

The primary goal of any database should be to store data in a format that allows for easy retrieval, whether by queries or by search commands that are part of the database software package.

### **3.3.2 Accessing the World Wide Web**

An example of a much larger data and retrieval system is the World Wide Web. The World Wide Web is a series of bulletin boards offering information ranging from technical reports to movie reviews. The popularity of the web, as well as it’s potential in many areas, has led to the birth of magazines and information groups specifically for perusing

the web. The World Wide Web offers the ability to obtain information from anywhere in the world, and this information can be retrieved from any computer terminal in the world using a modem.

The World Wide Web functions using a network of servers. These servers are used by universities, companies, and other entities to post related information on the web. Accessing these servers remotely requires the use of a general interface and a web browser.

The general interface provides access to the web for the user through several hardware options, i.e. telephone lines, ethernet, etc. An example of a general interface is Winsock, or Windows Socket Interface.

Once the general interface has been initiated, the user can activate his/ her web browser. The web browser is analogous to the menu or index of a manual. The web browser allows the user to connect with any of hundreds of servers around the world. Once a server has been accessed, the user can peruse that server via the general interface and access or download the required information. Examples of web browsers are Netscape (see Figure 3-3) and Mosaic.

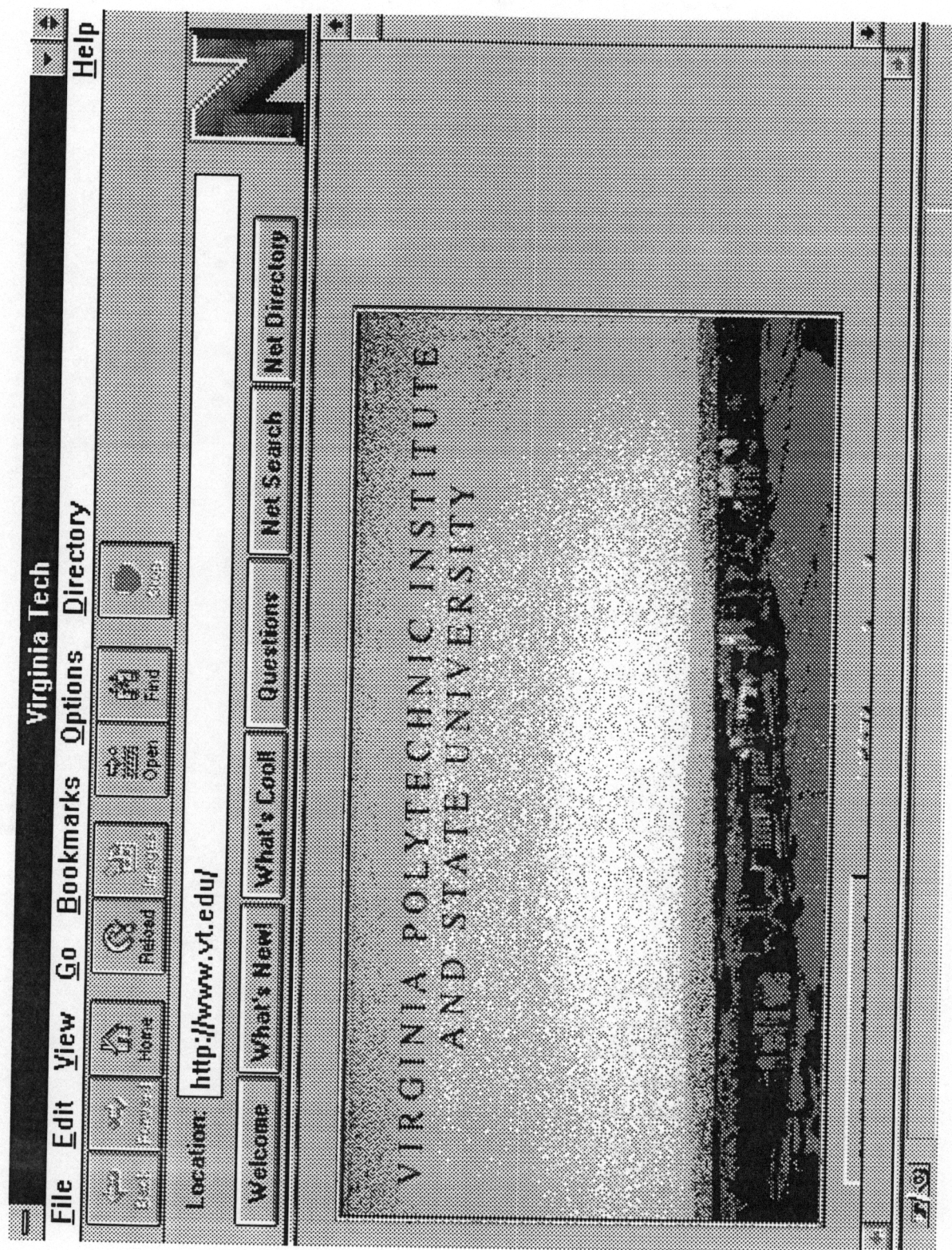


Figure 3-3 Home Page From Netscape

### ***3.4 Portable Computer and Video Components***

As computer components have become smaller and more powerful, the trend towards portability has been gaining momentum. Laptop computers are now being combined with cellular modems to allow for portable work stations that still have the ability to fax and use e-mail. One of the keys to a “Virtual Visit” system is the portability of the system for the on-site user. For this reason three portable computer and video components are introduced: flexible/ wearable personal computers, virtual image displays, and CCD cameras.

#### **3.4.1 Flexible/ Wearable Personal Computers**

When the computer was originally developed, it took up rooms of a building, while being able to do only some basic mathematical calculations. Today with the development of microtechnology computers may weigh only a few pounds with enough computing power to run compressed video in the form of quicktime movies. This trend towards smaller desktop and laptop computers has continued with hands-free flexible computers, such as the ones being developed by the Flexible PC Company (Flexible, 1995).

The Flexible PC Company was developed to complete development work and apply for utility and design patents for several versions of wearable flexible computers. The result is the ViA PC, a fully functional 486 DX4-75 PC computer that can be constructed in different forms of personal wear such as: belts, suspenders, holsters, vests, or bandoleers.

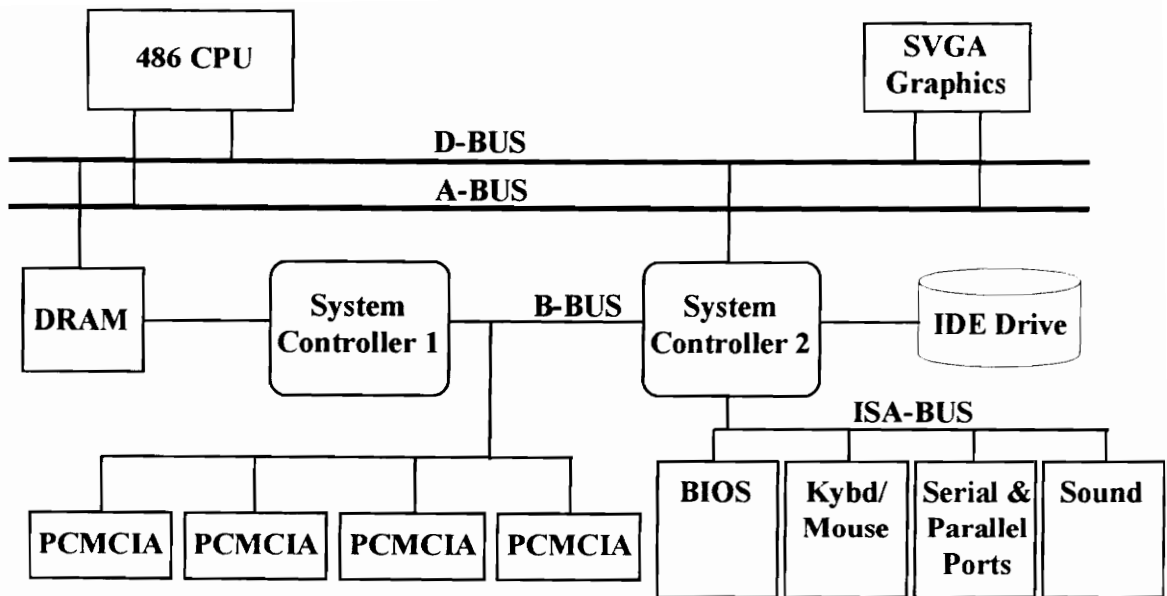


The ViA PC is compatible with monitors, keyboards, etc. through standard I/O ports. The primary benefit as seen by the manufacturer is the hands-free portability using voice recognition. Voice recognition allows the user to concurrently work on a project and speak to the computer, storing valuable information in voice icons (Flexible, 1995).

The designs for wearable/ flexible computers are based on the nearly simultaneous availability of five important developments:

1. Development of the PC in card format
2. Improvements in flexible circuit technology
3. PCMCIA standardization and proliferation
4. Rechargeable, flexible, moldable batteries
5. Improved voice recognition products

Each design configuration consists of a flexible circuit board providing functional connections between a computer processor card, a series of four PCMCIA cards, four standard I/O ports, docking port, and power. A four card version of the flexible/ wearable computer is shown in Figure 3-4 (Flexible, 1995).

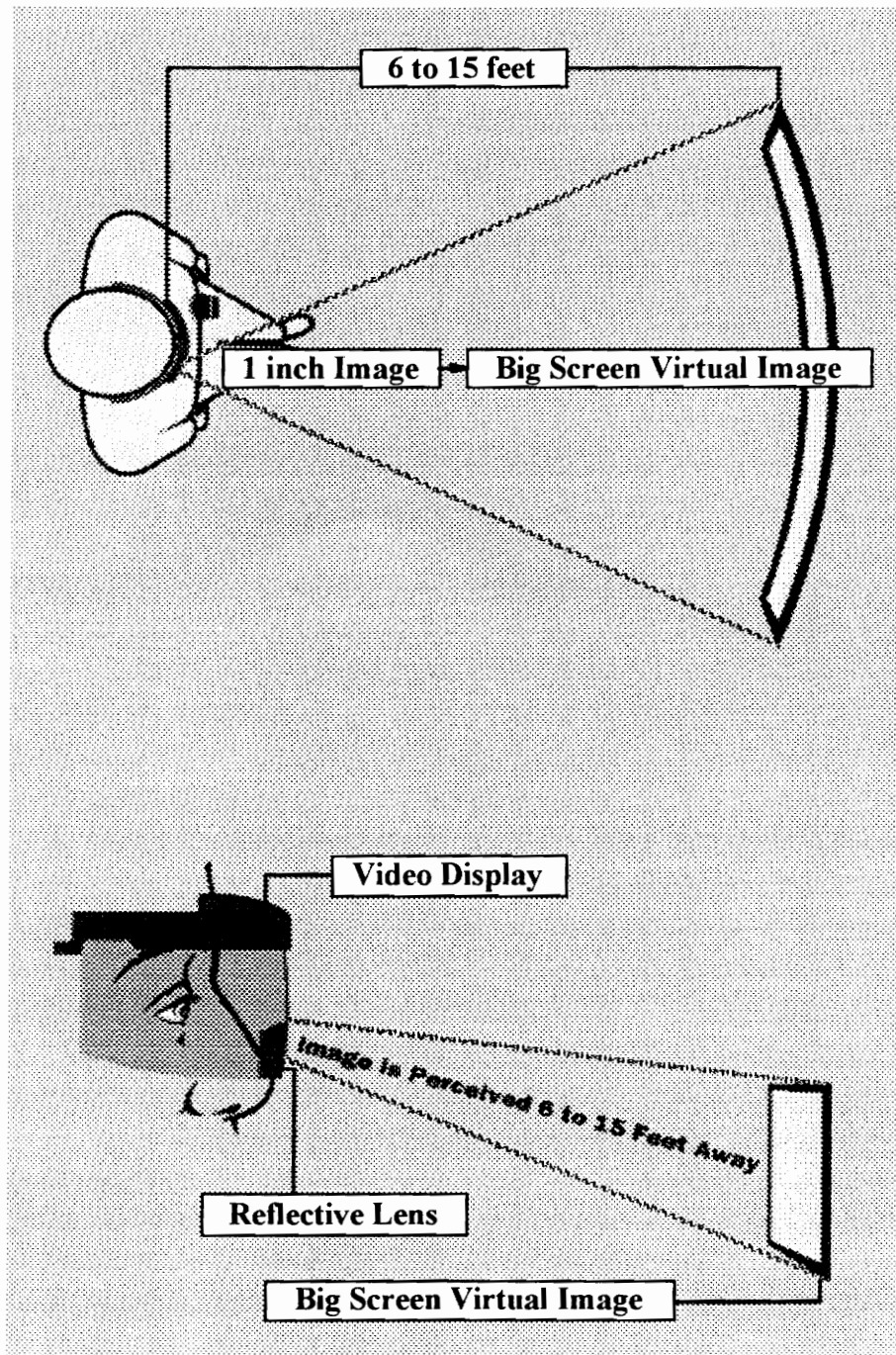


**Figure 3-4 Four PC Card Version of Flexible/ Wearable Computer, 1/30/95 (Flexible, 1995)**

### 3.4.2 Virtual Image Displays

Virtual image displays are essentially weightless displays that take up no space, except for the monocular imaging system (eyeware) that the user wears to view the image. A high resolution image of an LCD is sent to the dominant eye of the user. The user's brain gives priority to whatever image is viewed by the dominant eye, allowing the image to be viewed comfortably. The source of the image is under one inch, however; the user will see a large image floating 72 inches in front of him/ her (see Figure 3-5). The user only uses one eye for the image which allows him/ her to look away from the image and view the surroundings. The image that is projected is also somewhat transparent, which allows the user to "look through" if it is necessary (Virtual, 1995). At the time of this research,

Virtual Image Displays were available in monochrome resolution in VGA mode (640 by 480 pixels).



**Figure 3-5 The Creation of a Big Screen Image From a One Inch Screen**

### **3.4.3 CCD Camera**

A CCD (Charged Coupled Device) camera is used everyday by camcorder users all over the world. The video capturing portion of the camcorder is typically a CCD camera. CCD cameras do exist, however; independently of the camcorder. Today, CCD microcameras come in sizes of less than one inch in diameter and less than two inches in length. These cameras have the ability to capture full screen video with up to 500 line horizontal resolution. The GP-KS162 industrial Microcamera by Panasonic, for instance, consists of a small 1/2" diameter CCD camera, a connecting cable, two video outputs, and a camera control unit with a 12V DC power supply. The system can also have additional motor lenses placed on the camera to allow for auto focusing (GP-KS162, 1995).

## ***3.5 Wireless Data Transfer***

Wireless data transfer is now being offered to the public as an alternative to "hardwire" communication. This section discusses two types of wireless modems as well as one-way analog transmitters and receivers.

### **3.5.1 Wireless Modems**

The ability to send computer information via telephone lines has helped to create a portable information network for today's computer users. The computer information that is sent via telephone lines is first translated by modems. These modems convert the digital information into analog for the transfer along the telephone lines, and then converts the

analog back to digital when the data arrives at its destination. Today, typical desktop modems using POTS lines can obtain a data rate of up to 38.4 Kbps.

As the desktop modem became more popular a second generation of modems was developed, the wireless modem. Wireless modems can come in a number of forms. Two are discussed - cellular modems and RF modems.

Cellular modems utilize “cells” that allow for remote telephone conversations using cellular telephones. A cell is an area surrounding a central office in which transmissions can be transmitted and received from the central office to the cellular phone and vice versa. “Cells” exist adjacent to one another and are configured in various ways depending on the service that is being used, i.e. AT&T. When a cellular phone is activated it connects with the central office of a cell, and as the phone is moved beyond the original cell, the signal is transferred to a new cell. Cellular modems use the cellular phone in much the same way as desktop modems. The difference is that cellular modems can generally not achieve a reliable data rate above 10 Kbps. The cellular modem does, however, have the advantage of being able to contact other modems anywhere in the world.

RF modems on the other hand have limited range. Typically, RF modems are limited to a mile or two unless repeater stations are used. In addition, RF modems need a direct line

of sight to maximize their range. The more obstacles in the way of an RF modem, the weaker the signal becomes. The advantage of RF modems over cellular modems is the data rate. A typical RF modem can have a data rate of up to 38.4 Kbps. An example of an RF modem is the SpectraData 551 Series. These radio transceivers operate at up to 38.4 Kbps over a range of up to 1.5 miles or more if repeaters are used (max. of three). They also have the ability to detect and correct errors in the transmissions in point to point communication (SpectraData, 1995).

### **3.5.2 Analog Transmitters/ Receivers**

Analog transmitters and receivers can be used in the sending of analog audio or video signals one way. Analog signals have a much higher bandwidth than digital signals and therefore allow for a higher quality of transmission. An example of a transmitter/ receiver system is the 1/4 watt series “4” miniature transmitter and the series “2” receiver. This system allows for color video to be sent at bandwidths of 10Hz to 6Mhz. The system also has optional audio transmission capabilities (Series, 1995).

### ***3.6 Related Technology***

A “Virtual Visit” system combines a large number of technologies. One such technology is video compression. Video compression allows for movie clips that ordinarily would be too large to store on a computer, to be reduced in size for storage. This section describes video compression, and also introduces a new technology called service-on-demand, that utilizes video compression in order to send users video over copper telephone lines.

#### **3.6.1 Video Compression**

In order to view analog video on a computer screen the data must be converted to digital, and if the digital video is to be stored it must be compressed (Wood, 1994). Video compression is necessary due to the very large size in which video exists. One second of a movie at 30 frames per second can take 170 Mbps ( $512 \times 480 \times 8 \times 30$ ). Compressing the size of the video allows for the saving of computer space, as well as improving the data transfer rate of the video.

Video compression occurs primarily in two ways. The first is the dropping of frames from the video clip. An example could be the aforementioned 170 Mbps which can be reduced to 85 Mbps by having the movie run at 15 fps, which is accomplished by dropping every other frame of the movie (Nellist, 1992). The second is the manner in which the video is transferred. Rather than try to store 15 frames per second, the computer determines how much one frame differs from the previous. The difference between the two frames is then

stored, and this continues from frame to frame. Together these two methods can create a compression ratio of up to 200:1 such as in the case of MPEG-1 compression (Wood, 1994). MPEG-1 is discussed below.

The compression rate and the quality of the compression depends on the compression/decompression algorithms (CODECs) that are used. MPEG-1, or Motion Pictures Experts Group (Wood, 1994), is the emerging standard for video compression, however; the cost of MPEG compression hardware can run just under \$10,000 (Fitzgerald, 1994). Therefore other compression algorithms such as Indeo, which offers a lesser compression ratio of about 30:1 (Intel, 1995), are emerging as cheap substitutes to the higher quality and more expensive MPEG-1. The 30:1 compression rate, however is not necessarily a high enough for an effective "Virtual Visit" system (see Section 4.3.1.1).

### **3.6.2 Video-On-Demand**

The ability to watch movies in the home on a VCR, through cable channels, or by ordering pay-per-view channels are all technologies that are common in everyday life. These technologies, however; are just the beginning. The information superhighway is accelerating, and all forms of businesses are attempting to join the ride. One aspect of the information superhighway is video-on-demand.



The concept of video-on-demand is that the user may order a movie and within minutes it will appear on the user's computer monitor or television set. The technology is also targeting movie previews, home shopping, education, and video processing and authoring tools (Stewart, 1994). Both the cable and telephone companies are testing this new technology. Originally the telephone companies were excluded from the video-on-demand race, however; Bell Atlantic won a case on August 24, 1993 overturning a section of the 1984 Cable Act that barred the Baby Bells from creating, owning, or even packaging video programming distributed inside their respective telephone service regions (Calling, 1993).

At the time of this research Bell Atlantic had begun testing the world's first commercially deployable video-on-demand service. The service offers consumers more than 700 choices, available whenever they desire -- and with on screen control features such as pause, rewind, and fast forward. The video is conducted over copper wires using an ADSL compression scheme that gives VCR movie quality at a reduced data rate of 1.4 Mbps. The testing is to be conducted in Fairfax County, VA initially within 1000 homes and could jump up to a maximum of 20,000 homes by December 1995. The customers will be able to order by using a hand-held remote control device and a TV set-top unit (Bell, 1995).

## ***Chapter 4***

### ***A Conceptual “Virtual Visit” System (CVVS)***

This chapter conceptualizes a “Virtual Visit” system (CVVS). CVVS is presented as an option for a “Virtual Visit” System. The development of the system is broken down into four areas: (1) The creation of a Mobile On-Site Computer Unit (MOCU), (2) The issues concerning the transfer of data, both from MOCU to the on-site server, and from the on-site server to the off-site personnel (OFP), (3) The development of a permanent archive and it’s related security issues, and, (4) A model for the creation of an effective data storage and retrieval system with video capture and application sharing capabilities (DSeRViC). More information regarding pricing and specifications is provided in Appendix B.

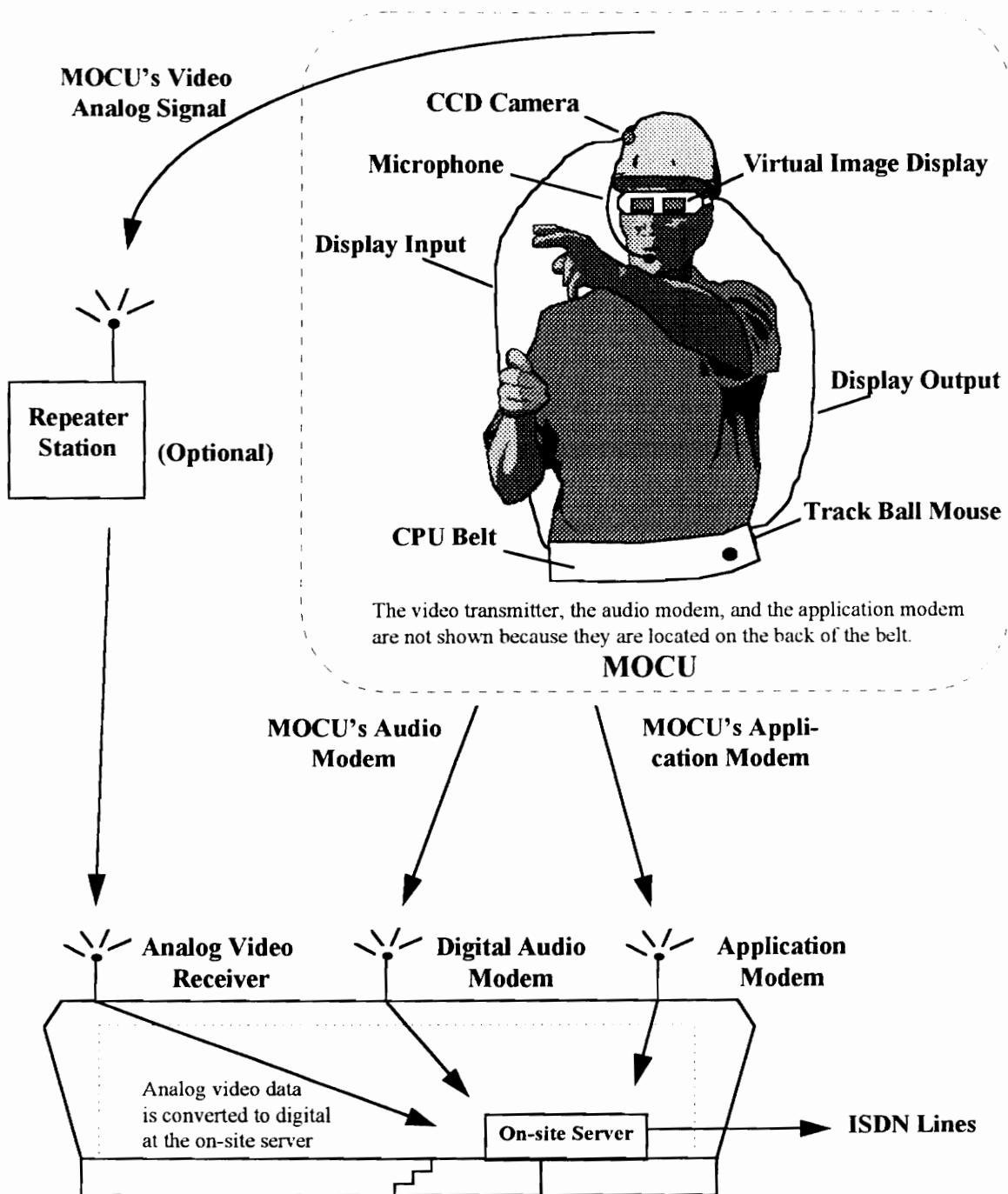
## ***4.1 System Overview***

CVVS is a conceptual system designed to present one possible solution for creating a “Virtual Visit” system. Due to the time and money constraints related to a thesis, the CVVS was not actually constructed, but was conceptualized after developing parameters for a “Virtual Visit” system. Each component of the system was researched, and representatives from each components’ manufacturer were consulted concerning compatibility and performance issues. Chapter presents testing of subcomponents to validate the potential feasibility of the CVVS system.

CVVS has four primary areas of development: (1) The creation of a Mobile On-Site Computer Unit (MOCU), (2) The issues surrounding the transfer of data, both from MOCU to the on-site receiver, and from the on-site receiver to the OFP, (3) The development of a permanent archive and it’s related security issues, and, (4) A model for the creation of an effective data storage and retrieval system with video capture and application sharing capabilities (DSeRViC). Each of these areas carries out a necessary function in order to allow CVVS to function effectively.

MOCU is the ONP’s portable computing center. It offers everything the ONP needs to function independently as a day to day recorder of data, or as a guide for the OFP as the OFP visits the site virtually (see Figure 4-1). MOCU was designed to allow the user to

remain active anywhere on the site, yet still have complete access to all of CVVS's capabilities.



**Figure 4-1 A Conceptual "Virtual Visit" System (CVVS)**

CVVS offers the ability to capture and store data in real-time as well as share the data with an OFP. Sharing that information instantaneously with an OFP becomes an issue of data transfer. The data must be transferred first from the ONP using MOCU to the on-site server, and second from the on-site server to the OFP using ISDN lines. This transfer must occur at a rate that allows for the application sharing and the video transfer to occur effectively. A low data rate can cause lags in the system that can render the system ineffective for a “Virtual Visit.” The transmission must also be clear enough to allow for effective communication between the two parties.

After the data has been collected and shared using the above features, it becomes necessary to store the data in a permanent archive. This archive acts as a bank of data for construction job sites, much the way the servers of the internet store information for a specific entity, i.e. VA Tech. Should a dispute arise this data can be used as a good source of information, and hopefully give evidence to end the dispute quickly. In order for this data to remain untainted security measures must be taken to insure that tampering does not occur.

Finally, DSeRViC is the model software package that ties in all of the capabilities for the user. DSeRViC acts as a data storage and retrieval system with video capture and application sharing capabilities. More specifically DSeRViC has the ability to capture still images from the video sent by MOCU’s CCD camera and place them into permanent

records. These records can then be enhanced with other related site data (item number, description, weather, etc.) to allow for a more complete account. The application sharing capability refers to DSeRViC's ability to be shared by the ONP and the OFP, allowing the OFP to use DSeRViC as if it were running on his/ her own computer.

The Hardware needed for MOCU and the on-site server are listed below. The expert should only need an office personal computer and an ISDN card (see also Appendix B).

**MOCU hardware:**

1. ViA PC - \$4000 w/ 16 Mb DRAM
2. SD55510V (Audio Modem @ 38.4 Kbps) - \$1110 ea.
3. CardCam PCMCIA Video In - \$320
4. GP-KS162/2 CCD Micro-Camera w/ GP-AD22TA and lens - \$1610
5. Series "4" 1/4 Watt Wireless Video Miniature Transmitter - \$4200
6. VIDI VGA - \$5000
7. Mb Flash Memory Hard Drive - \$170

**On-Site server hardware:**

1. 486 DX4-75 PC w/ 16 MB RAM - \$2200
2. Spectradata 551 - SD55514 (Data Modem @ 38.4 Kbps) - \$1320 ea.
3. Spectradata 551 - SD55510V (Audio Modem @ 38.4 Kbps) - \$1110 ea.
4. MPEG Video Card - \$11,000
5. Series "2" Video Receiver - \$4200
6. ISDN Card - \$400

## ***4.2 Mobile On-Site Computer Unit (MOCU)***

The mobile on-site computer unit, or MOCU, is the portable information gathering and storage system used to send audio and video data from the ONP to the OFP. The primary goal of MOCU is to enable the ONP to remotely communicate with the OFP's in an efficient manner. MOCU represents the hardware portion of CVVS, and when combined with the software portion (DSeRViC), CVVS offers the capabilities of a "Virtual Visit" as well as data storage and retrieval, video capture, and application sharing.

MOCU has four primary functions: (1) To capture the construction site video in real-time, (2) To capture audio conversations held off-site between the ONP and the OFP, as well as conversations held on-site between ONP's, (3) To display a virtual image that acts as the ONP's computer monitor, allowing on-site computer interaction, and, (4) To transfer all data (video, audio, and control data) to the off-site location in real time allowing the ONP and the OFP to act concurrently (see Section 4.4). These functions are illustrated in Figure 4-2 and are further described in the following sections.



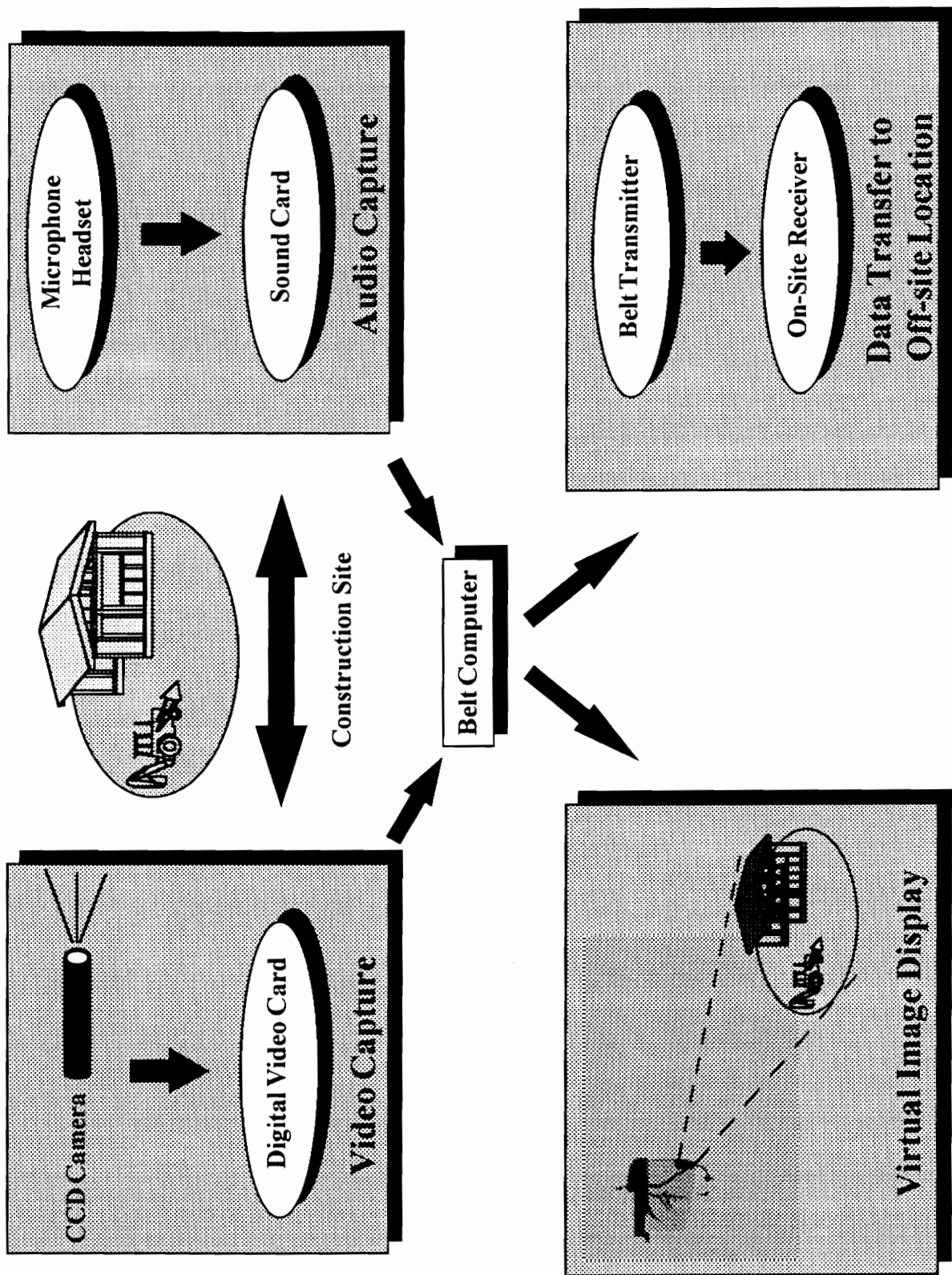


Figure 4-2 MOCU's Primary Functions

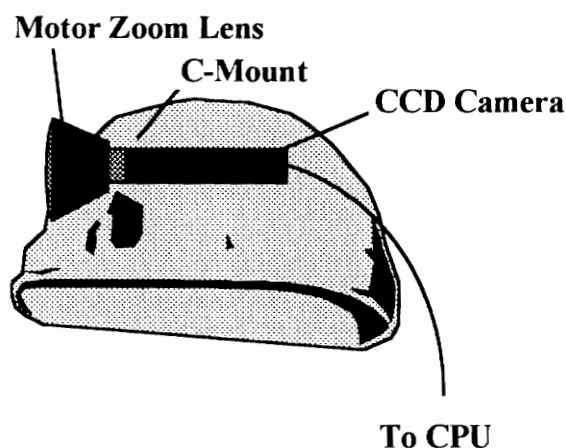
#### **4.2.1 Belt Computer**

The computer is the cornerstone of the MOCU system. All information is either received or sent by the computer. In order for the computer to be effective in a “Virtual Visit” system, it has to be portable, yet still powerful and expandable enough to operate all of MOCU’s functions. In order to accommodate both features the ViA PC (ViA, 1995) currently seems to be the best choice and thus was chosen for this discussion. The ViA PC is a flexible wearable fully functional 486 DX4 75Mhz belt computer. It offers a 16-bit Sound Blaster compatible sound card, as well as 4 PCMCIA card slots and four serial COM ports. The ability to expand the system using the additional card slots and serial ports allow for interfacing to occur with MOCU’s other functions.

#### **4.2.2 Still Image Capture From the Video**

To capture the single frames of video in order to store them in the archive, a CCD camera is used. The CCD camera was chosen because it offers high color resolution in a very compact form. For this research the GP-KS162/2 CCD Micro-Camera was selected due to it’s size and standard features. The high color resolution becomes important during the storage of still images to allow for the best possible picture. The CCD camera uses a C-mount in order to attach a motor zoom lens. This motor zoom lens allows the ONP to automatically focus in on objects around the site. One disadvantage of the motor zoom lens is that it adds one to two inches in diameter to the CCD camera, which is itself one inch wide and several inches long (see Figure 4-3). A second disadvantage is that the

camera will always focus on the closest object “seen” by the CCD camera. Despite these disadvantages experimenting with the CCD camera showed the advantage of having the camera automatically focus overcomes the disadvantages mentioned above. Another proof of this choice is the fact that in the amateur video market no cameras are produced anymore without autofocus features.

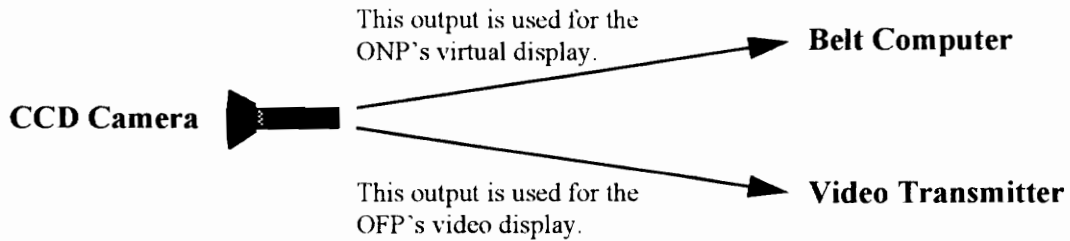


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**Figure 4-3 CCD Camera Mounted on a Hard-hat**

A CCD camera can output either an S-Video or a Composite Video signal. An S-Video signal offers less distortion and was therefore chosen for CVVS. The S-Video signal is sent from the CCD camera to a digital video card located on the belt computer, in order to convert the signal into digital video. Due to the compact nature of MOCU's CPU, a PCMCIA video card by CardCam (CardCam, 1995) was chosen. CardCam has a frame buffer which allows the frames of the video to be captured instantaneously; a feature that is needed for the DSeRViC software.

It should be noted that the CCD camera utilizes a second output to the Video transmitter (see Figure 4-4). The transmitter is further discussed in Section 4.4.



**Figure 4-4 CCD Camera's Two Video Outputs**

#### **4.2.3 Audio Capture**

CVVS must have the ability to capture two types of audio conversations - those off-site between the ONP and the OFP, and those on-site between two ONP's. The first case requires that the conversation be sent from MOCU's microphone, through the CPU and it's sound card to the OFP, and vice versa (Note that this is accomplished by using the audio modem which is further discussed in Section 4.4). The second case requires that the external microphone located on the computer belt be activated, and that the audio carry from the ONP, through the external microphone, to the sound card and the CPU. By running the conversation through the CPU in both cases, any portion of either type of conversation can be recorded and saved.

#### **4.2.4 Virtual Image Display**

The virtual image display acts as a portable monitor for the ONP operating MOCU. The image of either the video being collected by the CCD camera or the DSeRViC software package can be displayed and manipulated using the track ball mouse located on the CPU belt. The virtual image itself appears in a 640 by 480 VGA format, in monochrome resolution. While this does not allow the ONP to see the display in color, the ONP should not be disadvantaged since he/ she is located on the site. Furthermore, all of the data being sent to the OFP is sent in color as well as all of the data that is stored as still images. The virtual image display chosen for CVVS was the VIDI VGA by Virtual Vision (Virtual, 1995).

#### **4.3 Data Transfer**

In order for CVVS to function effectively, it is necessary to have efficient data transfer. Efficient data transfer refers to the ability of the system to function without data transfer related delays that are long enough to inhibit the system's effectiveness. This section deals with the three areas that require data transfer: (1) Video, (2) Audio, and, (3) Application sharing involving DSeRViC. Before these issues of data transfer can be discussed, however; it is first necessary to determine the data rates that are required for each of the aforementioned areas. After the minimum data rates have been resolved the data can then be transferred using the appropriate media. The data must first be transferred from MOCU to the on-site server, and then from the on-site server to the OFP.

### 4.3.1 Obtaining the Required Data Rate

The required data rate refers to the data rate of the video, audio, and application sharing that allows for the system to operate efficiently. These values are based on observations of similar systems, and the data rate field work discussed in Chapter Five.

#### 4.3.1.1 Video

In order to understand the data rate required for video, it is important to understand the parameters that make up a video frame. A video frame is defined by its size and its resolution (number of colors). CVVS uses a VGA screen with 256 colors. The unit that is used to define the size of a video frame is the pixel. The VGA screen is 640 pixels wide and 480 pixels high. Each pixel is determined to be either on or off using one bit per pixel. The 256 colors, however, require that one byte (eight bits) be used per pixel to define each pixel's color. Using these parameters the number of Kilobits per second (Kbps) per video frame can be determined with the following formula:

$$[(P_w * P_h) * B_{C256}] / 1024 = D_r \text{ (Kbits per second per frame)} \quad (4-1)$$

$P_w$  = Number of pixels wide

$P_h$  = Number of pixels high

$B_{C256}$  = The number of bits required for 256 colors

$D_r$  = Required data rate per second per frame

Note the 1024 is a conversion factor that is used to convert from bits to Kbits.

The minimum Kbits per second per frame will be determined:

$$D_r = [(640 * 480) * 8] / 1024 = 2400 \text{ Kbps per frame} \quad (4-1)$$

After the number of Kbits per second per video frame has been determined it is necessary to determine the number of frames per second (fps) that should be used. A typical movie or television show functions at 30 fps, however; for teleconferencing that data rate is usually halved to 15 fps to lower the required data rate. To determine the Kbits per second required for one second of video the following formula is used:

$$D_f * N_f = D_s \quad (4-2)$$

$D_f$  = Required data rate per second per frame

$N_f$  = Number of required frames per second

$D_s$  = Required data rate per second

The minimum number of frames per second must be used to determine the required data rate. During the field research discussed in Chapter Five, it was found that anywhere from 3 - 5 fps allowed for reasonable observation of slow moving objects. Since the construction industry is generally a static industry the minimum three fps are used.

$$D_s = 2400 * 3 = 7200 \text{ Kbps} \quad (4-2)$$

The 7200 Kbps data rate shown above is not the data rate that is used when transferring the data. First the data can be compressed. Compression ratios for video can occur at ratios up to 200:1 for MPEG-1 compression (Woods, 1994). Since the 200:1 compression ratio is the ratio under ideal conditions, a more conservative estimate is necessary for these calculations. As illustrated in Chapter Five, video transfer can perform as badly as about two-thirds the projected performance. Therefore the compression ratio

for these calculations is conservatively estimated at 120:1, and the 7200 Kbps is therefore converted to 60 Kbps.

The user may find that the construction site environment is moving too quickly and may wish to increase the number of frames per second. To accommodate this desire a new data rate can be determined using smaller images, one-fourth of a screen (320 by 240 pixels).

$$[(320 * 240) * 8] / 1024 = 600 \text{ Kbps per frame} \quad (4-1)$$

$$600 * 12 = 7200 \text{ Kbps} \quad (4-2)$$

After compression the new data rate becomes 60 Kbps.

Finally, to complete the analysis, the minimum possible data rate must be determined.

This occurs at three frames per second on a 320 by 240 screen.

$$[(320 * 240) * 8] / 1024 = 600 \text{ Kbps per frame} \quad (4-1)$$

$$600 * 3 = 1800 \text{ Kbps} \quad (4-2)$$

After compression the new minimum possible data rate becomes 15 Kbps.

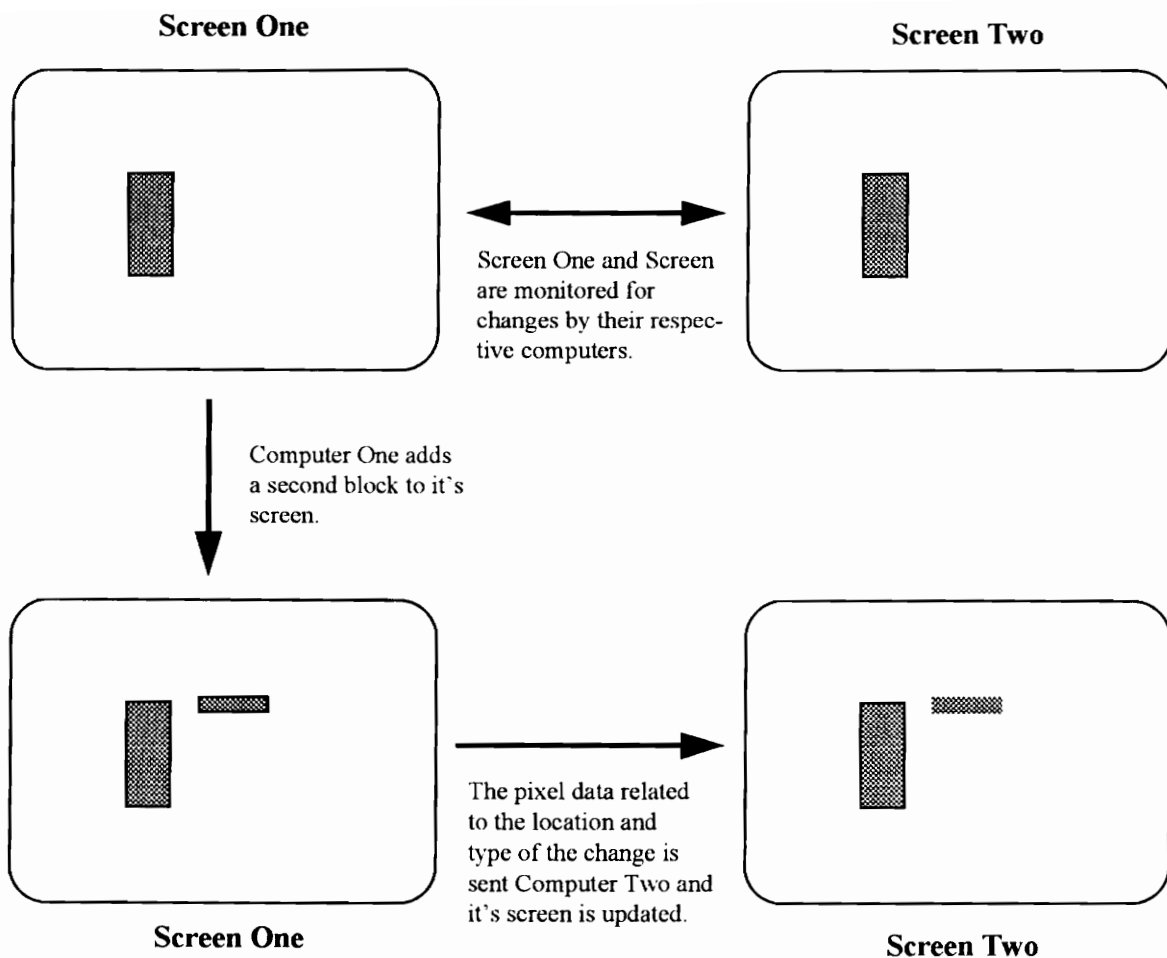


#### **4.3.1.2 Audio**

In order to convert analog to digital 64 Kbps must be used to obtain an exact replication of the audio (Nellist, 1992), however; this data rate can be reduced to 16 Kbps by sampling the audio. This sampling reduces the quality of the sound, but is acceptable for normal conversation. The audio can then be stored in one of two formats - MIDI or WAV. Since the MIDI format (Musical Instrument Digital Interface) is one-tenth the size of the WAV format the MIDI format should be used (Wood, 1994).

#### **4.3.1.3 Application Sharing Data Transfer**

Sharing an application requires that the users operating the applications have their applications updated periodically to coincide one another. For example, if a word processing document is being shared, and one of the user's wishes to bold a word, the screens of both users must show the word being highlighted, the mouse moving to the Bold button and pressing it, and the highlighted word changing to bold. This process is accomplished in much the same way as compression. Both the users' computers monitor for changes in the current application layout (a mouse moving for example). When a change occurs the difference in the pixels from one computer screen is transferred to the other computer where it's screen is updated (see Figure 4-5). This process continues as long as the application is being shared.



**Figure 4-5 An Example of how Application Sharing Occurs**

Application sharing can occur at data rates as low as 9600 bps, however; the lag in updating the application is very noticeable and can effect efficiency as discussed in Chapter Five. Therefore, a data rate of at least 19.2 Kbps is recommended for document sharing.

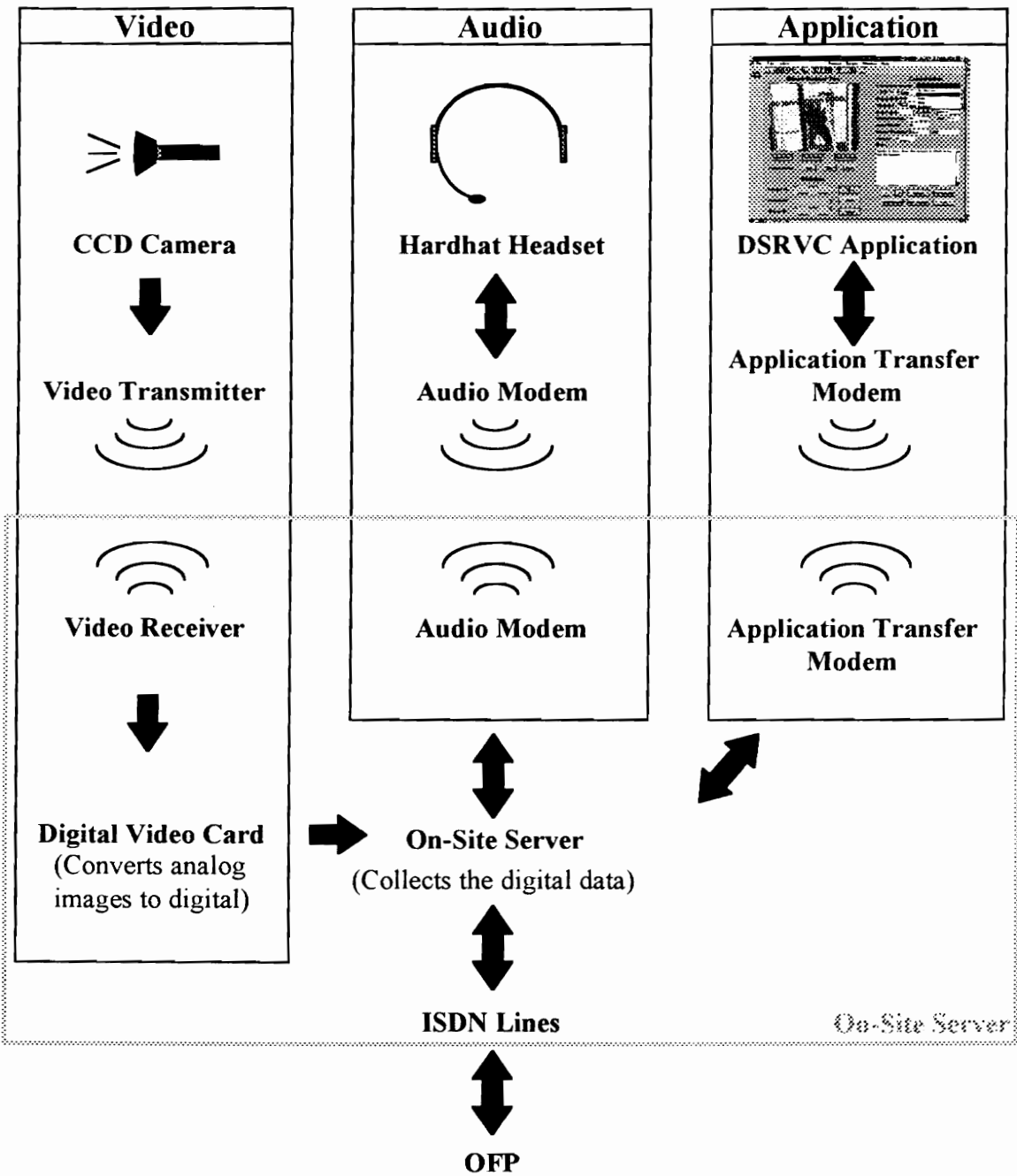
### **4.3.2 Transferring Data From MOCU to an On-Site Server**

The transfer of the video, audio, and application data from MOCU requires wireless transmissions that are received by an on-site server. The wireless transmissions for each of the three data transfer types must be individually transferred and then collected (see Figure 4-6). This is due to the high data rates that are used when transferring these types of data.

The transfer of the video signal occurs by using a wireless analog transmitter/ receiver system. The analog signal from the CCD camera is sent to the transmitter which then sends the signal to the receiver. Since the video signal is being sent in an analog form, no compression is used and the only loss that occurs is due to distance or large obstructions that make the transfer of the signal difficult. If either the range, which is between one-half to one full mile, or obstructions are a problem, repeaters can be added to help upgrade the signal as needed. After the video data is collected by the receiver, the analog information is sent to the on-site server. Further specifications and cost information are located in Appendix B.

The transfer of the audio signal occurs via a wireless modem operating at 19.2 Kbps. Unlike the video signal, this signal occurs in a digital format. The signal is sent from the hard-hat microphone to the audio modem located on MOCU, where it is transmitted to

the on-site server. The reverse is also true. The on-site server sends audio received from the OFP to the ONP using the wireless audio modems.



**Figure 4-6 The Transfer of Data from MOCU to the OFP**

The transfer of application data occurs using a 38.4 Kbps wireless modem. The data is sent from the computer belt to the application modem where it then is sent to the application modem operating with the on-site server. As with the transfer of the audio signal the reverse is also true. In this way both applications of DSeRViC can be updated consistently.

The on-site server is at least a 486 DX4-75 computer that collects the data sent from MOCU. The video data is compressed using a digital video card. This compressed digital video is then combined with the digital audio and digital application information. It should be noted that the video portion of DSeRViC is a separate application itself that is incorporated into DSeRViC. This allows for the separation of the video from DSeRViC as well as the combining of the two pieces of data without the use of an additional operator.

#### **4.3.3 Transferring Data From the On-Site Server to the OFP**

After the three data transfer types are collected by the on-site server, the information is then sent to the OFP using an ISDN line. Assuming the user has the option to have the video at full screen at three frames per second, or at 1/4 screen at 12 fps the video portion requires 60 Kbps. The audio requires 16 Kbps and the application sharing requires at least 19.2 Kbps. Therefore the minimum data rate is 95.2 Kbps. This number is deceiving, however; since the more changes that the compression algorithm is required to update, the

higher the necessary data rate. Therefore the data rate can increase. For this reason the ISDN line that is required as a minimum for CVVS is the 2B+D line which offers 128 Kbps for the user.

#### ***4.4 Permanent Archive***

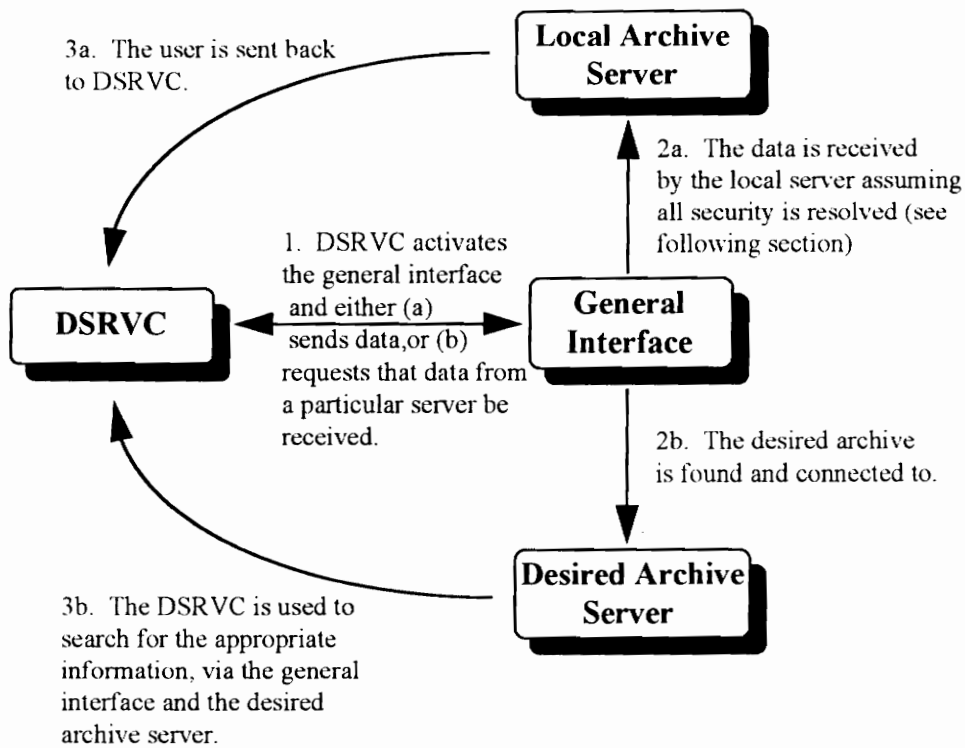
The permanent archive is equivalent to a bank of data for the construction industry. As CVVS is used to collect data on various construction sites, the data is stored in an archive for later retrieval. The development of such an archive brings to the forefront many issues. This section will discuss two - a proposed organization for a network of archives, and the security issues that should be considered when implementing the network.

##### **4.4.1 The Archive Network**

In order for construction companies to be able to store data from their construction sites to a neutral archive anywhere in the world, it is necessary to have a network of archives. The world wide web functions using a network of servers in order to access a large quantity of data. For this reason the world wide web was used as the model for the archive network (see Figure 4-7). However, the World Wide Web was not used as the archival system due to security issues as discussed below.

The first step is for DSeRViC to activate the general interface. The general interface acts to connect the system to any one of the many hardware types to allow for the transfer of data (i.e. telephone lines, etc.). The general interface is comparable to Winsock which

serves the same function when accessing the web. This general interface sends queries, as well as receives information. The general interface essentially acts as a link from DSeRViC to the network of servers.

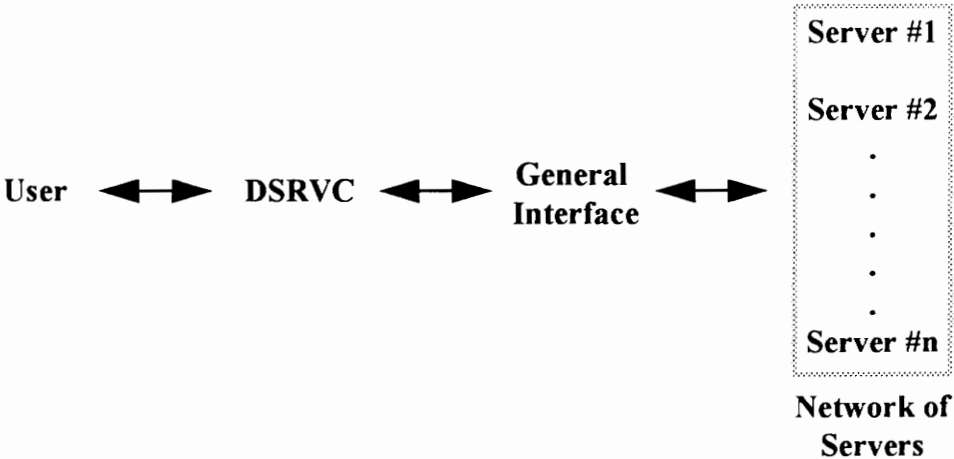


**Figure 4-7 Methodology of the Archive Network**

The second step is the connection to the correct server. The server is the information bank. In order to serve a large area, at least one server must be present in each region in order to store the construction data from that particular region. The number of servers and the size of each region is determined by the construction activity in the area. Servers

provide two functions; data storage and data retrieval. If on-site data is being sent to the server, then the information automatically transfers to the local server and the user completes the cycle by returning to DSeRViC.

If the user is requesting access to already stored information for viewing, however; the third step of the cycle is slightly more complicated. The user is returned to DSeRViC, and DSeRViC acts as a browser for selecting the proper server (see Figure 4-8). After the server is selected the cycle begins again, as the query is sent through the general interface to the chosen server. At this point the home page for that server is viewed using DSeRViC. The user then chooses the correct category (Desired Job, Concrete Work, etc.) on the home page and the cycle continues. The cycle will continue until the user has narrowed his/ her choice down to the correct job record. This selection process is comparable to the manner in which web browser packages, such as Mosaic and Netscape, obtain information from the world wide web.



**Figure 4-8 Selection of the Desired Server**



#### **4.4.2 Archival Security Issues**

The ability to store information in the archive network offers the chance to end disputes before they go to litigation by having access to information quickly. The information that is retrieved from the archive, however, can be for private viewing only, and must not be tampered with. In order to insure the privacy of the clients, as well as the security of the stored data, security measures must be taken. This proposal suggests two primary issues of security - user identification and channel security as well as a new breed of private eyes known as Cyber Sleuths.

##### **4.4.2.1 User Identification**

User identification is the forefront of security. If a potential user is correctly identified, and his/ her security clearance verified, then the data is safe assuming the user is not participating in illegal acts. The most common method for identifying a potential user is by passwords. Passwords should be long, at least six symbols, and complex enough to insure that the password is not easily determined (Messmer, 1994). For the security of a construction job three categories of passwords are proposed: (1) a company password, (2) a job password, and, (3) a personal password. It should be noted that computer experts agree that the threat to computer system security is almost always greater from insiders of the company than outsiders (Lang, 1995). For this reason passwords and their respective clearances should be given out with care, and passwords should never be shared!

The company password is used to insure that the person attempting to obtain data is affiliated with the company, the job password insures that the person is affiliated with the job, and the personal password determines which records the individual has access too. The company password necessarily has to be changed periodically, to keep up with employee turnover, and the job password and the personal passwords also need to be altered occasionally. The recommended time limit recommended by most security managers is 90 days (Messmer, 1994). It is recognized that not all three of these passwords are necessary for all circumstances. For instance, the viewing of daily records may not present a high security risk, however; the appending of existing data should carry a high risk and therefore require more intense user identification.

#### **4.4.2.2 Channel Security**

When accessing the archive network, it cannot be assumed that access to the server is limited to the correct personnel. For this reason the security of the channel must be insured. The best defense for insuring that access to the various channels is limited, is by encrypting the data. Encrypting refers to encoding the data before the data is transferred, and then decoding the data after it arrives at it's destination. In order for encryption to be effective, however; it must use access keys. The access keys are used to first encode the data, and then to decode the data (see Figure 4-9).

For this proposal, both private and public access keys are used. Public access keys are assigned to all clients and servers. During a session a one-time session key is created to encrypt the file using cryptography. Then the recipient's public key is used to encrypt the session key. The encrypted session key is sent along with the file to the recipient. This prevents all but the intended recipient from reading the file. The public keys are used only for encrypting and the private keys only for decrypting (Network, 1994).

#### **4.4.3 Cyber Sleuths**

A third alternative to archive network security is cyber sleuths. Cyber Sleuths are companies that monitor the net and keep an eye out for hackers and other hints of information security breaches. The Cyber Sleuth is hired to both protect against information security breaches as well as to help locate culprits when security breaches occur. In a study by Earnst & Young, on 1,271 North American companies polled, over half reported losses due to information security problems (Lang, 1995). With these kinds of information security problems, Fortune 500 companies have been forced to hire Cyber Sleuths in order to add to their internet security.

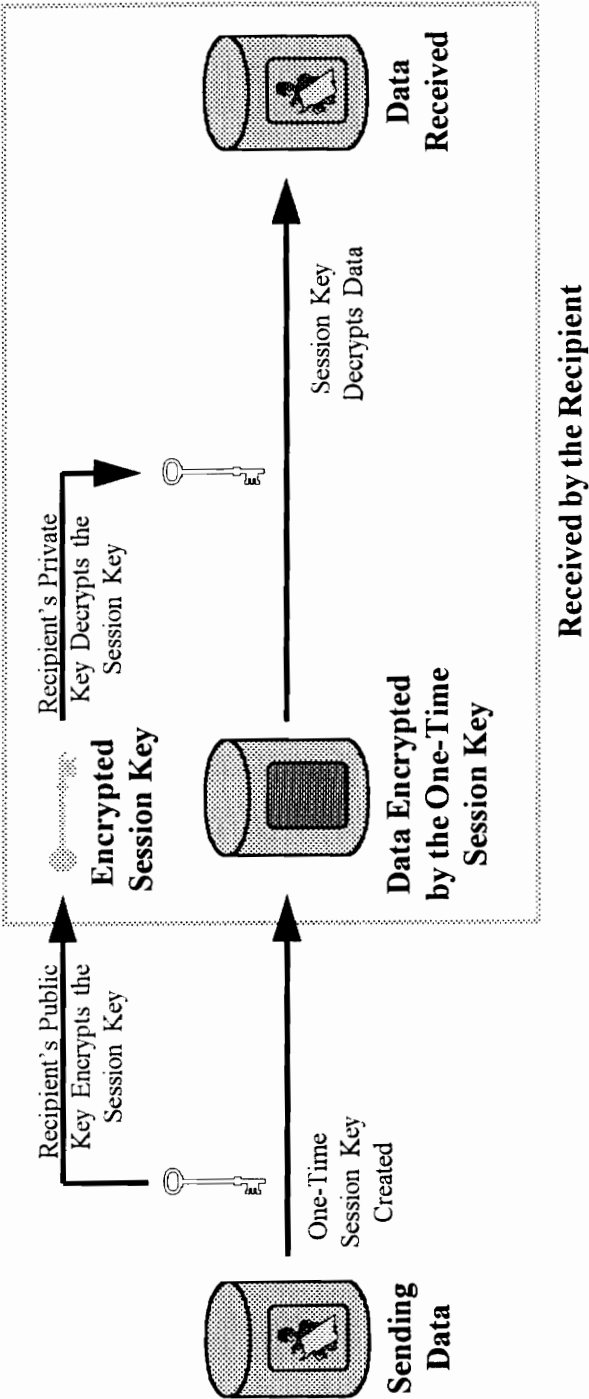


Figure 4-9 The Encryption Process

#### ***4.5 Proposed Software Design (DSeRViC)***

DSeRViC is the proposed design for a software package that incorporates all of the functions mentioned in the previous sections, and empowers the user to implement them when required. The primary job of DSeRViC is to capture data on the site and store it in a manner that allows for immediate retrieval. DSeRViC can contact any server in the archive network, as well as capture video from the CCD camera. All of these capabilities require an organized menu of options for the user.

DSeRViC is designed to allow the user to perform most functions using the track ball located on the computer belt of MOCU. A keyboard can be connected to the system and used with DSeRViC, however; the extra bulk can inhibit the user under field conditions. In order to make DSeRViC a mouse driven application, pop-up lists are used (see Figure 4-10) where data is entered into fields. Putting a new name into a pop-up list can be done easily, by selecting -New- located at the bottom of the pop-up list. The new entry can then be entered by an external keyboard or by using the Keyboard view, as discussed later.

**Conversation**

Conversation from ONP:

to GFP:  Date:

Primary:

Description:

Daily P:

Actual Quantity:  **Pop-up List**

Weather Conditions:  and

Temp (F):

Memor:

**Figure 4-10 Pop-up list**

DSeRViC has the ability to be shared with OFP's even if DSeRViC is not installed on the OFP's system. The sharing of DSeRViC allows the OFP the ability to fill in fields with appropriate information during the course of a "Virtual Visit" and otherwise control the visit while DSeRViC runs on the ONP's system.

The data presented in DSeRViC can be viewed in a number of ways, however; the primary forum is the Daily Record view. The daily record contains all of the data that is being collected on the construction site. Daily records are primary information that make up the entire job record. As an ONP discovers activities that he/ she feels should be stored

permanently, a new daily record is created for that activity. An example of a daily record is shown in Figure 4-11. The daily record consists of a Main Menu, Picture Fields, Dialogue Fields, Conversation Fields, and Toolbar Buttons.

#### **4.5.1 Main Menu**

The Main Menu contains commands that are used to manipulate DSeRViC. Each command serves a function that can be accessed by the user. The Main Menu consists of five menu items: (1) File, (2) Edit, (3) View, (4) Text, and, (5) Help. Each of these menu items have commands under them that serve various functions (see Figure 4-12). These commands are discussed in some detail in the following sections.

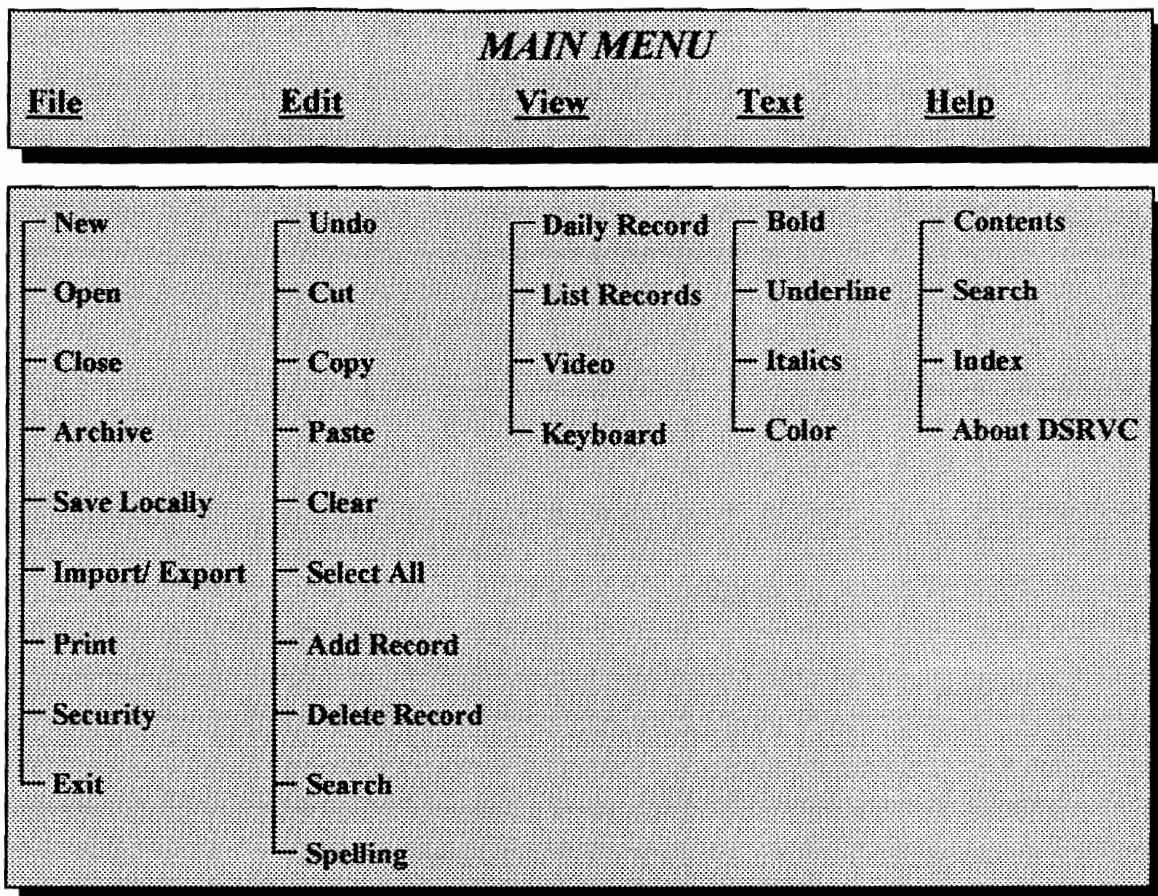


Figure 4-12 DSeRViC's Menu Structure



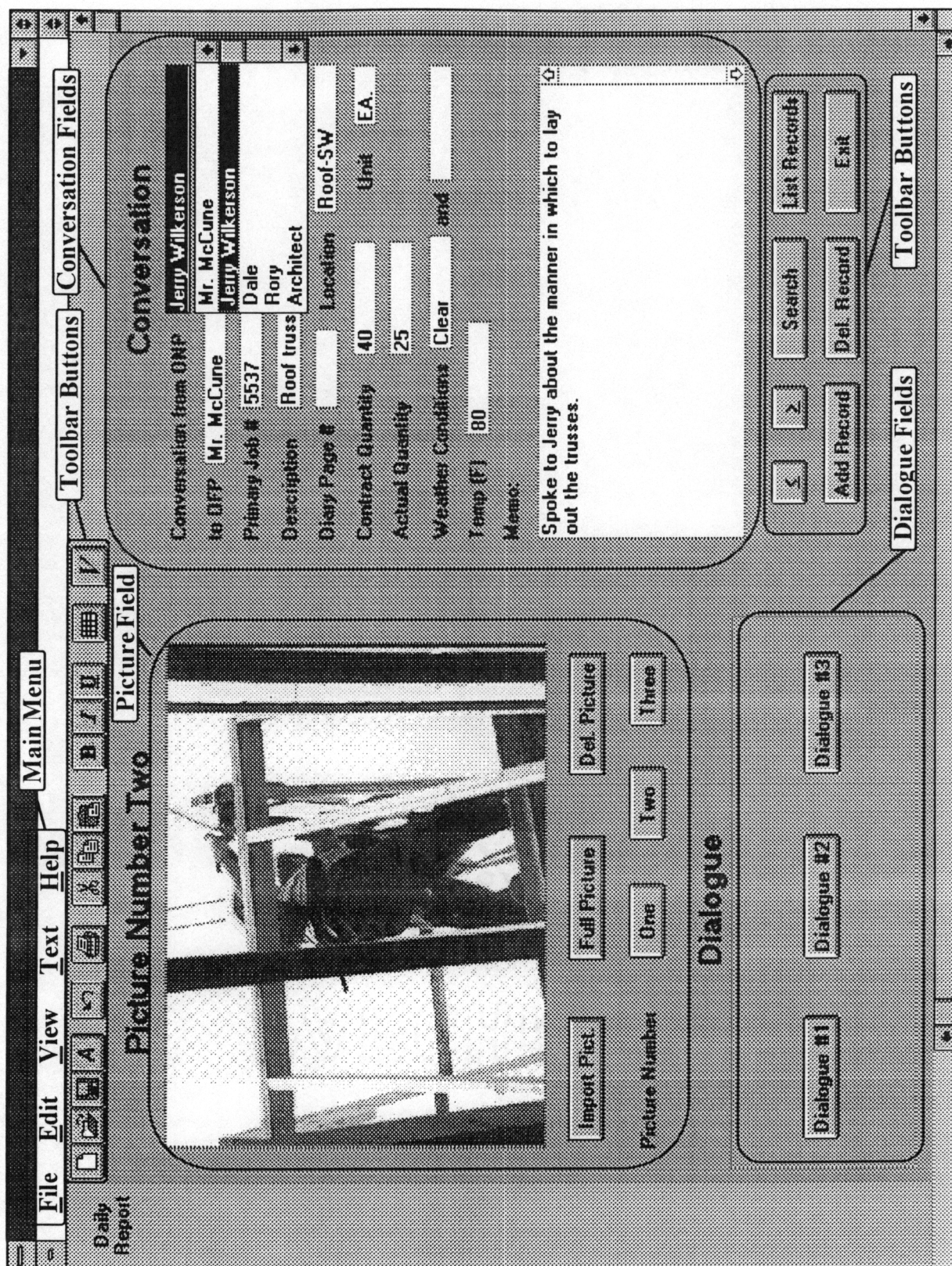


Figure 4-11 Daily Record

#### **4.5.1.1 Creating or Opening a Job Record**

Creating a new job record is accomplished by selecting the New command. Before a new job record can be created, however, a number of issues must be resolved: (1) The local server that is being used for archival storage must be identified, (2) A client/ server relationship must be established. This may include a storage fee, legal written agreements, etc., (3) The user must identify which companies and personnel have access to the new job record and passwords must be allotted to the appropriate parties, and (4) The basic information concerning the A/E, general contractor, and owner must be entered (see Figure 4-13). After the user has completed these steps, a blank daily record appears on the screen and the job may begin to be recorded.

The Open command is used after a job record has already been created and the user wishes to either view or append the existing job record. Opening a job record can occur in two ways: (1) The job record can be opened from a local drive, or (2) The job record can be retrieved from the archive network.

The job records located on the local drive are retrieved by selecting the appropriate drive, directory, and filename (see Figure 4-14). After the path has been selected, the OK button is pushed using the mouse and the file is opened.

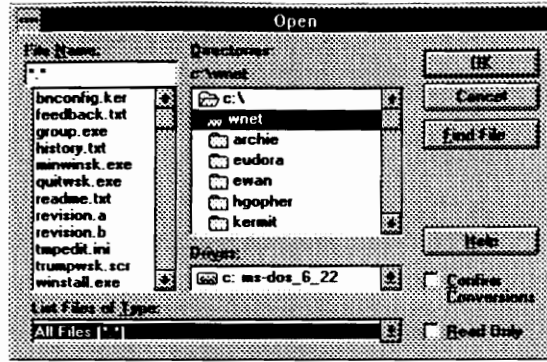
File Edit View Text Help

Party Info.

<b>JOB INFORMATION</b>	<b>CONTRACTOR INFORMATION</b>
Job Party Affiliation	Name
Job Name	Street Address
Job Designation Number	
Route	City
District	State
<b>ARCHITECT INFORMATION</b>	<b>OWNER/ GOV. AGENCY INFO.</b>
Name	Name
Street Address	Street Address
City	City
State	State
Continue	Main
	Exit

Figure 4-13 Basic Party Information





**Figure 4-14 Typical Open Window**

The job records located in the archive network must be retrieved in a slightly different manner. First the user must connect with the correct archive server and identify the job record. The search for the server and the job record is accomplished by using an archive browser analogous to a web browser, i.e. Netscape or Mosaic. The user is shown the archive server's home page, and using the home page the user begins to narrow his/ her search. After finding the correct job record, the file is downloaded to the user's computer and viewing or appending the record may begin.

#### **4.5.1.2 Archiving or Saving a File**

After new daily records are added to the job record, it becomes necessary to store the job record. The storing of a job record occurs in two ways - storage in the archive network, or storage on a local drive.

Storage in the archive network is accomplished by selecting the Archive command in the File menu. The Archive command allows the user to save a job record to the regional

server that has been allocated to the user's construction job site. Before the user may store anything, however, the user is prompted for the appropriate passwords. After the passwords have been accepted the new daily records are stored in the job record. The user is not permitted to edit a previously stored record and then store the edits in the archive. If a daily record is found to have been altered, the archive identifies that a change has occurred and does not save that particular daily record. The user is, however, notified that the edited daily record was not saved. This allows the user to save the record locally.

The Save Locally command allows the user to save a job record to his/ her local directory. The Save Locally command is analogous to the Save As command found in other applications. The user must identify the appropriate drive, directory and filename in which to store the job record. After the information is entered, the user pushes the OK button to store the job record.

#### **4.5.1.3 Importing or Exporting a Record Field**

The Import/ Export command allows the user to either import information (i.e. an image scanned in from a camera photo) into any of the fields that exist in the daily record or to export information (i.e. a picture that should be included in a written report) to a file located on the user's local drive. The information that the user wishes to import can range from a picture, to a short Word document. In either case, the destination field must be identified along with the imported information. The Export command works similarly, as

the field containing the data to be exported must be identified, and then the location for the field's information must be located somewhere within the user's local drives (see section on Saving Locally).

#### **4.5.1.4 Printing**

The Print command allows the user to print any of the daily records located in the job record. The daily records that are to be printed are identified and then printed in a landscaped format. The list records view, as well as the full picture view may also be printed. The records can either be printed to a file or to a printer.

#### **4.5.1.5 Security**

The Security command allows the user to add, delete, or change personnel security clearances. This amounts to changing either the passwords or an individuals responsibilities associated with the job record. This command may only be accessed by the highest level of secured personnel, and the changes must be made with the permission of the highest ranking personnel on the job site. This permission is given by the ranking person by him/ her using their password.

#### **4.5.1.6 Closing a Job Record or Exiting DSeRViC**

A job record can be closed using the Close command. Close removes the current job record from DSeRViC without exiting from DSeRViC. This differs from the Exit command which ends the current session of DSeRViC and all associated job records. In

either case, when a job record is closed the user is prompted to save the record if the user has not already done so. If the job record has not been saved and the user chooses to do so, the user may choose to archive the job record or save it locally as per the previous section.

#### **4.5.1.7 Editing in DSeRViC**

The first six commands located within the Edit menu are used to edit the fields of the daily records. These commands are: Undo, Copy, Cut, Paste, Clear, and Select All. The Undo command allows the user to undo his/ her previous action. The Copy command copies the highlighted portion of the record to the Clipboard Manager located in Windows. The Cut command also copies the highlighted portion of the record to the Clipboard Manager located in Windows, however; in addition the highlighted portion of the record is deleted. The Paste command places whatever has been placed into the Clipboard Manager at the location of the cursor at the time of the command. The Clear command acts as the Cut command without copying the information to the Clipboard Manager. Finally, the Select All command selects all fields within a record in order to manipulate the fields with the above commands.

The remaining four commands are: Add Record, Delete Record, Search and, Spelling. The Add Record command creates a blank daily record in which new information can be inputted. The Delete Record command deletes the currently selected daily record. Note

that the Delete Record command does not delete records in the Archive. Only records that are currently being created and have not been archived can be deleted. The Search command allows the user to enter parameters for a search of the daily records. These parameters can be any one of the text fields, or a combination of the them. For example, one search may ask for all records conducted by John Doe on August 12, 1994. The Spelling command checks the records for spelling using a computerized dictionary. Note that the majority of the time the editing tools used for text are unnecessary because the daily records use pop-up lists.

#### **4.5.1.8 Viewing Different Screen Layouts**

The View menu allows the user to change the current layout that is appearing on the monitor screen. The View menu has four views: the Daily Record, List Records, Video, and Keyboard. The Daily Record view shows the current job data of one daily record at a time (see Figure 4-15). The List Records view shows some of the job data fields in a list form to allow the user to view more than one daily record at a time (see Figure 4-16). The Video view allows the user to see the daily record with the exception of the still pictures, which are replaced by the video from MOCU's CCD camera (Figure 4-17). Finally, the user may use the Keyboard view if it is necessary to key in data when a keyboard is unavailable (see Figure 4-18).



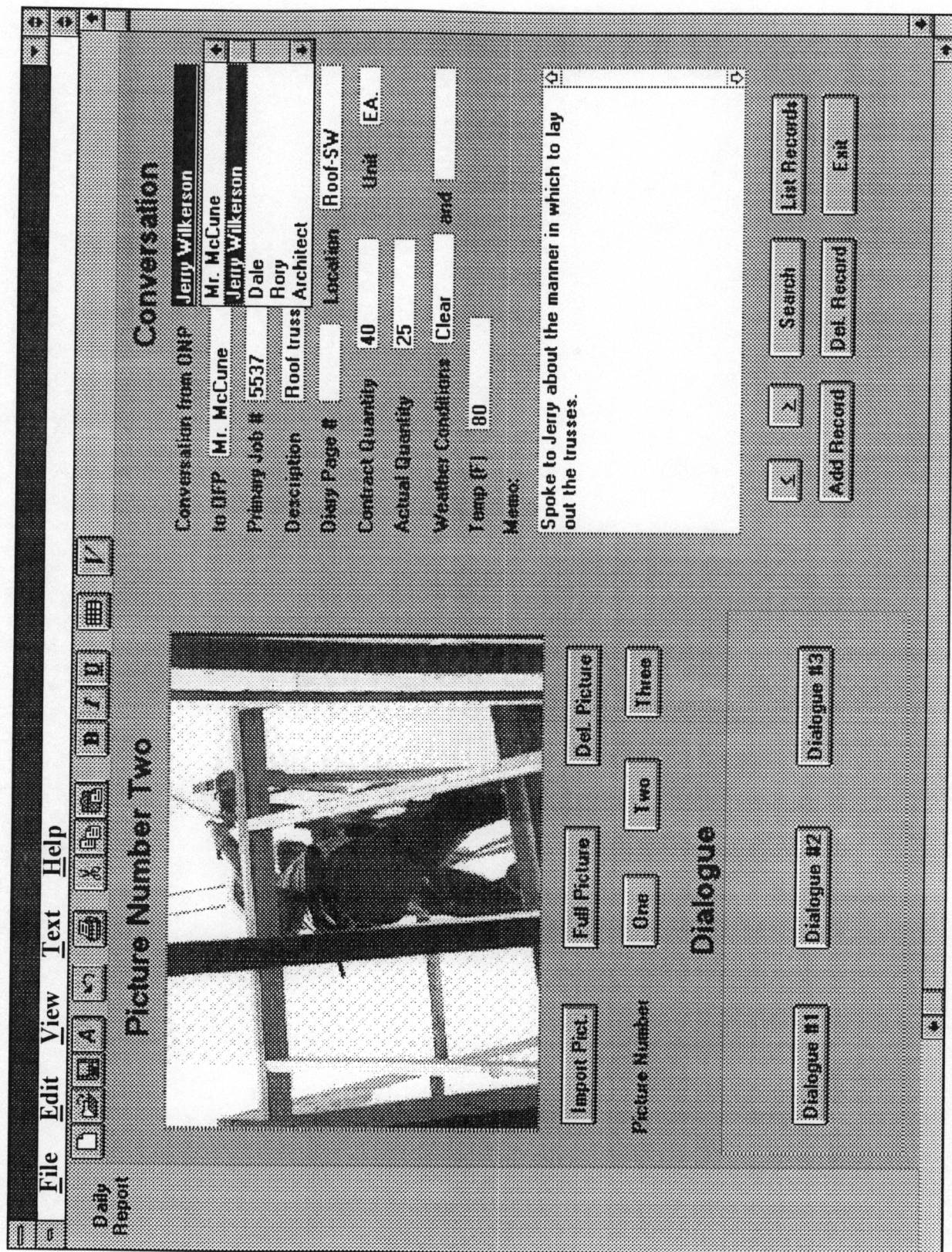


Figure 4-15 Daily Record View

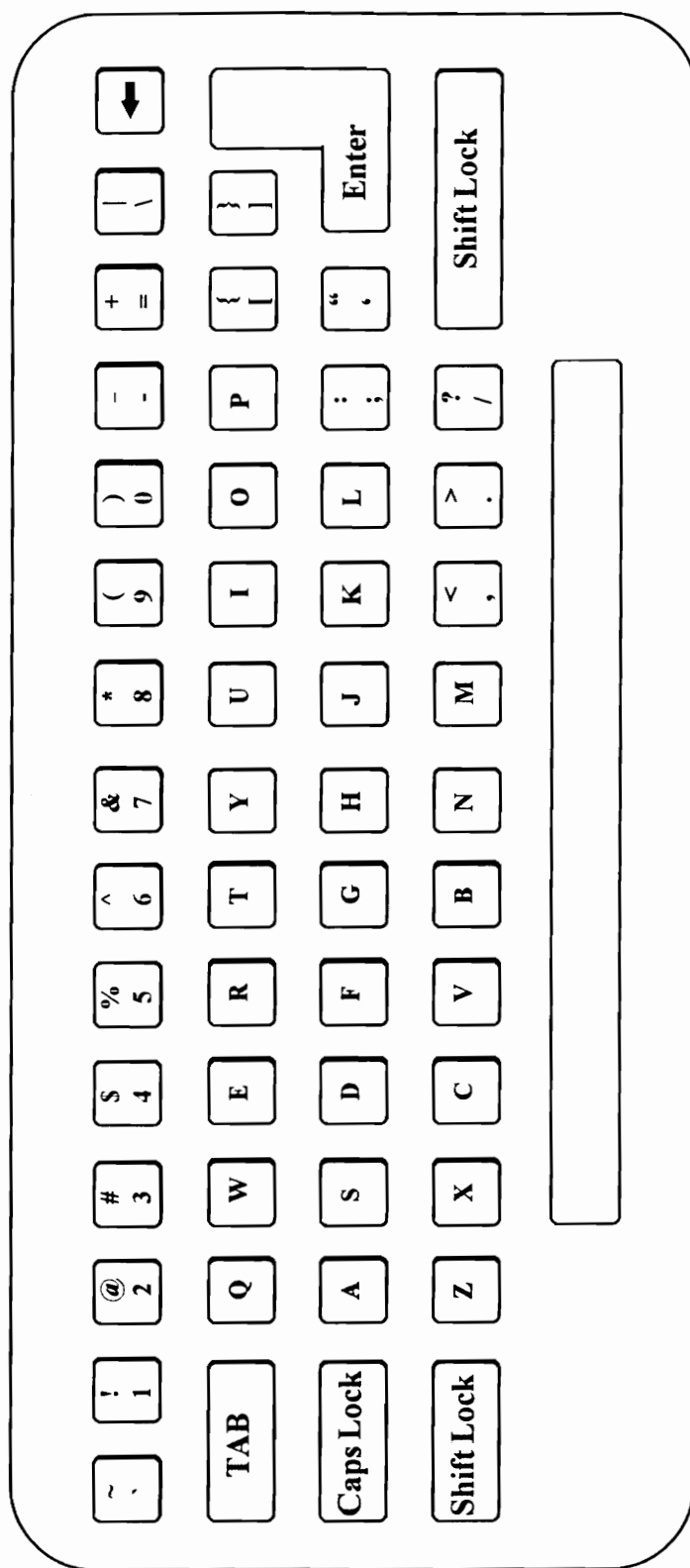
File Edit View Text Help									
Return Send Exit									
ONP	QFP	Prim job	Item Number	Description	Stored Date	Location	Contract Quantity	Actual Quantity	Unit
Rory				Laying plywood	5/11/95				
Rory	Jerry Wilkerson	5537	3314	Plywood Subfloor	5/11/95		300	275	EA.
Jerry Wilkerson	Mr. McCune	5537		Window	6/9/95	Southwest	50	46	EA.
Jerry Wilkerson	Mr. McCune	5537		Roof trusses	6/9/95	Roof-SW	40	25	EA.

Figure 4-16 List Records View





### Figure 4-17 Video View



**Figure 4-18 Keyboard View**

#### 4.5.1.9 Changing the Format of the Text

When text is being inputted into the computer, or the user wishes to emphasize a pop-up list's entry, the text commands can be used. The text commands include: Bold, Underline, Italics, and Color. By highlighting a portion of text any one of these commands can be used to alter the text. The Bold command bolds an entry, i.e. **Bold**. The Underline command underlines an entry, i.e. Underline. The Italics commands italicizes an entry, i.e. *Italics*. The Color command changes the color of an entry, Color.

#### 4.5.1.10 Help

The Help menu allows the user to seek help while using DSeRViC. The Help menu is analogous to a computerized User's Manual. The Contents commands shows the user what can be found in the Help menu. The Search command allows the user to search the Help menu using categories and keywords found in the menu. The Index command shows the same information found in a User' Manual index. Finally, the About DSeRViC command gives basic product information such as registration and copyright data.

#### 4.5.2 Picture Fields

The picture fields consist of two categories -- the fields active in the Video view, and the fields active in the Daily Record view. When the user is in the Video view, up to three still images can captured per daily record (Three still images was found to be a reasonable number during the filed testing that occurred in Chapter Five). The still images can be captured in the Video view (refer to Figure 4-17) or they can be captured when the Video

view has been switched to Full Video (see Figure 4-19), using the Full Video button. In either case the Capture Pict. button is used.

When the user is in the Daily Record view, the user can view any of the three still images by selecting the appropriate picture number (refer to Figure 4-15). The user can also import a picture that was not captured by MOCU's video camera using the Import Pict. button, can view the still picture as a full picture (640 by 480 pixels) using the Full Picture button, or can delete the currently selected still image by pushing the Del. Picture button.

#### **4.5.3 Dialogue Fields**

Dialogue can be recorded in the dialogue fields in one of two types of conversations - an off-site conversation when an ONP speaks to an OFP, or an on-site conversation when an ONP speaks with another ONP. To pick the proper dialogue, the user clicks on one of the three dialogue buttons. The user is then asked which type of dialogue is going to be used. If the user selects off-site conversation, then MOCU's sound chip records the conversation occurring across the hard-hat microphone and the OFP's telephone. If the user selects on-site conversation, then MOCU's sound chip records the conversation using the external microphone located on MOCU's belt computer. In either case, an Audio Recorder window appears that allows the user to record, play, rewind, fast-forward, or clear the dialogue.



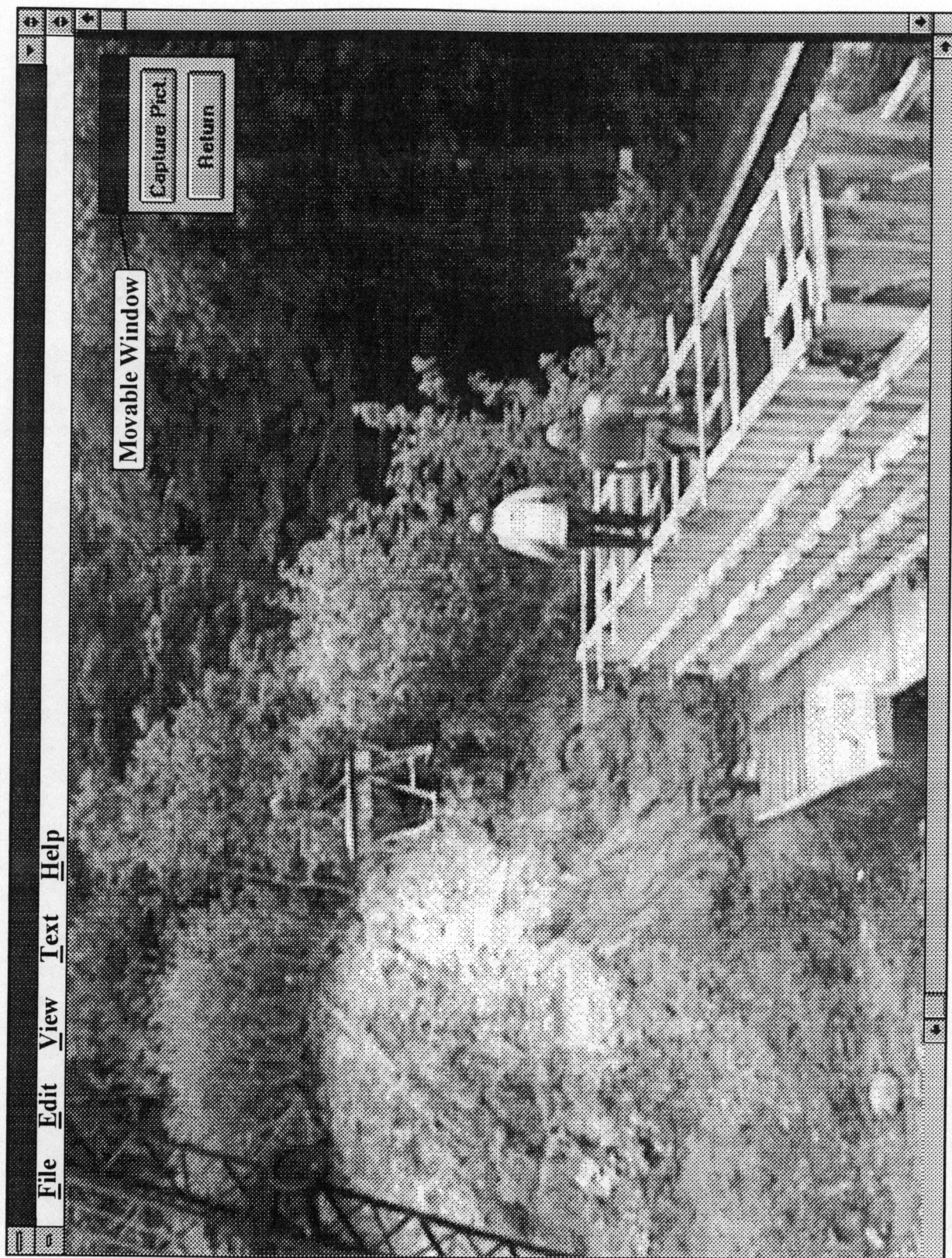
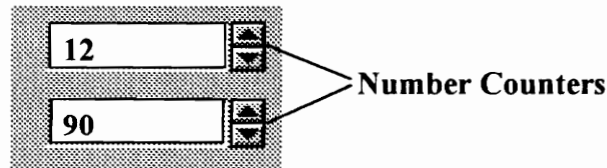


Figure 4-19 Full Video

#### 4.5.4 Conversation Fields

The conversation fields deal with information occurring at the time the data was recorded. Most of the conversation fields use pop-up lists as discussed earlier with the exception of conversation fields using numbers (Item No., Diary Page #, Contract Quantity, Actual Quantity, and Temp.) and the memo field. The conversation fields using numbers use number counters (see Figure 4-20) that can be pressed to raise the number or pressed to lower the number. The memo field is typed in using the keyboard, or the Keyboard view.



**Figure 4-20 Number counters used in conversation fields**

#### 4.5.5 Toolbar Buttons

The toolbar buttons refer to the buttons located at the top of the Daily Record, List Records, and Video views, and the group of buttons located in the bottom right-hand corner of the Daily Record and Video views. The toolbar buttons are to allow the user access to the main menu's function without actually having to use the main menu. The toolbar buttons are for the user's convenience, and with the exception of the navigation buttons that allow the user to move from one daily record to the next, they do not offer



any new functions not already available using the Main Menu. The toolbar buttons and their functions are shown in Figure 4-21.

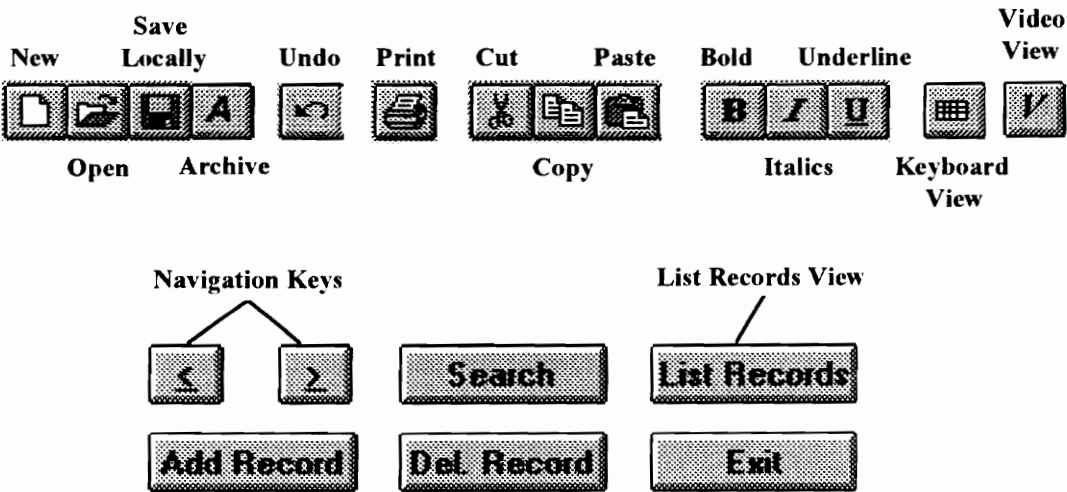


Figure 4-21 Toolbar Buttons

## ***Chapter 5***

### ***Validation of the “Virtual Visit” System***

This chapter describes the development of a working data storage and retrieval system (DSR), the testing that occurred to determine the limitations of examining a construction site virtually, and the effects that the data transfer rate has on the efficiency of a “Virtual Visit” system.

### ***5.1 Overview of the “Virtual Visit” Validation***

The concept of a “Virtual Visit” system presents the opportunity for off-site personnel (OFP) to have access to on-site information that they would not otherwise have using audio, video and still pictures captured in real-time. Theoretically this information can be used in improving the overseeing of a site or in helping the OFP’s to make real-time decisions about on-site activities. In order to determine the benefit that a “Virtual Visit” system can bring to the construction industry, it is necessary to test whether the information collected by the “Virtual Visit” system can be used effectively by construction personnel.

Testing the “Virtual Visit” model will be broken down into three phases. These phases are: (1) Development of a data storage and retrieval system (DSR) that is used in phases two and three, (2) Construction of a model system that is used to determine the limitations of examining a construction site virtually; and, (3) Testing the effects that the transfer of data has on the efficiency of the “Virtual Visit” system.

### ***5.2 Phase One - The Data Storage and Retrieval System (DSR)***

This section discusses the developmental background behind DSR and introduces the capabilities of the DSR system.

### **5.2.1 The Background of the DSR**

The “Virtual Visit” system offers the potential to collect a large amount of data relevant to the construction site. The construction industry; however, is notorious for collecting large amounts of data and obtaining very little information from them. It is often said that the construction industry is “data rich and information poor.” It is due to this reality that the development of an effective data storage and retrieval system is vital. If the “Virtual Visit” system is going to add even more data to the construction industry, it is imperative that the data be stored in a manner that allows it to be accessed quickly and easily, thereby becoming a source of good information.

Before developing the DSR system it was first necessary to find a successful system that could be used as a model. The model chosen was the Construction Workbook System (CWB) used by the Virginia Department of Transportation (VDOT). The CWB was developed to computerize the daily chores of monitoring and managing construction projects within the Commonwealth of Virginia, Department of Transportation, realm of responsibility, and was developed after years of input from sources both within and outside of VDOT. The CWB program was designed to track work and has been used on a variety of project types (Virginia, 1989). These credentials made it an ideal model for the DSR system.

The next step was to find a database software package that could be used for the development of DSR. After looking into a number of database software packages, FileMaker Pro 2.1 was chosen. The primary reasons for choosing FileMaker Pro were the successful completion of similar databases within the Construction Engineering & Management Division at Virginia Tech, the relative ease in which scripting could be accomplished, and the ability of FileMaker Pro to accommodate the easy storage and retrieval of audio and video.

During the scripting of DSR, relevant fields were chosen from the CWB and incorporated into DSR. It became apparent, however; after the initial scripting that some of the fields used in another FileMaker Pro database, Project Tracker, could help to improve DSR. Thus Project Tracker became the second model used in the development of DSR. Project Tracker is a customized FileMaker Pro 2.1 database, that was created by members of the Construction Engineering & Management Division at Virginia Tech. It was developed to illustrate how an off-the-shelf database application can be customized for field documentation of the construction process (Grieshaber, 1995). The relevant fields used by Project Tracker were incorporated into DSR.

DSR was developed using two databases, a VDOT software package called CWB that had been proven successful in the field, and Project Tracker, which has been proven

successful in an academic environment, as models for it's development. The next section describes the setup and fields used in DSR.

### **5.2.2 An Introduction to the DSR System**

The DSR system is a customized multimedia FileMaker Pro 2.1 database that contains fields that are necessary should a "Virtual Visit" system be implemented. The primary goal of DSR is to store a large amount of different types of data (still pictures, audio, job specific information, etc.) and allow that data to be retrieved quickly using dates, job and item numbers, etc. The immediate retrieval of data can help to expedite decisions and hopefully reduce controversy between the construction parties.

The DSR system can be used by any one of the three primary parties. The test system, which was designed specifically for testing the "Virtual Visit" concept, allows access to three separate databases, one for each party. When DSR is started, it's main menu allows the user to indicate which party he/ she represents (see Figure 5-1), as well as allowing him/ her to input information about the job and the primary parties involved on the job (see Figure 5-2).

After the job/ party information is inputted, the user is moved to the daily report page (see Figure 5-3). The daily report page is broken down into three types of fields: (1) Conversation, (2) Picture; and, (3) Dialogue. The Conversation fields consist of job

specific information such as weather, item numbers, and quantities, as well as storing the parties' names that are involved in each particular daily report. Ideally, most of the conversation fields could be scripted to use pull down menus in order to save time on the job. If a topic arises that is not covered in one of the Conversation fields, a memo field is included to allow for miscellaneous comments.

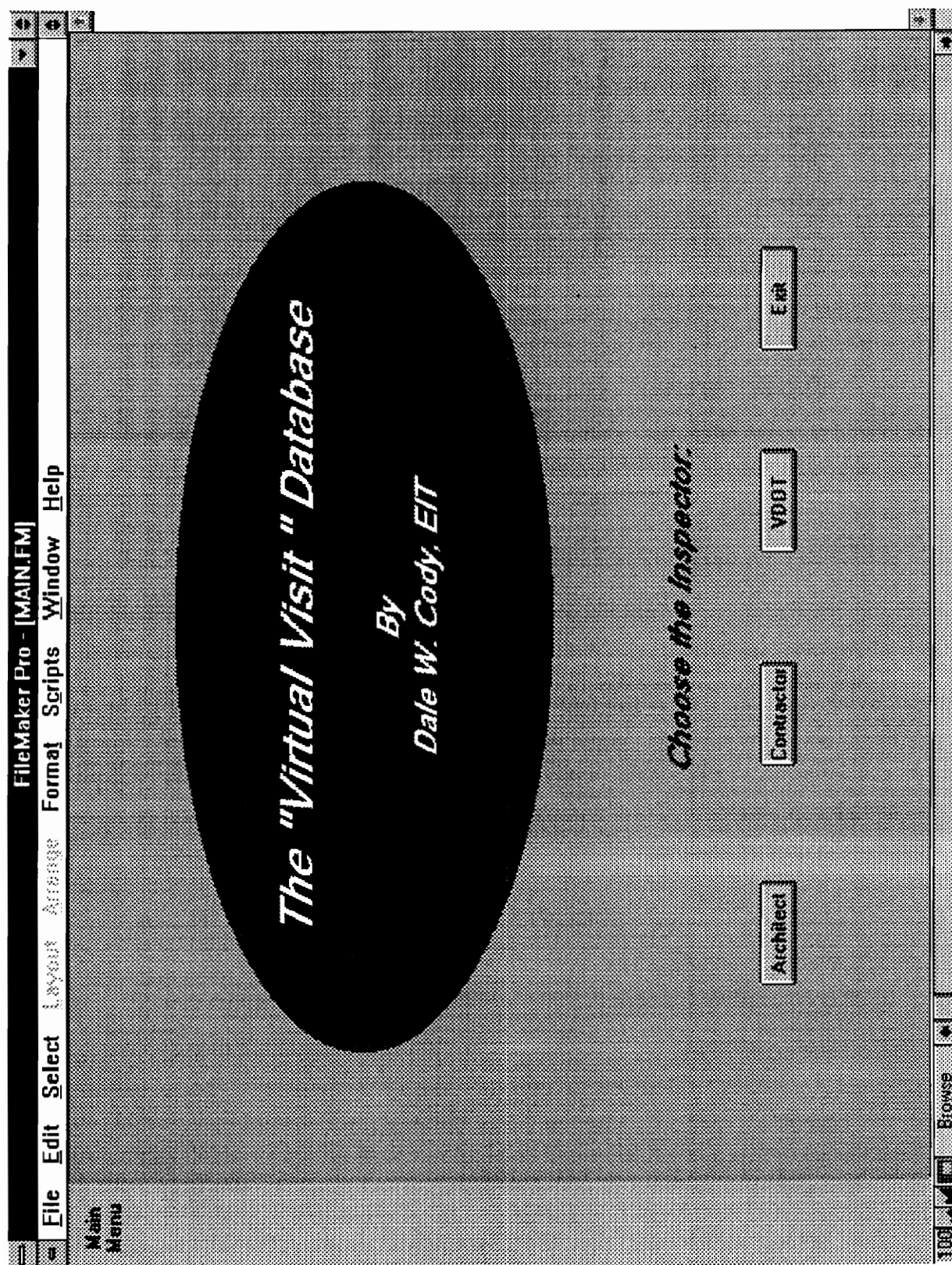


Figure 5-1 Main Menu



FileMaker Pro - [CONTR.FM]

File Edit Select Layout Arrange Format Scripts Window Help

Party Info.

JOB INFORMATION		CONTRACTOR INFORMATION	
Job Party Affiliation	<input type="text"/>	Name	<input type="text"/>
Job Name	<input type="text"/>	Street Address:	<input type="text"/>
Job Designation Number	<input type="text"/>		<input type="text"/>
Route	<input type="text"/>	City	<input type="text"/>
District	<input type="text"/>	State	<input type="text"/>

ARCHITECT INFORMATION		OWNER/ GOV. AGENCY INFO.	
Name	<input type="text"/>	Name	<input type="text"/>
Street Address:	<input type="text"/>	Street Address:	<input type="text"/>
City	<input type="text"/>	City	<input type="text"/>
State	<input type="text"/>	State	<input type="text"/>

Continue Main Exit

100% Browse

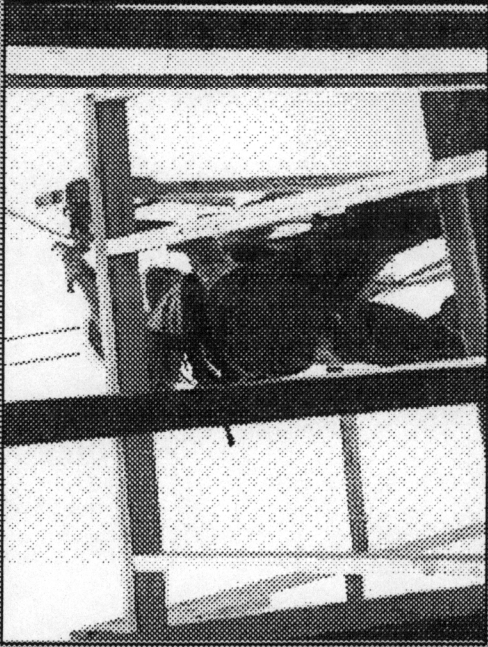
Figure 5-2 Information About the Primary Parties

FileMaker Pro - [CONTR.FM]

File Edit Select Layout Arrange Format Scripts Window Help

Daily Report

Picture Number One



Import Pict.

Full Picture

Del. Picture

One

Two

Three

Dialogue

Dialogue #1

Dialogue #2

Dialogue #3

Double

Click

Clear

Double

Click

Clear

Double

Click

Clear

Conversation

Conversation from GNP

Jerry Wilkerson

to GNP

Mr. McCune

Date

6/9/95

Primary Job #

5537

Item No.

Description

Roof trusses

Diary Page #

Location

Roof-SW

Contract Quantity

40

Unit

EA.

Actual Quantity

25

Weather Conditions

Clear

and

Temp (F)

80

Memo:

Spoke to Jerry about the manner in which to lay out the trusses.

Sort

Add Record

Browse

Main

Del. Record

Find

Exit

List Records

5

2

Figure 5-3 Daily Report Page

The Picture field allows still pictures to be imported into the database. These pictures appear at 320 x 240 pixels (about 1/4 of the screen) on the daily report page, but may be increased in size to 640 x 480, using the 'Full Picture' button (see Figure 5-4). The source of the imported pictures is designed to be the snapshots captured from the Camcorder using the Proshare Video system (see Section 5.3), however; any type of FileMaker Pro compatible picture can be imported. Three still pictures can be stored with each individual daily report.

Finally, the Dialogue field allows for on-site conversations to be stored using FileMaker Pro's audio recorder. Much like the memo field, conversations can be used to add to or augment the information that is stored in DSR's conversation fields. DSR is capable of storing up to three conversations in a daily record.



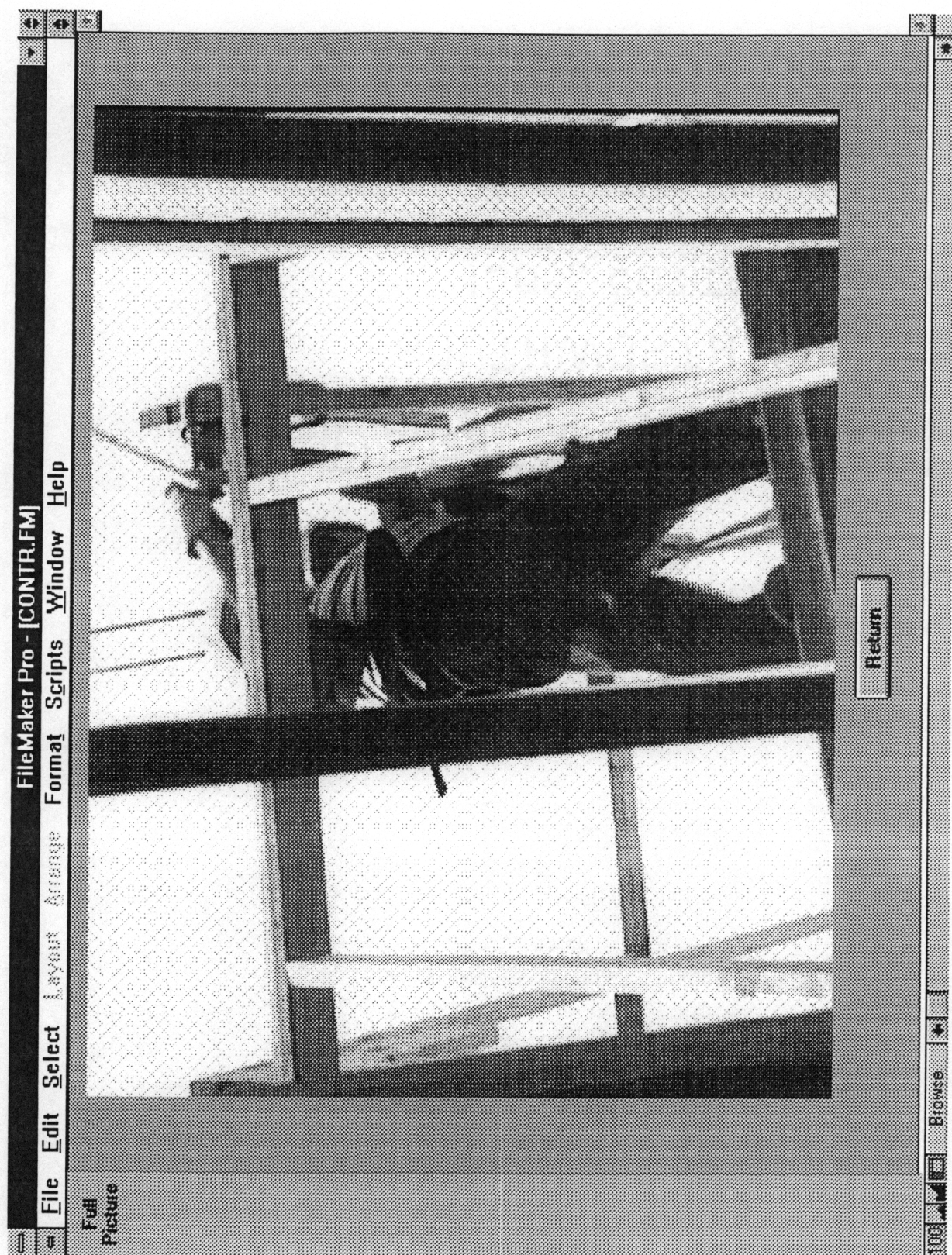


Figure 5-4 Full 640 by 480 Image

### ***5.3 Phase Two - Determining the Limitations of Examining a Construction Site Virtually***

This section discusses the background and methodology of a “Virtual Visit” model that is used to determine the limitations of examining a construction site virtually. The results of the tests are given and conclusions are drawn.

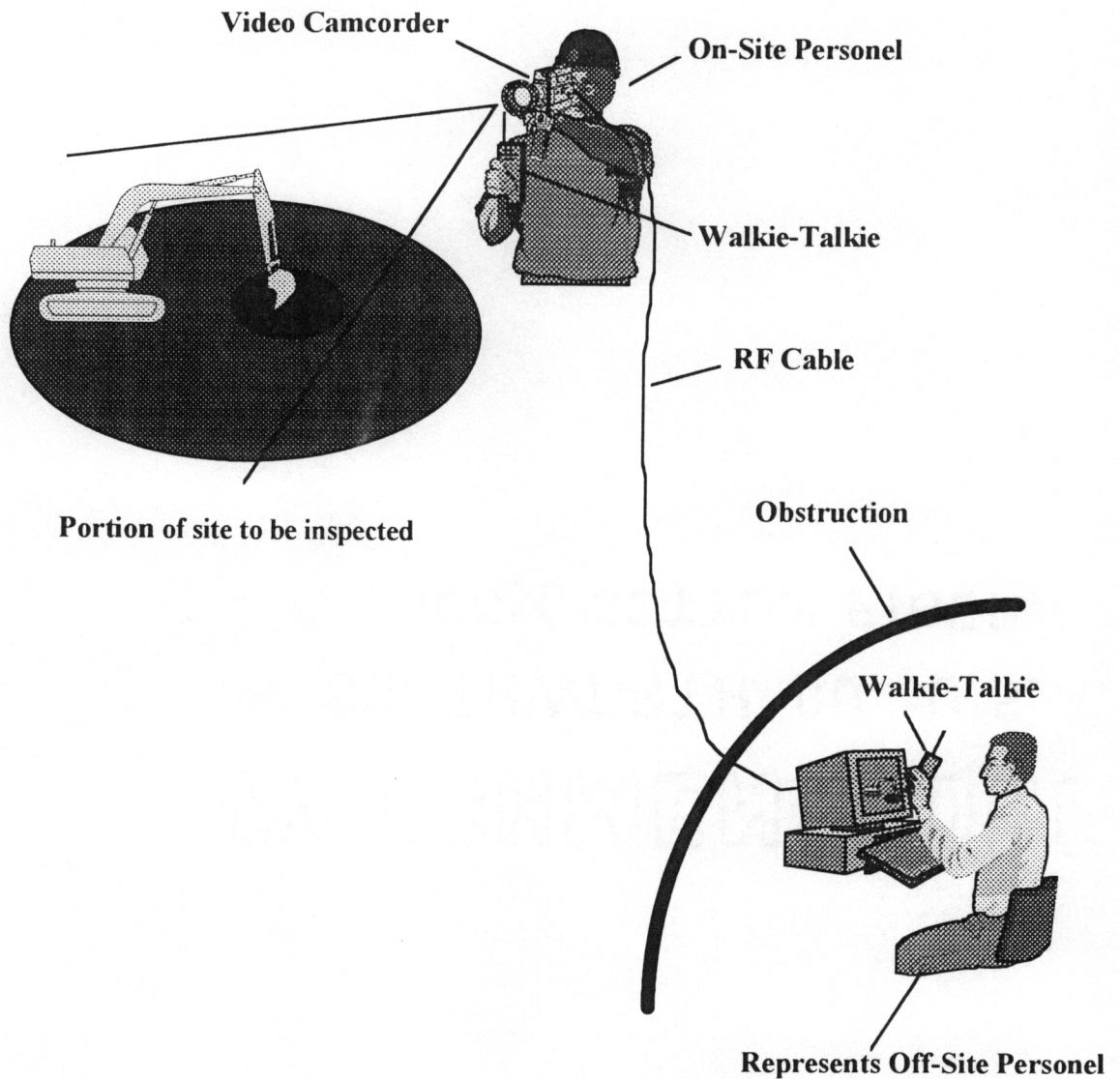
#### **5.3.1 Background for Developing the Model**

The construction industry oversees work on a construction site using a variety of inspectors, project managers, and engineers. It is their job to see that the project is built at a high level of quality and at a reasonable cost. Due to this responsibility, it is only natural that construction personnel feel more comfortable being on the site and watching the project to completion, however, as discussed in Chapter Two, this is not always possible. The “Virtual Visit” system offers an alternative to on-site visits, but the question remains as to how much can be accomplished virtually. In an industry typically resistant to change, the idea of examining a site virtually is one that will certainly be greeted skeptically. It is for this reason that testing the limitations of the “Virtual Visit” concept is important.

#### **5.3.2 Methodology for Model Development**

The model attempts to simulate the environment of a “Virtual Visit” system. The primary goal of the model is to determine the extent that off-site personnel (OFP) can direct on-site personnel (ONP), and what kind of decisions can be reached using this type of interaction. Some of the issues that the model attempts to determine are: (1) How the

ONP's experience within the construction industry affects the efficiency of the "Virtual Visit" system, (2) How the familiarity of the OFP with the construction project effects the efficiency of the system, and, (3) Whether a complete tour of the site is possible, or if the "Virtual Visit" system should be limited to evaluating specific activities. Figure 5-5 shows the model as it is described throughout this section.



**Figure 5-5 Model Set-up**

The first step of the “Virtual Visit” model was to simulate the separation that the OFP would normally have from the site. This was accomplished by obstructing the OFP’s view

in some manner. By blinding the OFP, the OFP was then forced to use just the model's audio and video tools to make decisions.

The second step was to set up communications between the OFP and the ONP. The party's phone conversation was simulated using walkie talkies and the video information from a camcorder operated by the ONP. The video input was transferred from the camcorder to the computer using RF cables. Upon reaching the computer the RF cables were plugged into a Proshare Video video card where the analog information was converted to digital to allow it to appear on the computer monitor. Proshare Video's software was used for the display and capturing of the video. The video appeared either in a 320 by 240 window or in a 640 by 480 window (see Figures 5-6 and 5-7) with the larger window using a lower frame rate per second (fps) to accommodate the larger amount of data.

The third step was for the OFP to determine what portions of the video should be captured for later retrieval. After capturing the relevant frames in the form of snapshots, these snapshots were stored in the Picture fields of DSR with any other relevant information that the OFP felt was necessary.



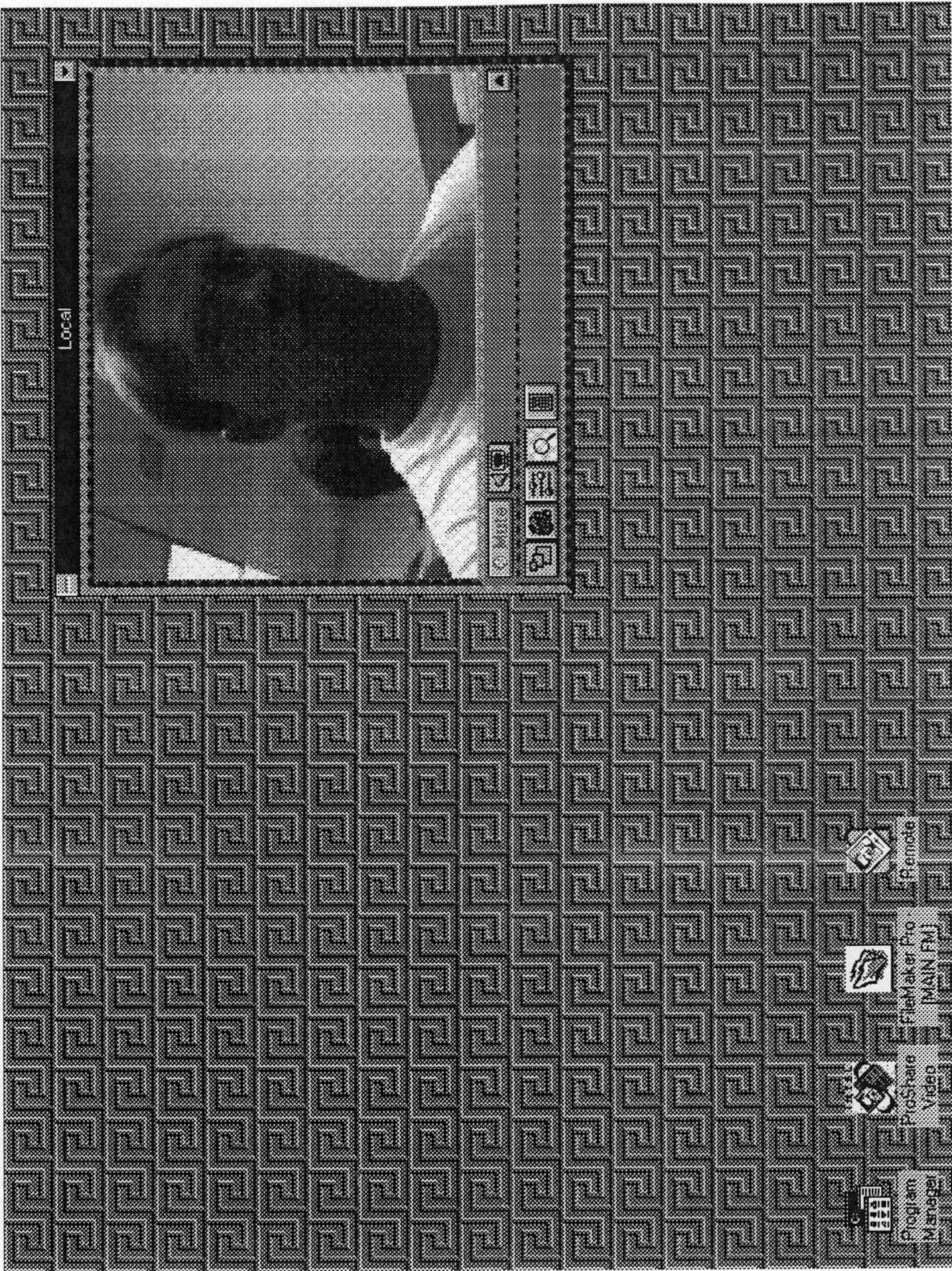


Figure 5-6 320 by 240 Window



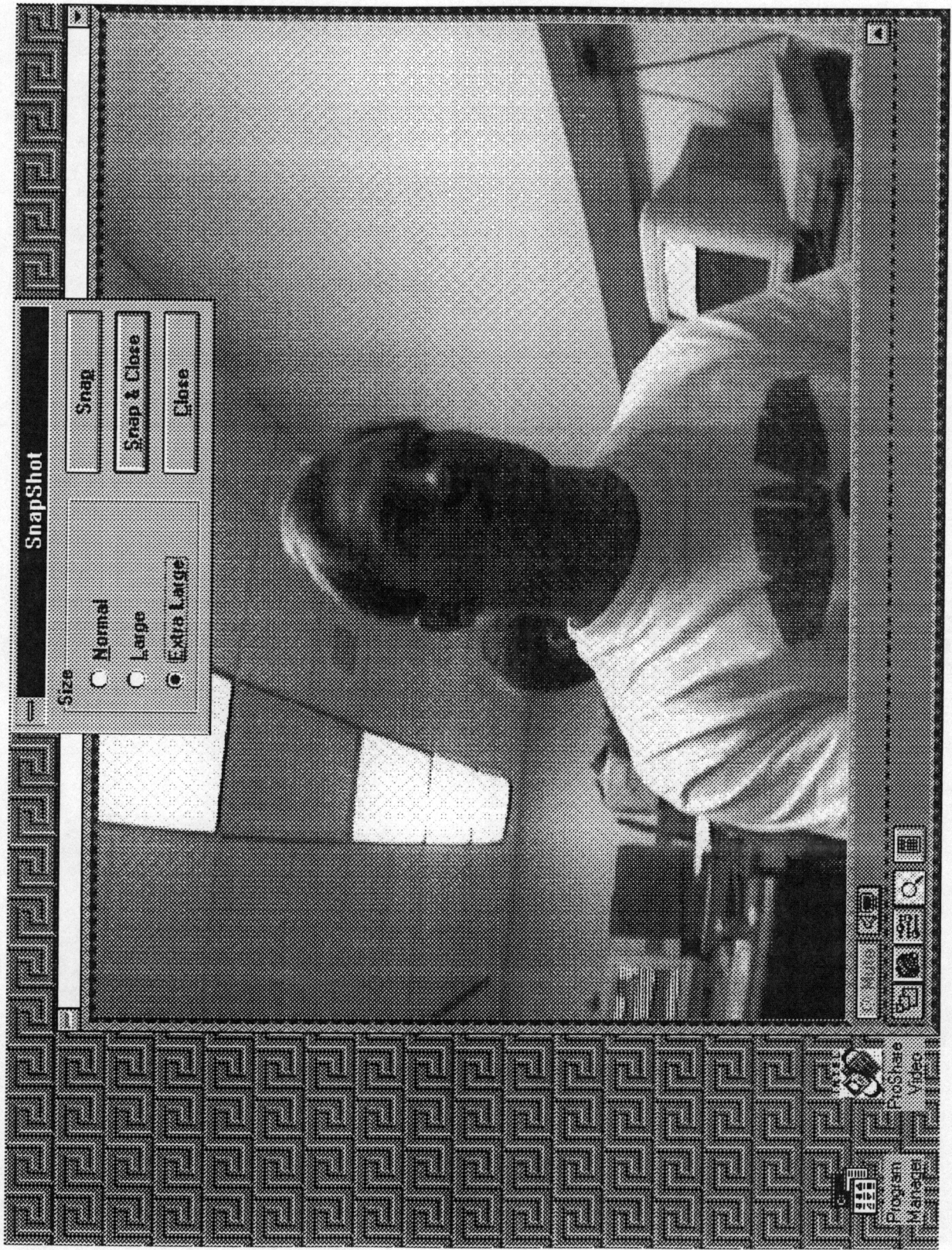


Figure 5-7 640 by 480 Window

The fourth and final step was to evaluate the performance of the model. This was done using evaluation forms that were filled out by the OFP. These forms were tabulated and appear in the following data and results section. Note that the exact system specifications are given in Figure 5-8.

<b>Computer</b>	486 DX2-66 w/ 16 MB RAM and 520 MB of storage space
<b>Computer Monitor</b>	SVGA non-interlaced
<b>Sound Card</b>	8 bit Soundblaster compatible
<b>Teleconferencing Hardware and Software</b>	Proshare Video v. 1.8 and Proshare Premier v. 1.6
<b>Camcorder</b>	Sony Handycam with 8x's power zoom
<b>Cables</b>	100 feet of standard RF cables
<b>Operating System</b>	DOS 6.22 with Windows 3.1
<b>Database Software</b>	FileMaker Pro 2.1
<b>Walkie Talkies</b>	Radio Shack's 300mW 3-Channel

**Figure 5-8 Model Specifications**

### **5.3.3 Results of the Model Field Test**

The evaluation of the model field test was accomplished using evaluation forms (see Figure 5-9). These forms were divided into two categories - evaluator's personal information, and the system's evaluation.

## ***Phase 2 - Virtual Construction Examination***

### **Evaluation Form**

Job Name \_\_\_\_\_ Job Description \_\_\_\_\_

Activity Name \_\_\_\_\_ Activity Description \_\_\_\_\_

Evaluator's Name \_\_\_\_\_ Evaluator's Position \_\_\_\_\_

#### **Evaluator's Personal Information**

Last Grade Completed				
Years in Construction				
Familiarity w/ Project	Poor	Fair	Good	Excellent
Familiarity w/ Computers	Poor	Fair	Good	Excellent

#### **System Evaluation**

1. System ease of Use	Poor	Fair	Good	Excellent
2. Layout of DSR	Poor	Fair	Good	Excellent
3. Efficiency of System	Poor	Fair	Good	Excellent
4. Inspection Acceptability	Poor	Fair	Good	Excellent
5. Concept of the "Virtual Visit"	Poor	Fair	Good	Excellent

**Figure 5-9 Evaluation Forms**

The evaluator's information was used to determine how the experience of the OFP could effect the use of the system. It was also used to determine if any biases existed, for or against the system, based on that past experience. It should be noted that, although the experience of the cameraman (ONP) was not on the evaluation sheet, it was found that ONP's experience did have an effect on the system, and therefore his experience was included as well.

The system evaluation was accomplished using a four point rating scale: One - Poor, Two - Fair, Three - Good, Four - Excellent. The system evaluation categories ranged from specific questions about DSR, to conceptual questions regarding the system. After the evaluation form was completed, the OFP's were asked for additional comments concerning the system. These comments are included after the tabulation of results.

	<b>Personnel #1</b>	<b>Personnel #2</b>	<b>Personnel #3</b>	<b>Personnel #4</b>
<b>Job Type</b>	Bridge	Building	Building	Concept
<b>OFP's position</b>	VDOT Inspector	Super.	Project Manager	Professor CE
<b>OFP's last grade completed</b>	H.S.	H.S.	3 yrs. coll.	Doctorate
<b>OFP's years in construction</b>	33	22	30	11+
<b>OFP's familiarity with the project</b>	4*	4*	4*	NA
<b>OFP's familiarity with computers</b>	2*	1*	1*	3*
<b>ONP's position</b>	Unrelated	Unrelated	Super.	NA
<b>ONP's last grade completed</b>	MS	BS	H.S.	BS
<b>ONP's years in construction</b>	0	0.5	22	NA
<b>ONP's familiarity with the project</b>	1*	1*	4*	NA
<b>System's ease of use</b>	3*	3*	3*	2*
<b>Layout of DSR</b>	4*	3*	3*	2*
<b>Efficiency of System</b>	3*	2*	2*	1*
<b>Inspection Acceptability</b>	3*	3*	3*	3*
<b>Concept of the "Virtual Visit"</b>	3*	3*	4*	4*
* Refers to Number Rating System      1 - Poor,      2 - Fair,      3 - Good,      4 - Excel.				

**Figure 5-10 Results of Model Evaluation**

While most of the categories from Figure 5-10 are self explanatory, a few require additional comment: (1) Under Job Type for Personnel #4, "Concept" refers to the fact that the evaluation was done in an academic environment rather than on an actual construction site, (2) "NA" refers to not applicable, and (3) "Unrelated" refers to the ONP having no official affiliation with the project.

During the course of using the model system, each evaluator was given the opportunity to give his general comments concerning the system. These comments are listed below:

Personnel #1

“The system was fine, although the speed of the software slowed down operations.”

Personnel #2

“The data storage was the best benefit, and would help in the management of the sub-contractors. Additionally, when the system is developed I would be interested in trying it on a construction site.”

Personnel #3

“A good way to evaluate a number of projects at once. In the future I could see these systems helping to evaluate construction projects.”

Personnel #4

“The ability to view all of the item numbers and descriptions at once should be added, and the capturing of the still pictures into DSR should be accomplished in one step rather than two steps; first capturing the picture and then storing it in one of DSR’s picture fields.”

#### **5.3.4 Summation**

The use of the model system proved very effective in obtaining good feedback concerning a “Virtual Visit” system. It was found that the level of computer experience and the educational background of the OFP did not significantly effect the effectiveness of the system. On the other hand, the experience of the ONP did have a direct effect on how

efficiently the system was used. When the ONP's experience level and familiarity with the project was high, the OFP was able to communicate more effectively and the evaluation was done more quickly. As the ONP's experience level and familiarity with the project dropped, however, the OFP had more difficulty directing the ONP and the system was operated more slowly. For this reason it is recommended that the ONP generally be someone who does not necessarily possess a great deal of experience in construction, but does know his/ her way around a construction site.

The system was generally found to have good operability and ease of use. The OFP's had little problem determining how it worked and how it was relevant to the construction project. They felt DSR's layout was good and that all relevant information was represented in the appropriate fields.

Finally, all of the personnel interviewed felt that the concept of the "Virtual Visit" system was good to excellent, and while there were reservations as to whether or not the system could replace on-site inspection, the general consensus was that the "Virtual Visit" represented the best alternative for evaluating a site when an actual on-site inspection was not possible.



## ***5.4 The Effects of Data Transfer Rates***

Data transfer can have a significant effect on the efficiency of the “Virtual Visit” system. Two areas of data transfer are discussed and examined: (1) Video frame rates for dynamic movement and video frame rates for slower more static movement, and (2) The effect data transfer has on the real-time application of document sharing.

### **5.4.1 Video Frame Rates**

When video is transferred, it must be compressed. One of the easiest methods of compression is the reduction of the number of frames per second in which the video appears. The effects of lowering the frames per second must be determined in order to allow the amount of data sent per second to be minimized without sacrificing the quality of the transmission.

In order to determine the appropriate data rates, two scenarios were used: (1) Dynamic movement, and (2) Slower more static movement. Both scenarios used a UNIX based teleconferencing system called Show Me. Show Me allowed the users to adjust the video frames per second that were displayed on the screen.

The first scenario involved a very dynamic scene where the movement was fast paced and changing. In this case, it was found that any data rate below 12 frames per second had a lagging, and choppy effect on the video. This effect caused the viewers annoyance when

watching the screen, and it was concluded that an OFP who was forced to view a construction site for a long period of time would find the video inefficient.

The second scenario involved a more static scene. In this case a frame rate of three to five frames per second was found to be effective. This frame rate proved effective when a user wished to view a static item on the construction site more closely, and the ONP managed to keep the camera still. Any fast movements at this frame rate, however, demonstrated an intolerable lag that often did not even pick up on the movement.

#### **5.4.2 Document Sharing**

The ability for DSR to be shared effectively by two people at isolated locations was determined using Intel's Proshare Premiere and Proshare Video 200 as test programs. DSR was shared using ISDN lines, which can use up to 128 Kbps, a 19,200 bps modem, and a 9,600 bps modem. The goal of this test was to determine at what baud rate a shared application would be effective. The effectiveness referring to the ability of the remote user to activate, for example Capture Picture, with no significant lag before the command was initiated.

The test with the ISDN lines was different than the other two which used POTs. The allocation of the ISDN lines data transfer rate was split between video, audio, and the shared application. In order to determine the effectiveness of a shared application at this

data rate, it was therefore necessary to discontinue the video by minimizing Proshare Video's teleconferencing windows and by not using the audio. This gave the shared application the majority of the data rate transfer of the ISDN line. In this scenario it was found that the shared document had almost no lag with respect to its ability for the remote station to run the application. Even when the video and audio were activated the only noticeable lag concerned the refreshing of the remote computer's display. For example, if a new window was opened, it didn't appear on the remote computer's screen for a few seconds.

The 19,200 and 9,600 bps modems produced similar results. In both cases the remote user could activate the shared application with no apparent lag. The delay came in the updating of the application. For these data rates, however, the refreshing was predictably slower.

The refreshing delay is bearable, since the primary goal of document sharing is to allow the remote user (the OFP) to capture pictures and otherwise update DSeRViC in real-time. Although it can slow the remote user down, it does not diminish the remote user's ability to run shared applications.

## ***Chapter 6***

### ***Summary and Conclusions***

This chapter summarizes the “Virtual Visit” system and the research associated with it. Recommendations for the development of a working model are made and potential benefits of the “Virtual Visit” system are reviewed. Future technology is discussed as it relates to various aspects of the “Virtual Visit” system, and conclusions are drawn regarding the research as a whole.

## ***6.1 Summary***

The construction industry is a dynamic industry where change is an everyday occurrence. Due to this tendency for change, it is important to maintain good communication between all parties on the construction site. Good communication can help to maintain good relations between traditionally adversarial parties, and help to reduce the time that is spent on resolving disputes.

One of the best ways to maintain good communication, is for everyone to be familiar with the current status of the construction job. Familiarity by all of the parties allows for better scheduling, improved problem solving, and quicker decision making by allowing the parties to spend more time discussing the issues and less time updating themselves on the events leading up to the current problem.

Unfortunately, it is not always possible for related personnel to visit the construction site due to other responsibilities. These off-site personnel (OFP) are generally experienced members of the construction team, so not only do they remain less informed than if they were on the site, the construction site does not receive the benefit of their expertise. This can lead to problems that might otherwise have been “nipped in the bud” had the OFP been more informed. Even when the OFP can get to the construction site, his/ her visit is not always necessary, and the OFP finds that he/ she has wasted valuable time.

The “Virtual Visit” system conceptualized in this thesis was developed to improve communication between on-site personnel (ONP) and the OFP’s. The system can accomplish this by augmenting typical telephone conversations with video combined with the storage capabilities of a computer. The goal of the “Virtual Visit” system is to allow personnel to view, evaluate, or clarify what is occurring on the construction site, and to allow them to store that information as a permanent record. The “Virtual Visit” is designed to give OFP’s a better option when visiting a site is inconvenient or impossible, or when the determination of whether or not to visit a site must be made.

The “Virtual Visit” is broken down into four areas: (1) The creation of a Mobile On-Site Computer Unit (MOCU), (2) The transfer of data, both from MOCU to the on-site server, and from the on-site server to the off-site personnel (OFP), (3) The development of a permanent archive and it’s related security issues, and (4) The creation of an effective data storage and retrieval system with video capture and application sharing capabilities (DSeRViC).

MOCU is the hardware portion used by the ONP. It allows for the capturing of audio and video using a sound card and a CCD camera, the transfer of data through wireless modems, interaction with the system by the ONP using a belt computer and virtual imaging goggles, and real-time communication with the OFP.

The transfer of data from MOCU to the on-site server is accomplished using wireless modems, transmitters, and receivers that transmit data in analog (for the video) and digital (for the audio and document sharing) formats. The on-site server is used to consolidate and compress all of the information sent from MOCU in real-time, in order for the information to be transferred over long distance lines and received by the OFP.

The permanent archive is a network of regional servers resembling the World Wide Web. These regional servers store data and allow for the retrieval of construction data from various construction sites. The data in these servers is assumed to be untouchable, and untainted. In order to insure the purity of the data, two forms of security are suggested -- user identification using passwords, and channel security using encryption.

DSeRViC is the software interface, and allows the user(s) to utilize the capabilities of the "Virtual Visit" system. DSeRViC allows for the capturing of data, the storage and retrieval of data using the archival network, and the real-time communication between the ONP and the OFP. DSeRViC is designed to allow the user easy access to data, while remaining user friendly enough for novice users.

## ***6.2 Recommendations and Potential Benefits***

The “Virtual Visit” system has the potential for benefiting all parties in the construction process by allowing OFP’s an alternative to actual site visits. This section recommends a process for the development of a “Virtual Visit” system as well as discussing the benefits that could come from a “Virtual Visit” system.

### **6.2.1 Recommendations for Development**

This research has conceptualized a system that offers a definite benefit (see below) to the construction industry. It is now necessary to develop a working model of the system. A four step process is suggested:

1. The first stage in developing a “Virtual Visit” system should be the development of MOCU and DSeRViC because they offer immediate benefit to the developer. That is, the two can function independently of the “Virtual Visit” system as a data storage and retrieval tool. Although the off-site communications will not yet be in effect, the system’s ability to capture and store information locally offers an improvement on current methods of data storage and retrieval used on construction sites. MOCU and DSeRViC should also be developed so that expansion into wireless communication is easily implemented.



2. The second stage of development should be the wireless communication using the on-site server as a testing mechanism. The on-site server should be used to test the transfer of video, audio, and application data from MOCU, in order to insure that the quality of the transmissions are acceptable. In effect, the on-site server can simulate the OFP and his/ her remote system.
3. The third stage involves consolidating all three data formats (video, audio, and application data) and compressing them so that long distance lines can be used for direct transfer to the OFP. Depending on the timing of this stage those lines may be ISDN lines or could be another form of telecommunication such as fiber optics. The type of line transfer must be considered carefully considering cost, availability, and quality of transmission. By the end of this stage the ONP should be able to effectively communicate with the OFP, thus allowing for the "Virtual Visit."
4. The fourth and final stage involves developing the archival network and security for the construction data. The first part of this stage is the technical portion. Using the World Wide Web as a model should allow for the rapid development of the technical considerations. The second part of this stage, however, involves the actual implementation of the network. This requires deciding on the entity that will run the regional servers as a governing body, as well as developing policies and procedures for

the entity and the users. This final portion will require funding, political support, and a great deal of planning and coordination in order to be successful.

### **6.2.2 Benefits**

There are two primary benefits to the “Virtual Visit” system. The first is the improved communication between the ONP’s and the OFP’s, and the second is the improved data storage and retrieval.

Improving communication between the ONP’s and the OFP’s by allowing for more site visits using the “Virtual Visit” technology, allows the OFP’s to be more involved in more aspects of the construction job. This will benefit the job in two ways. First, the OFP will be knowledgeable about job occurrences and will be able to speak knowledgeably concerning issues on the site. Second, the ONP’s will have the benefit of more contact with the OFP, allowing for quicker decision making and more immediate problem solving.

An off-shoot of using the “Virtual Visit” system, is the ability of the OFP to save time and money traveling to the sites. The “Virtual Visit” will allow the OFP to communicate more effectively with the ONP, and the OFP may find that some decision-making does not require a site visit.

The construction industry is often said to be “data rich and information poor.” That is there exists a lot of data concerning a construction job, however, the retrieval of this data is difficult, and the documentation of the data is often unintelligible or incorrect. The “Virtual Visit” system offers the ability to easily record occurrences on the site using a multimedia format of video, audio, and text documentation. The combined power of all three makes the job record easier to understand, and the layout devised for DSeRViC insures that the data will be retrieved quickly and easily allowing it to become a source of good information. In addition, the archival network insures that the construction data will be untainted and therefore can be used to help resolve disputes concerning the construction job.

### ***6.3 Future Technology***

Technology is constantly changing, and these changes have a direct effect on the future development and operation of the “Virtual Visit” system. This section discusses predicted improvements and their effects on the “Virtual Visit” system in: (1) Long Distance Data Transfer, (2) Compression Techniques, (3) Virtual Imaging Displays, and (4) Voice Recognition Software.

#### **6.3.1 Long Distance Data Transfer**

Currently long distance data transfer is accomplished at least in part using copper wiring. The copper wiring limits the data rates that can be attained in telecommunications. The next step in the development of the information superhighway is “Fiber to the Curb.”

“Fiber to the Curb” refers to the running of fiber optic lines directly to the curb of a group of seven to ten homes or businesses. The homes or businesses could then connect to the curb using coaxial cables. While this process could cost as much as \$1000 to \$1500 per home, the improved data rates of up to 40 Mbps would allow for interactive programming and the development of a home communications center (Bell, 1995).

The significance of “Fiber to the Curb” to the “Virtual Visit” system is that the increased availability of fiber optics could allow even remote construction sites access to fiber optics. This access would improve the data rates being suggested by this research by at least one hundred-fold. Increased data rates would improve the efficiency of the “Virtual Visit” system, both in the quality of the system, and in the quantity of data that could be transferred.

### **6.3.2 Compression Techniques**

MPEG-1 is generally considered the current standard for compressing video, however, a second compression technique known as MPEG-2 is currently being developed. MPEG-2 offers much improved compression quality while maintaining a good compression ratio. The disadvantage of MPEG-2 is its requirement of high-speed data transfer lines. While these lines are not readily available today, the increased availability and affordability of high speed data transfer lines will one day allow higher compression techniques, such as MPEG-2, to come to the forefront. When that time comes, the improved compression

techniques will offer the “Virtual Visit” system improved video quality, better data transfer of audio, as well as improved application sharing. All of these things will add up to an even more efficient “Virtual Visit” system.

### **6.3.3 Virtual Imaging Displays**

Currently, virtual imaging displays for computers are primarily in a monochrome VGA format. As research in this area improves, however, the ability to support crisp color, as well as SVGA resolution will offer the potential to improve the ONP’s display, as well as allowing more information to be displayed on the screen at one time.

### **6.3.4 Voice Recognition Software**

Currently, voice recognition software suffers from a lack of efficiency. For the computer to distinguish verbal words and then to record them in a text format, requires a large verbal library which in turn requires a lot of computing power. For this reason voice recognition software is just beginning to come of age. As computing power continues to increase, and as computer portability continues to grow, the computer industry is beginning to move towards voice recognition software in order to allow for hands-free applications (Flexible, 1995).

Voice recognition software implemented in a “Virtual Visit” system has the potential to allow the ONP to record data using only his/ her voice. This would improve the efficiency of the system by allowing the ONP to function in a hands-free atmosphere that would

allow for concurrent collection of data while an activity was being accomplished. As an aside, the voice recognition software could also help to further improve the user friendly environment of DSeRViC.

## ***6.4 Conclusions***

The construction industry relies heavily on good communication between all parties on the construction site in order to complete the project at a high level of quality, on-time, and within budget. Good communication between the parties can help to reduce the number of disputes that occur on the job, and can help to reduce the typically adversarial relationship that exists between the parties. One way to improve communication is through site visits, unfortunately site visits are not always possible for the OFP's. The OFP's have other responsibilities that do not allow them the time to visit the construction site. It is in this situation that the "Virtual Visit" can prove to be invaluable. If the OFP's are not capable of traveling to the site, the "Virtual Visit" offers an alternative to the actual site visit.

A "Virtual Visit" is defined as a visit to any location, in this case a construction site, that occurs without an individual actually being there. The visit occurs by augmenting telephone conversations with video, combined with a computer for data storage and retrieval. The idea of a "Virtual Visit" is to allow personnel to view, evaluate, or to clarify in their own minds what is occurring on the construction site.

A portion of this research developed a model system that was used to test the concept of the system using actual construction sites and construction personnel. It was found that the “Virtual Visit” does have potential to help the construction industry, both in communication and in data storage and retrieval.

This research conceptualized a “Virtual Visit” system using existing technology. The system can be developed today. Recommendation have been made as to how the development can occur and what process should be used. In order to further determine the potential of the “Virtual Visit” system, it is important to develop a working model of the system. After a working model has been developed, an archival structure can be implemented.

The “Virtual Visit” system offers the ability to help the construct industry communicate better. It also allows for better storage and retrieval of data that is collected on the construction site. With telecommunications taking off in the form of the World Wide Web and Interactive Television, the “Virtual Visit” is a logical step for the construction industry. As telecommunications becomes even more ingrained in today’s society, it is important for the construction industry to take advantage of the technology in the form of a “Virtual Visit.”

## *Appendix A*

### *DSR Reference Manual*

This chapter is a reference manual for using the DSR software developed in Chapter Five. The reference manual assumes that the user is somewhat familiar with FileMaker Pro 2.1 and other forms of Window's software. The Reference Manual is meant as a guide, not as a full user's manual.



## ***Beginning to Use DSR***

This section explains how to set up DSR and complete the Party Information Screen. It should be noted that the notation File|Open refers to the File menu located on FileMaker Pro's main menu, and that within the File menu the Open command is selected. This form of notation is used throughout the reference manual.

### **Setting Up DSR**

1. FileMaker Pro 2.1 must be installed on your computer.
2. Check to be sure that your computer matches the specifications for FileMaker Pro 2.1.

The computer specifications for DSR are identical to those of FileMaker Pro.

3. Set the computer resolution to 800 by 600 pixels at 256 colors.
4. After being certain that FileMaker Pro is running correctly on your computer, copy the following files to a directory called c:\DSR.

- "arch.fm"
- "contr.fm"
- "main.fm"
- "vdot.fm"

5. Start FileMaker Pro.
6. When prompted to open a file, select 'main.fm'.
7. Click OK.
8. The Main Menu Screen will appear on your screen.

9. Choose Select|Layout
10. Click on the Architect button.
11. Choose Scripts|Scriptmaker.
12. Select “Open Architect”
13. Click on the Edit button
14. Select Open [“ARCH.FM”].
15. Click on the File button.
16. Go to the c:\DSR directory and click on “arch.fm.”
17. Click the OK button.
18. Click the OK button again.
19. Click on the Done button. DSR has now been told where to look for the “arch.fm” file on your computer.
20. Repeat steps 9 through 19 for the Contractor and the VDOT button, except substitute the “contr.fm” file for the “arch.fm” file when selecting the Contractor button, and substitute the “vdot.fm” file for the “arch.fm” file when selecting the VDOT button.
21. The buttons are now set properly.
22. Choose Select|Browse.
23. DSR is now ready to use

### **Completing the Party Information Screen**

1. From the Main Menu, click on the Contractor button. (Note: The Architect or the VDOT button could have also been used, the Contractor button is used as an example.)
2. The Party Information Screen appears
3. Click on the Job Party Affiliation field. A pop-up list appears.
4. Choose your party affiliation (Who you work for)
5. Using the mouse select each of the fields and fill in the appropriate information. For example, you might type in Lionberger Construction under the Contractor name field (see Figure A-1).
6. After all of the party information is entered click on the Continue button.

FileMaker Pro - [CONTR.FM]

File Edit Select Layout Arrange Format Scripts Window Help

Party Info.

### JOB INFORMATION

Job Party Affiliation:

Job Name:

Job Designation Number:

Route:

District:

### CONTRACTOR INFORMATION

Name:

Street Address:

City:  State:

### ARCHITECT INFORMATION

Name:

Street Address:

City:  State:

### OWNER/ GOV. AGENCY INFO.

Name:

Street Address:

City:  State:

100% Browse

Figure A-1 Party Information Screen

## ***Using the Daily Report Screen***

The daily report screen is the primary screen in DSR. It is within the daily report screen that all information can be entered and viewed.

### **Filling in the Conversation Fields**

1. After clicking the Continue button on the Party Affiliation Screen, the Daily Report Screen appears (see Figure A-2).
2. Using the mouse click on the field next to "Conversation from ONP". A pop-up list appears.
3. Select the ONP from the pop-up list by double clicking the selection. If the name of the desired personnel does not appear on the pop-up list, see the section "Adding to a Pop-Up List."
4. Click on the OFP field and select the desired name.
5. Click on the Primary Job# field and type it in.
6. Click on the Item No. field and type it in.
7. Click on Description field and type it in.
8. Click on Diary Page # field and type it in.
9. Click on the Location field and type it in.
10. Click on the Contract Quantity field and type it in.
11. Click on the Unit field and select the unit from the pop-up list.
12. Click on the Actual Quantity field and type it in.



FileMaker Pro - [CONTR.FM]

File
Edit
Select
Layout
Arrange
Format
Scripts
Window
Help

Daily Report

Picture Number One

Import Pict.

Full Picture

Del. Picture

Picture Number

One

Two

Three

Dialogue #1

Double

Click

Clear

Dialogue #2

Double

Click

Clear

Dialogue #3

Double

Click

Clear

Conversation

Conversation from GNP

Rory

to GNP

Date

5/11/95

Primary Job #

Item No.

Description

Laying plywood

Diary Page #

Location

Contract Quantity

Unit

Actual Quantity

Weather Conditions

Cloudy

and

Temp (F)

80

Memo

Rori at camera - first day  
Only activity on-site today

5

2

List Records

Add Record

Del Record

Exit

Figure A-2 Daily Report Screen

13. Click on one or both of the Weather Conditions fields and select the type of weather from the pop-up list.
14. Click on the Temp (F) field and type it in.
15. If any memo comments are desired, click on the Memo field and type them in.

### **Adding to a Pop-Up List**

If a pop-up list does not have the desired information in it, it can be added.

1. Choose Select|Define Fields...
2. Select the name of the field that you wish to alter.
3. Click on the Options button.
4. Click on the Edit Values button.
5. Type in the new value.
6. Click the OK button.
7. Click the OK button again.
8. Click the Done button.
9. The new information has been added to the pop-up list.

### **Importing a Picture**

1. Click on the picture number that you wish the picture to be stored under (one, two, or three).
2. Click on the Import Picture button.
3. Select the filename of the picture.

4. Click on the OK button.
5. The picture is imported.

### **Viewing a Picture in Full View**

1. Click on the picture number that you wish to view.
2. Click on the Full Picture button.
3. The Full Picture is displayed.
4. To return to the Daily Report Screen click on the Return button.

### **Deleting a Picture**

1. Click on the picture number that you wish to delete.
2. Click on the Del. Picture button.
3. The picture is now deleted.

### **Recording Dialogue**

1. Double Click on the dialogue field in which you would like to record. The sound recorder appears (see Figure A-3).
2. Click on the Record button and begin to speak into your computer's microphone.
3. Click on the OK button when completed.
4. The audio is recorded.



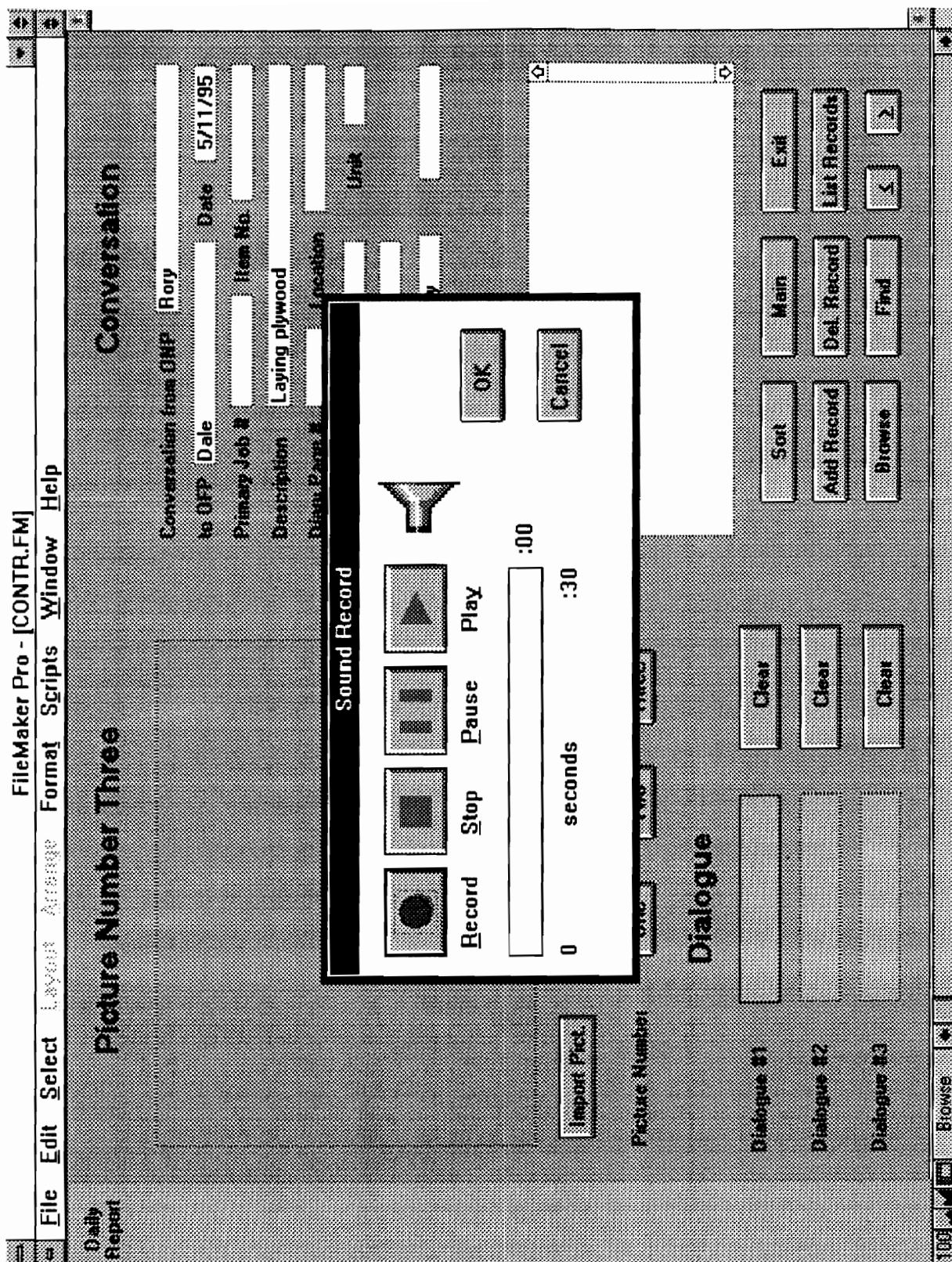


Figure A-3 Sound Recorder

### **Playing Dialogue**

1. After dialogue has been recorded a speaker appears between the words “Double Click.” To play the dialogue, double click on that button.
2. The dialogue plays.

### **Clearing a Dialogue Field**

1. To clear a dialogue field click on the Clear button adjacent to the desired dialogue.
2. The dialogue is now clear.

### **Navigating Between Records**

To display the next record click on the  $\leq$  button.

or

To display the previous record click on the  $\geq$  button.

### **Adding a Record**

1. To add a record click on the Add Record button.
2. A blank new record is added.

### **Deleting a Record**

1. To delete a record click on the Del. Record button.
2. If you still wish to delete the record, click on the delete button. If you have changed your mind, however, click on the Cancel button.

### **Returning to the Main Menu**

1. To return to the Main Menu click on the Main button.
2. The Main Menu is displayed.

### **Viewing the List Records Screen**

1. To view the List Records Screen, click on the List Records button.
2. The List Records Screen appears.

### **Exiting DSR**

1. To exit DSR, click on the Exit button. All information will be automatically saved for you.
2. DSR is exited.

### ***Using the List Records Screen***

#### **Editing the Records**

The records may be edited by clicking on the desired field in the exact manner as the daily report.

## **Navigating Among the Records**

To navigate, use the vertical scroll bar on the right of the list.

## **Returning to the Daily Report Screen**

- a) To return to the Daily Report Screen, click on the Return button.
- b) The Daily Report Screen is displayed.

## **Sorting the Records**

Sorting the records causes the records to be placed in ascending order using the following criteria:

- a) Primary Job Number
  - b) Item Number
  - c) Description
  - d) Stored Date
  - e) Location
  - f) OFP
  - g) ONP
1. To sort the records using the above shown criteria, click on the Sort button.
  2. The records are now sorted.

### **Returning to the Main Menu**

1. To return to the main menu, click on the Main button.
2. The main menu is displayed.

### **Exiting DSR**

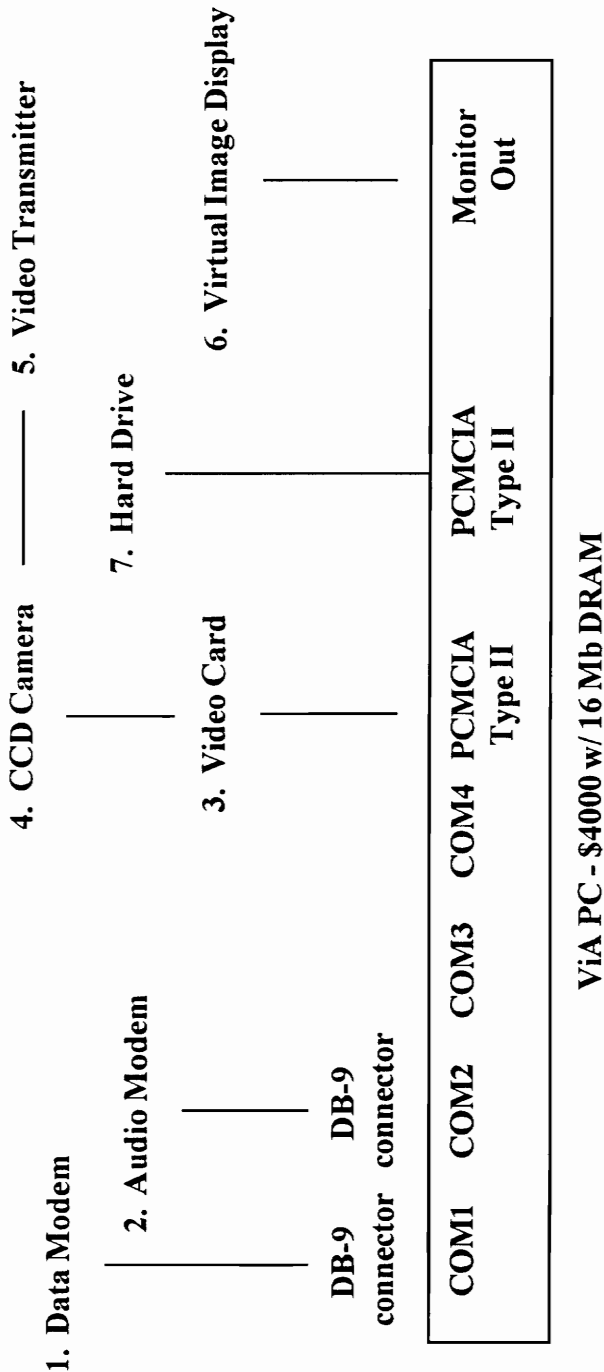
1. To exit DSR, click on the Exit button. All information will be automatically saved for you.
2. DSR is exited.

## ***Appendix B***

### ***MOCU and the On-Site Server's Specifications***

This chapter presents the hardware specifications for both MOCU and the on-site server. Figures B-1 and B-2 show how the hardware is integrated, while the remaining portion of this chapter is delegated to the actual individual specifications of the various hardware components. Not all of the hardware components are represented by individual specifications, however, since some of the components are very common and self-explanatory.

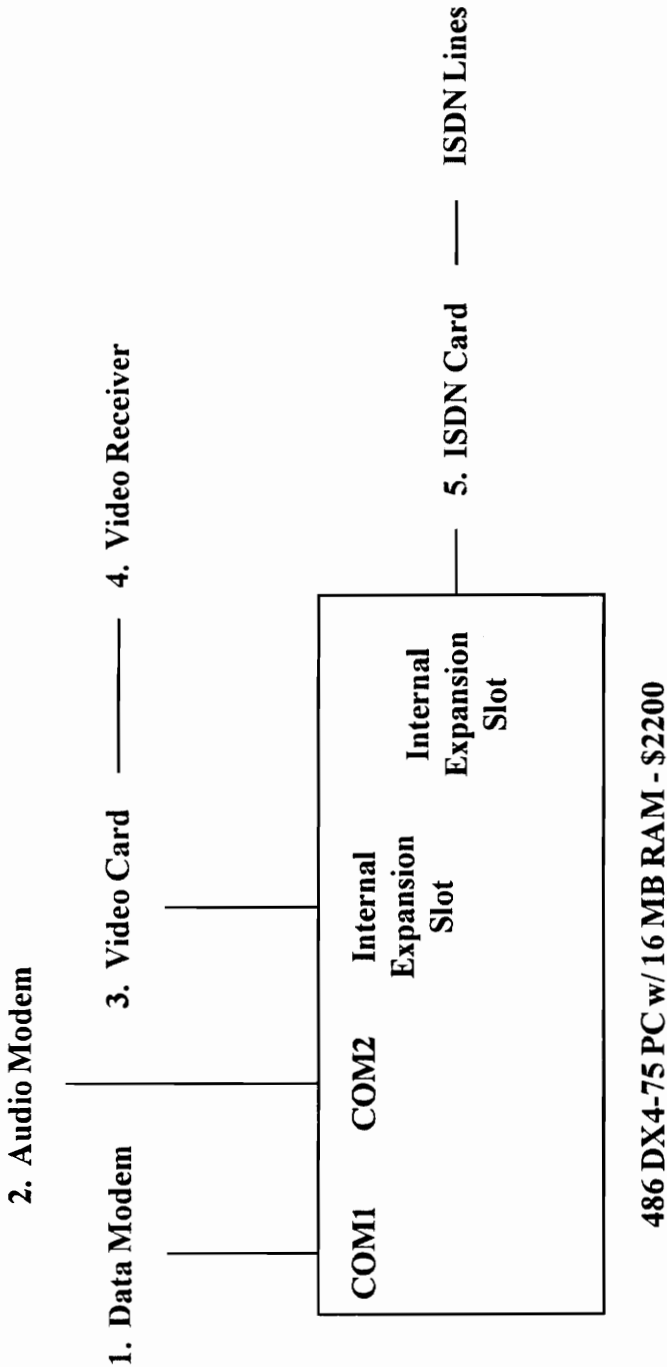
# MOCU SPECIFICATIONS



- 1. SD55514 (Data Modem @38.4 Kbps) - \$1320 ea.
- 2. SD55510V (Audio Modem @ 38.4 Kbps) - \$1110 ea.
- 3. CardCam PCMCIA Video In - \$320
- 4. GP-KS162/2 CCD Micro-Camera w/ GP-AD22TA and lens - \$1610
- 5. Series "4" 1/4 Watt Wireless Video Miniature Transmitter - \$4200
- 6. VIDI VGA - \$5000
- 7. 170 Mb Flash Memory Hard Drive - \$170

Figure B-1 MOCU Specifications

**ON-SITE SERVER SPECIFICATIONS**



- 1. Spectradata 551 - SD55514 (Data Modem @38.4 Kbps) - \$1320 ea.
- 2. Spectradata 551 - SD55510V (Audio Modem @ 38.4 Kbps) - \$1110 ea.
- 3. MPEG Video Card - \$11,000
- 4. Series "2" Video Receiver - \$4200
- 5. ISDN Card - \$400

**Figure B-2 On-Site Server Specifications**



# ViA PC

## FEATURES

Hardware Specification - Version 0.9

80486 Intel CPU (DX4 75Mhz)

### DRAM Memory

- 8 Megabytes onboard
- Expandable to 24MB

4 Megabyte boot Flash ROM

4 PCMCIA v2.01 & JEIDA-4.1 PC Card slots

- Vcc 3.3 and 5.0 volts
- Vpp = Vcc or 12V
- Mixed voltage operation

### PC Card options

- Hard Disk Drives
- SRAM
- LAN (wired/wireless)
- Serial/Parallel (I/O)
- SCSI
- Flash memory
- GPS
- Cellular - modems/pagers/fax/phone
- Video capture
- Encryption

4 Serial COM ports

Keyboard & Mouse PS/2 style Interface

16-bit Sound Blaster compatible Stereo Sound

- Audio recording (e.g. voice mail)
- Voice Recognition
- Duplex sound (Stereo-out mono-in)

### Power Status Indicator

### Power Management & Battery operation

*Rechargeable battery backup during battery replacement operations during suspend mode*

*Backup configuration to maintain real time clock information during processor power down*

*Run time of 8 to 10 hours*

*Lithium Ion Polymer Flexible battery (planned)*

Environment (0 °F to +150 °F) Weight (1.5 lbs.)

Dimensions (9"L x 4.5"H x 0.9"D) Battery Included

**"The real advantage is this product's hands-free portability using voice recognition."**

## BENEFITS

### ViA, the elegant PC

For individuals on the go, who require information on demand, anywhere, anytime.

*Applications* for flexible wearable computers include settings in industry, military, police, fire, transportation, medical, food handling, places where hands-free computing and communication allow continuation of hands-on work.

*Uses* include accessing JIT training, safety reminders and verification, stock & inventory management, documentation referencing, personnel coordination, production information, equipment sensor and equipment operations I/O, general communications and more can be handled to and from each networked wearable computer.



ViA, The Flexible PC Company's patented flexible, wearable PC is a fully functional computer.

- ✓ Light weight, ideal human factors/ergonomic design
- ✓ Upgradeable and modular using standard interconnects, a PCMCIA and PC Card plug and play environment
- ✓ Dependable and fast using flash memory disk drives with no moving parts
- ✓ Portable voice-interfaced with cellular phone and data secure spread spectrum wireless LAN connectivity
- ✓ GPS to provide direction or geographic information
- ✓ Sensor I/O information for medical advice, instruction or relay of data
- ✓ Automated Voice Messages for just-in-time information, training and staff coordination

## The Flexible PC Company

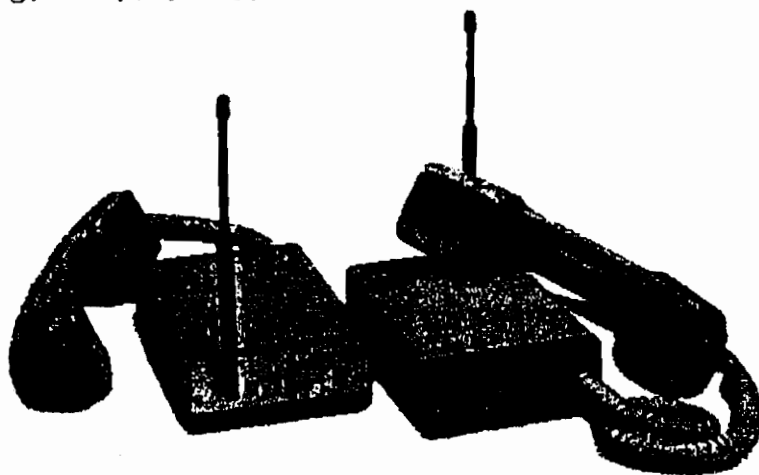
320 Division Street

Northfield, MN 55057

Call us today at 1-800-FLEXI-PC.

# SPECTRADATA 551 SERIES DATA COMMUNICATION LINKS

SD5514/V, SD5516/V, SD5510/V, SD5512/V



## Standard Features

- Radio transceivers provide wireless serial data communications.
- Range to 1.5 miles. Extended range is possible using repeaters.
- RS232 communications at 1.2 to 38.4 kbaud.
- Operate in 900 MHz and 2.4 GHz bands.
- Easy to use.
- High degree of immunity to electromagnetic interference.
- FCC Certified. No site license is required.

## Description

The STI SpectraData 551 Series is a family of radio transceivers for wireless communication of serial data. These radios provide reliable communication without the expense of site licensing. Spread spectrum technology was originally developed for military use to prevent jamming. SpectraData transceivers use this technology to ensure data integrity by minimizing the effects of electromagnetic interference. These units are self-contained, compact and easy to use. Between transceivers, the SpectraData units operate in half-duplex mode. The baud rate between radios is much higher than from the hosts to the radios. This allows the radios to simulate full duplex operation in many applications. The SpectraData 551 radios come in two types: *intelligent* and *transparent*.

## Intelligent Type (SD5514, SD5516)

Intelligent radios packetize the data and they provide error detection and correction. They operate in a point-to-point mode only, although the host can instruct the radio to disconnect its link to a radio and reconnect to another. Installation of the intelligent radios requires setup of various parameters for the specific application using simple mnemonic commands issued by means of terminal emulation software. SpectraData Link™ software provided with the radios can also perform this function. Intelligent types support hardware flow control.

For two intelligent radios to communicate, either one must be instructed to link to the other. This allows the flexibility of connecting and disconnecting at will to any radios on the same channel. Up to 99 units can be used on the same channel. When power is lost, the link between units is lost, and must be established again. If automatic linking upon startup is needed, you can normally write a script or subroutine to perform this function in your software.

To extend the range of units or to communicate around RF

## WIRELESS DATA COMMUNICATIONS

"obstacles", as many as three repeater stations can be used between a unit and its final destination. The repeaters are simply additional radios of the same model. Their use as a repeater is completely transparent to their normal operation as a radio. For example, radio A can communicate to radio B through the repeater radio, unit C. At the same time, radio C can have an independent link to radio D. Note that voice channels do not repeat.

To accomplish error detection and correction, the intelligent units calculate a checksum using a 16 term cyclical redundancy algorithm as the data is entered. This generates a unique value which is appended to the data to form a packet for transmission. When the data is received, the checksum is recalculated to ensure it matches the appended checksum value. If they match, the receiving radio transmits an acknowledgment. If the transmitter fails to receive this acknowledgment, it will transmit the data again. The number of retries can be set to any value between 3 and 255.

Intelligent units have two communication modes. The *transparent mode* transmits data as each character is entered. The *converse mode* allows transmission of data when a user specified character is given, usually the enter key. In this mode, data will also be sent when the buffer becomes full. The two linked radios can be set for different communication modes.

**Transparent Type (SD5510,SD5512) Operation**

Transparent radios require no setup except for channel selection. This is quickly accomplished by setting DIP switches on each unit. These types operate in a broadcast mode, where all radios set for the same channel share any information broadcast on that channel. Point-to-point mode can be simulated by selecting different channels for specific radio pairs. Transparent radios do not incorporate error detection, so they are ideal for systems where this is included in the software driving the radios.

Since these units operate in the broadcast mode, the units do not require linking between radios.

These types do not support repeater stations, nor do they support hardware flow control.

**Voice Channel**

All models of the SD551 Series are available with a voice channel in addition to the normal data channel. These are useful in applications when a person at each station controls the transfer of data, as in downloading files. The voice channel is carried on a narrow band (not spread spectrum) at the same frequency as the data. Because these channels operate in half-duplex (conversation in one direction only), standard telephone handsets are incompatible. These models are supplied with compatible handsets that incorporate press-to-talk switches.

Three indicators on the front of the SpectraData indicate status of the unit. PWR indicates that the unit has power. TXD flashes as transmissions are issued. RXD flashes as transmissions are received. Messages are sent to the host's monitor to indicate any errors.

**Range**

The specified range of 1.5 miles (2.4 km) is based on a clear line-of-sight with no obstructions. The effective range in real world applications will vary with the specific environment. When used indoors, obstacles such as walls, floors, ceilings, furniture, and equipment can decrease the range. Outdoors, buildings, machinery, trees, mountains, and hills do the same. To determine range, it is easiest to test the units in the actual environment where they are to be used.

**Antennae**

The FCC requires that these units be sold only with the specific type of antenna used to obtain certification. STI cannot offer antennae to increase the broadcast power output of these units. Other antennae may be available, however, to meet specific mounting requirements. Contact STI for up-to-date information on availability of other antennae.



# CARDCAM<sup>TM</sup> PCMCIA VIDEO IN

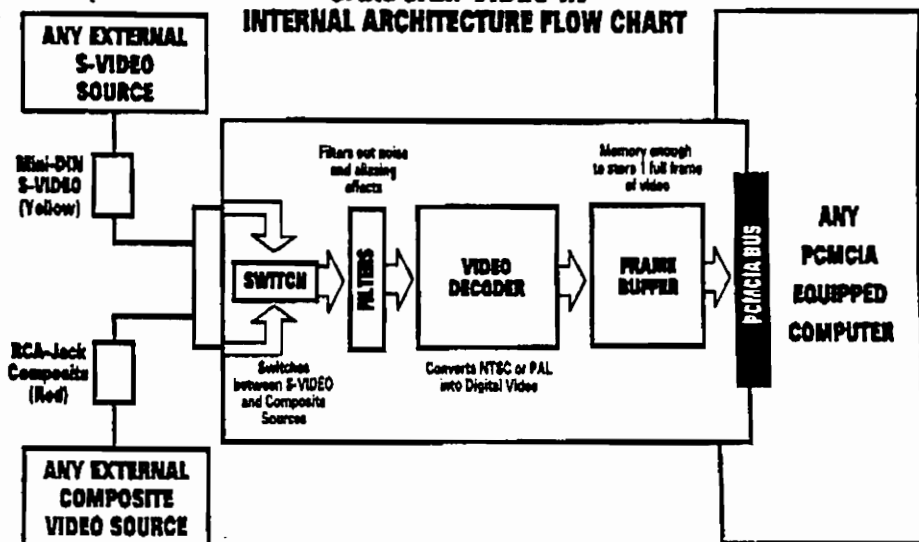
## SOFTWARE:

### CardCam Driver Suite

- **PCMCIA Driver** — Ensures compatibility across a broad range of platforms.
- **CardCam-VideoInstaller** — Installs and configures the drivers and application software to suit specific customer system requirements.
- **Video for Windows Driver** — Allows CardCam to be used with Video Grab, CardCam's own full-featured capture application software, or any other Video for Windows compatible capture program. Compatible software includes, but is not limited to: Microsoft® VidCap and VidEdit, Adobe Premier™, and Asymetrix's Digital Video Producer™.
- **CardCam-Video Grab** — This full-featured still image and motion capture application is completely Video for Windows™ compatible. The user can grab a still image or motion video in flexible resolutions and color depths (including Black & White, Grayscale, 16-color, 256-color and, of course, 24-bit color!) or load it from disk. Once the images are in the computer, they can be manipulated using either the included image processing tools like clip, scale and color conversion, or simply imported into your favorite image processing software package. Once the final image(s) is complete, it can be saved in standard Windows™ file formats.

## HARDWARE:

### CARDCAM-VIDEO IN™ INTERNAL ARCHITECTURE FLOW CHART



## Technical Specifications:

### Agency Approval:

FCC Class B approved

### Power Consumption:

300mA max. operation current  
Power Down mode for battery savings

### Operating Temperature:

0 - 55 degrees Celsius

### Weight:

Card plus cable — 1.70 oz. (49g)

### Form Factor:

PCMCIA Type II  
3.37 (85.6) L x 2.126 (54.0) W

### Video Standard Compliance:

NTSC, PAL

## Recommended Hardware:

IBM PC Compatible  
80486/25 MHz or better  
4MB RAM

PCMCIA Type II  
MS DOS 3.1 or later  
Windows 3.1 or later

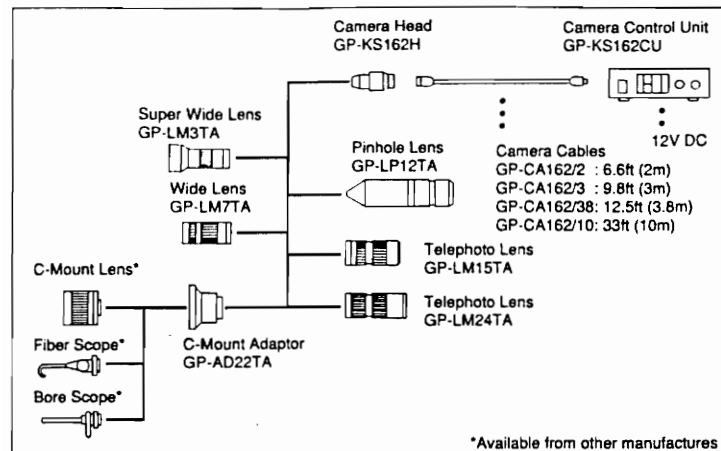
**No additional software or hardware required except for your video input source and PCMCIA-equipped computer.**

CardCam-VideoIN is a registered trademark of Quadrant International, Inc. Video for Windows and Windows are trademarks of Microsoft Corp. Adobe Premiere is a trademark of Adobe Systems Inc. Asymetrix Digital Video Producer is a trademark of Asymetrix Corp. All other trademarks are the property of their respective owners.  
Capture/Playback rates may vary depending on CPU, Memory or Hard Drive capacity.  
Specifications subject to change without notice.



170 SOUTH WARNER ROAD, SUITE 102  
WAYNE, PA 19087-2191 USA  
TEL (610) 964-7600  
FAX (610) 964-8195

## System Block Diagram



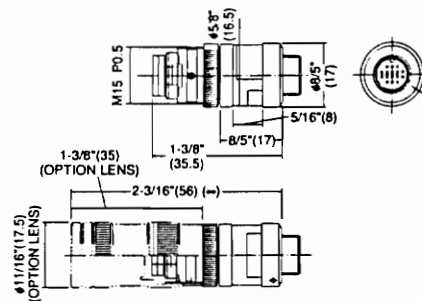
Camera Head	Camera Control Unit	Camera Cable
GP-KS162H	GP-KS162CU	GP-CA162/2 : 6.6ft (2m) GP-CA162/3 : 9.8ft (3m) GP-CA162/38 : 12.5ft (3.8m) GP-CA162/10 : 33ft (10m)
Super-Wide Angle Lens GP-LM3TA	Wide-Angle Lens GP-LM7TA	Pinhole Lens GP-LP12TA
		Telephoto Lenses GP-LM15TA GP-LM24TA
		C-Mount Adaptor GP-AD22TA

## Specifications

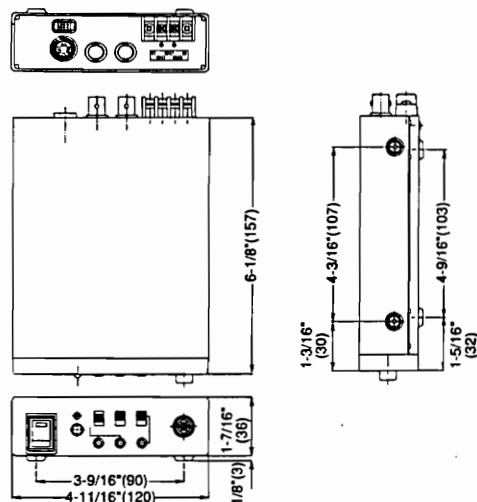
<b>Camera system</b>	NTSC
<b>Pick-up device</b>	768 (H) x 494 (V) pixels, Interline Transfer CCD
<b>Scanning area</b>	6.5 (H) x 4.8 (V) mm (Equivalent to 1/2" Tube)
<b>Scanning</b>	525 Lines/60 Fields/30 Frames Horizontal 15.734kHz, Vertical 59.94Hz
<b>Scanning system</b>	2:1 interlace
<b>Synchronization</b>	Internal
<b>Horizontal Resolution</b>	480 TV lines (typ.)
<b>S/N ratio</b>	50dB (min.) (luminous S/N) (at AGC OFF)
<b>Mini. Illumination</b>	3lx (typ.) (F1.4 AGC ON 30IRE)
<b>Auto Light</b>	ON/OFF (ELC and AGC is set independently)
<b>Video Level</b>	ON/OFF
<b>White balance</b>	MANUAL/AWC/ATW
<b>Power source</b>	DC 12V $\pm$ 10%
<b>Power consumption</b>	300mA (typ.)/DC12V input
<b>Dimensions</b>	CAMERA HEAD $\phi$ 17 (W) x 35.5 (D) mm CCU 120 (W) x 36 (H) x 157 (D) mm
<b>Cable</b>	2m, 3m, 3.8m, 10m (Option)
<b>Ambient Operating temperature</b>	14°F ~ 122°F (-10°C ~ 50°C)
<b>Humidity</b>	Operating range less than 90%RH

## Dimensional Drawings

### GP-KS162H: Camera Head



### GP-KS162CU: Camera Control Unit



## Applications

### Industrial

- Sensor for checking completed printed circuit boards
- Internal inspection of engines and precision machinery
- Visual sensor for factory robots, etc.

### Medical

- Microscopic camera observation of microorganisms and bacteria
- Use as an endoscopic camera, eyepiece etc.

### Scientific

- Time-lapse observation and surveillance of experiments

### Educational

- Monitor display of teaching materials, etc.

### Special Applications

- Peripheral supervision of production machinery and factory robots
- Filming and observation of hazardous areas from the air via radio-controlled helicopter

### Other Applications

- Sporting events and other broadcast applications
- Assistance with installation and maintenance of machinery

Weights and dimensions shown are approximate.  
Specifications are subject to change without notice.  
These products may be subject to export control regulations.

# Panasonic

Broadcast & Television Systems Company

Division of Matsushita Electric Corporation of America

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Panasonic Sales Company  
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B. MOCU and the On-Site Server's Specifications

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# SPECIFICATIONS

## SERIES "4" 1/4 WATT WIRELESS VIDEO TRANSMITTER

Frequency:	350-440MHz UHF 1710-1900MHz L-Band 2200-2300 MHz S-Band 2400-2484 MHz S-Band
Frequency Stability:	± 20 PPM
Input Power:	+11-16VDC 250mA Max
Power Output:	.25 W
Audio Subcarrier (Option):	Single
Type of Modulation:	FM
Output Impedance:	50 Ohms
Frequency Deviation:	±3MHz
Video Input:	1VPP/75 Ohms
Modulation BW:	6MHz ± 1.5dB
Output VSWR:	<2:1
Antenna Mismatch (Open/Short):	No Damage
DC Reverse Polarity Protection:	Yes
Harmonic/Spurious Distortion:	>47 dBc
<b>Audio:</b>	
Input (mic):	2mVPP/2K
Audio Bandwidth (±3dB):	100Hz to 15KHz
Audio Distortion:	<1%
Audio Deviation :	±35KHz
<b>Temperature:</b>	
Operate:	-20° C to +60° C
Storage:	-40° C to +80° C



COMMUNICATIONS AND SURVEILLANCE SYSTEMS

12310 PINECREST ROAD, RESTON, VA 22091  
TELEPHONE (703) 620-6200 FAX (703) 620-3169

**SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE**

# SPECIFICATIONS

## SERIES "2" RECEIVER

Frequency Range:	350 - 450MHz 1710 - 1900MHz 2200 - 2300MHz 2450 - 2483MHz
Frequency Stability:	± 20ppm
Video (75 ohms)	1 VPP (Adj. ± .5VPP)
Sensitivity (12dB S+N/N):	-82dBm (Color Video)
Reverse Polarity Protection:	YES
Deviation:	± 3MHz
Color Video Bandwidth:	10Hz to 6MHz @ 3dB
Optional Audio:	
Number of Channels:	Up to Two
Audio Output:	.77Rms into 600 Ohms
Frequency Response:	100Hz to 15KHz @ 3dB
Audio Distortion:	<1%
DC Input:	11-16VDC @ 450 mA (typical)
Temperature:	
Operating:	-10° C to +50° C
Storage:	-40° C to +80° C
Dimensions:	6.30" x 9.70" x 2.50"
Weight:	3.5lbs.



ENGINEERING AND SURVEILLANCE SYSTEMS

12310 PINECREST ROAD, RESTON, VA 22091  
TELEPHONE (703) 620-6200 FAX (703) 620-3169

**SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE**

A13642-1A

The VIDI VGA takes up a mere fraction of weight, space, and power consumption used by large LCD displays in portable computers, freeing up those resources for other tasks. In addition, with the VIDI VGA, you have complete security while working next to others.

Combined with mass data storage and cellular or spread spectrum transmission techniques, the VIDI VGA represents a revolution in high-powered portable computing. For instance, workers can be at work in the factory while accessing documents and data on a mainframe.

Other products available from VIDI

The Virtual Vision Sport 100 series—Perfect multimedia system with VV eyeware and modular backpack powered by rechargeable NiCad battery.

The Virtual Vision Sport 200 series—VV eyeware with TV tuner backpack powered by AA alkaline batteries.

The RemoteVIEW 900—900 MHz FM audio/video transmitter and receiver with a line of sight range of up to 300 feet.

The Virtual Vision RX—Industrial-grade VV eyeware with ruggedized audio/video interface and external power.

#### **VIDI VGA specifications**

##### **Eyeware**

**Monocular Dominancy:** Interchangeable optics for right or left-eye viewing

**Binocular:** Available with additional LCD and optics

**Display:** Active matrix display, 640 x 480 monochrome resolution

**Viewing Image:** Image appears 60 inches diagonally at 10 feet

**Standard focal length:** Image focuses comfortably 6 feet and beyond

**Display format:** VGA

**Brightness:** Adjustable

**Cord:** 5 foot

**Adjustments:** Distance between LCD and lens adjustable for focus. Head strap adjustable for size. Can be worn over conventional eyeglasses.

**Operating temperatures:** 32-100° F

**Humidity:** 20-80% relative humidity

**Eyeshades:** Interchangeable, UV blocking, Hard coated, Impact and scratch resistant, 60% and 90% light blocking

**Weight:** approximately 8 ounces

**Dimensions:** 3.5 x 7 x 6.75

**HFOV:** 30°

##### **Audio**

**Earphones:** Various options available

##### **Interface**

**Brightness:** Pass through control for developer use

**Volume:** Pass through control for developer use

**Power-in jack:** Accepts 6-12 V DC input

**Power consumption:** 2 W

**Weight:** 8 ounces

**Dimensions:** 5 x 3.75 x 1.75

# **VIDI**

**Virtual Image Displays Inc.**

16625 Redmond Way, Suite M-452  
Redmond, WA 98053  
tel: (206) 882-4800  
fax: (206) 885-1156  
e-mail: vidiw@aol.com

For information or to order, call  
**1-800-755-4378**

Specifications subject to change without notice. US and foreign patents pending. Virtual Vision and Eyeware are trademarks of Virtual Vision, Inc. Copyright 1995, VIDI.



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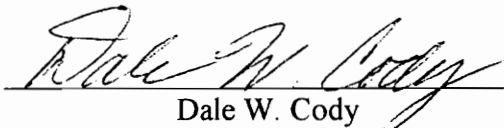
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## Vita

I was born on July 21, 1970 on an Air Force Base in England, where my father was stationed. I moved back to the United States two years later, and after living in various parts of the continental U.S. my family and I settled permanently in Alexandria, VA in 1979. It was in Alexandria that I attended West Potomac H.S. which I graduated from in 1988. From Alexandria, I moved to Blacksburg where I began to work on my B.S. in Civil Engineering at VA Tech. Upon the completion of my Bachelor's in 1993, I began work on my M.S. in Civil Engineering in the Construction Engineering and Management division at VA Tech, which I completed in the Fall of 1995.

I look back fondly at my time at VA Tech. The institution's people, both attending classes and teaching them, helped to mold me in many positive ways. I would also be remiss not to thank the two people that helped mold me most of all; my mother Eileen Cody and my father William Cody. At the time of this writing, I am currently working in DeLand, Florida as a Professional Engineering Trainee for the Florida Department of Transportation (FDOT).

  
Dale W. Cody