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Low Cost Video for Distance Education

by

Michael J. Simpson

A Dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy

School of Computer and Information Sciences
Nova Southeastern University

1996

We hereby certify that this dissertation, submitted by Michael J. Simpson, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirements for the degree of Doctor of Philosophy.

Jacques C. Levin, Ph.D. Date
Chairman of Dissertation Committee

John A. Scigliano, Ed.D. Date
Dissertation Committee Member

Steven R. Terrell, Ed.D. Date
Dissertation Committee Member

Approved:

Edward Lieblein, Ph.D. Date
Dean, School of Computer and Information Sciences

School of Computer and Information Sciences
Nova Southeastern University

1996

Certification Statement

I hereby certify that this dissertation constitutes my own product and that the words or ideas of others, where used, are properly credited according to accepted standards for professional publications.

Michael J. Simpson

Date

An Abstract of a Dissertation Submitted to Nova
Southeastern University in Partial Fulfillment of the
Requirements of the Degree of Doctor of Philosophy

Low Cost Video for Distance Education

by

Michael J. Simpson

May, 1996

A distance education system has been designed for Nova Southeastern University (NSU). The design was based on emerging low cost video technology. The report presented the design and summarizes existing distance education efforts and technologies.

The design supported multimedia electronic classrooms, and enabled students to participate in multimedia classes using standard telephone networks. Results were presented in three areas: management; courseware; and, systems.

In the area of management, the report recommended that the University separately establish, fund, and staff the distance education project. Supporting rationale was included.

In the area of courseware, the importance of quality courseware was highlighted. It was found that the development of distance education courseware was difficult; nevertheless, quality courseware was the key to a successful distance education program.

In the area of systems, component level designs were presented for a student system, a university host, and a support system. Networks connecting the systems were addressed.

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The student system was based on widely available multimedia systems. The host system supported up to sixteen participants in a single class. The support system was designed for the development of courseware and the support of future projects in distance education.

The report included supporting Proof of Principle demonstrations. These demonstrations showed that low cost video systems had utility at speeds as low as 7.2 kbps. They also showed that high quality student images were not crucial to the system.

The report included three alternate implementation strategies. The initial capability could be operational in 1997. A multi-session, 2000 user system was projected for early in the next century.

Acknowledgments

I would like to express my sincere appreciation to the individuals who have supported me and contributed to this effort. First and foremost, I would like to thank the committee Chairman, Dr. Jacques C. Levin, and the committee members--Dr. John A. Scigliano and Dr. Steven R. Terrell.

Dr. Levin has proved to be an outstanding educator, and I feel fortunate to have had the opportunity to work with him. I am grateful to Dr. Scigliano for sharing his vision and experience in distance education, and to Dr. Terrell for his insights on distance education. I am extremely indebted to these educators for their extensive efforts on my behalf.

I would also like to thank Dr. Edward Lieblein for encouraging me to attend NSU, and to my wife Maureen who helped keep up my spirits through the dissertation. Lastly, I dedicate this work to my sons, Scott and Neal, in the hope that they find the joy of life-long learning.

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Chapter I Introduction

Problem, Objective, and Solution

The design of a distance education system was the problem addressed by this dissertation. The objective was the design of a multimedia electronic classroom for Nova Southeastern University (NSU) that was effective and affordable for both the student and the University.

The objective was achieved. Component and module level designs were developed that are low in cost for the student and the University.

The solution is standards based and presented in this document. Designs are presented for an initial University system that will support a multimedia class with sixteen users. A system capable of eight simultaneous classes is projected to be achievable early in the next century. The system would support up to two thousand students.

The designs presented can be implemented at no cost to a student with an Intel 486 multimedia system. The system supports two way audio and uses software to receive one way video from the University. Two way video can be added for under \$100.00 using the camera identified.

The designs support heterogeneous network connections, including POTS (Plain Old Telephone Service), ISDN (Integrated Service Digital Network), and Local Area Networks (LAN). Connection to the Internet was deferred until real-time improvements in the Internet Protocol are demonstrated.

It was found that a demonstration system could be built for less than \$2,000 in 1997. An operational system for sixteen POTS users could be built for less than \$11,000 in the same period.

Background

Nova Southeastern University has obtained a position as a leader in distance education. The University provides innovative programs that enable professionals to earn advanced degrees without career interruption.

The programs are based on face-to-face instruction, Electronic Mail (E-mail), and participation in Electronic Classrooms (ECRs). The E-mail system and text based ECR were state of the art at their inception in the 1980's, but are now being overtaken by emerging communications equipment and software.

In response to this development, the University initiated a project to upgrade its system with emerging information technology. The intent of the project was to improve the quality of learning and enable Nova Southeastern to remain a leader in the field of distance education.

The project leader, Dr. J. C. Levin, briefed the 1994 NSU Summer Institute on the goals of the effort. He formed a "MultiMedia Electronic Classroom Research (MMECR)" group consisting of graduate students working toward the common goal of an improved ECR.

The group was divided into three sub-groups with a doctoral student as the leader. The sub-groups were management, courseware, and systems and networks. The groupings enabled students to select an area of interest while maintaining an informal structure and common goal.

The project is continuing, and the group uses E-mail for message exchange. ECRs are conducted regularly by Dr. Levin to exchange information on the project. ECRs are also conducted as required by the group leaders.

The team has identified a number of research areas for the MMECR, and the leader has promulgated baseline requirements for the project. The requirements were determined in conjunction with the leadership and staff of NSU.

Relationship To Other MMECR Efforts

The goal of the MMECR project is to upgrade the original text based ECR to a full multimedia system. This dissertation was performed in support of the MMECR project.

Figure 1 graphically depicts a four-stage evolution from the current text based electronic classroom to a full multimedia system. The four stages represent a natural evolution of the system from text to full multimedia. The figure was developed in conjunction with Dr. Levin. It can be used as a technological framework for ongoing group efforts, including this proposed effort.

Stage 1 (Text) represents the original ECR capability created at NSU by Dr. John Scigliano, Dr. Jacques Levin, and Donald Joslyn. NSU began delivering its computer-based programs in the fall of 1983, and the ECR provided a ". . . face to face classroom where groups of students can participate on-line . . ." (Scigliano, Levin, & Joslyn, 1989, p. 64).

The system was one of the first operational electronic classroom systems joining those of Massachusetts Institute of Technology and Carnegie Mellon (Scigliano et al., 1989). The system provided a capability that has served the University since its inception, and is still in use today. It has been successful in enabling students with limited equipment to participate in text based group sessions.

Stage 2 (Graphics) is reflected in the transition of the text based ECR to graphics. It is the first major upgrade of the basic ECR. It has recently been introduced by Dr. Levin and is based upon the use of HyperText Markup Language (HTML) and Netscape (Levin, 1995). Using this system, the instructor and the student can communicate in a graphics based environment. Additionally, the system provides a point and click interface.

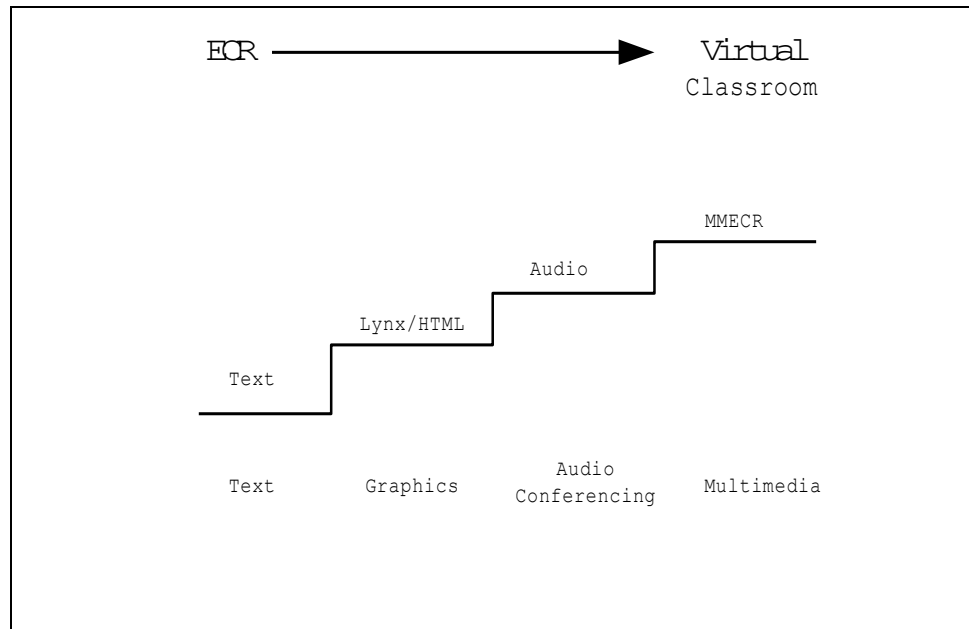


Figure 1. ECR Evolution

Stage 3 (Audio) encompasses audio conferencing and early efforts in collaborative software. The addition of an audio conferencing capability to the ECR will provide a significant increase in the utility and user friendliness of the ECR.

Stage 4 (Multimedia) involves the integration of graphics, motion video, collaborative groupware, and instructor and student support software. This stage envisions a system that meets the teaching requirements that have been specified for the full MMECR. Stage 4 efforts are aimed at building a system that supports both the student and the instructor in an effective distance based environment.

This effort is aimed at Stage 4. The design presented here supports multipoint, multimedia conferences.

The MMECR efforts are proceeding, and products are continuing to be introduced and evaluated by the group. Some of these products show excellent potential for use in the ECR upgrade effort. A partial list of the interest areas of the MMECR is listed in Figure 2.

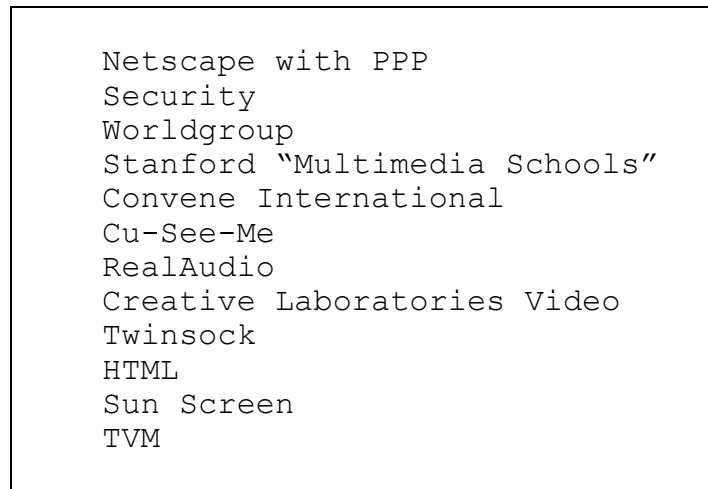


Figure 2. MMECR Products and Areas of Interest

Relevance And Significance

This dissertation is significant because of the importance of distance education and video technology. National leaders have recently attested to the significance of both.

With respect to education, the Nova Southeastern University MMECR program echoes the calls from National leaders for educational improvements based on technology. The Chairman of the Federal Communications Commission, Reed Hundt, expressed the need for emerging technology in the schools.

As the keynote speaker at a major government and industry conference ("ComNet 95"), Mr. Hundt lamented on the current state of technology within the United States schools (Hundt, 1995). A former educator, Hundt gave a variety of examples of how technology could be used to improve education.

Hundt spoke of the Ralph Bunche school in Harlem and its consortium project with Apple, Bolt Beranek, and Neuman, and the National Science Foundation. At the school, Hundt witnessed fifth and sixth graders sharing a lesson distributed between Harlem, Nova Scotia, and Hawaii. "They use the world fact book to conduct science projects . . . they trade E-mail with researchers in Australia" (Riezenman, 1995, p. 2).

The Chairman asked: ". . . shouldn't public money be used to create incentives for networks to spread our education community." Mr. Hundt's vision leaves no doubt on his answer to the question. In an inspiring speech, he stated that: "I have seen the future, and it is in networking the schools." He stated that he shared the vision of both "Bill Clinton and Al Gore--classmates from grammar and high school."

The networking of the schools is a worthy topic for the Chairman of the Federal Communications Commission due to the significance of distance education in the United States. There are 750,000 students involved in distance education; these students attend 87 four year colleges, 700 junior colleges, and 80 Department of Defense Schools (Gomez, Judice, & Grady, 1992).

Michael Nelson from the White House Office of Science and Technology indicated that the Department of Education is spending \$50M a year in projects related to education. He indicates that NASA and the Department of Energy are also funding networking projects (Nelson, 1994). Additionally, the National Institute of Standards and Technology sponsors a workshop program on video and applications to bring together participants of varied interests to discuss the Department of Commerce programs (Fenimore et al., 1994).

The use of technology in education is a topic pursued by educators. Ben Shneiderman of the Massachusetts Institute of Technology called for a one-hundred billion dollar Strategic Education Initiative. The proposal includes funding for the National Data Highway, the on-line Library of Congress, and funding for over 100,000 schools and 2,000 Universities. The funding would be used to provide schools with the hardware, networks, software, and training for a national multimedia educational system (Shneiderman, 1992).

The significance of distance education is recognized worldwide. Hiltz reported: "The need to provide access to higher education for working adults is also widely recognized in Europe, where institutions such as the British and Danish Open Universities have provided opportunities for tens of thousands of distance learners" (Hiltz, 1992, p. 347).

Distance education projects have been reported in areas where the geography of the region is a major consideration. Examples include distance education projects in South Africa (De Villers & du Plooy, 1992), Newfoundland (House & Keogh, 1989), and Saskatchewan (Kindred & Harley, 1991).

The use of distance education can be expected to expand as low-cost video and networks enter the marketplace. An Intel video teleconferencing system has been announced for less than \$1,000 (Maney, 1995). The cost is less than a New York student would pay to attend one Nova Southeastern Institute in Fort Lauderdale, Florida. This cost comparison is indicative of how decreasing technology costs can affect the economics of education.

In addition to the significance of distance education, the technology is significant. Industry leaders, including Intel and Microsoft, are pursuing video and group conferencing as a major technology area.

In 1993, Dr. Andrew Grove, Chief Executive Officer of Intel stated: "PC desktop conferencing is the tidal wave that will lift all PC companies and the industry to the next prosperity" (Heish, 1994, p. 103). Paul Osborne, the head of the Microsoft multimedia department announced: "Every Chicago and Windows NT PC will be a media-conferencing ready PC" (Osborne, 1994, p. 329).

The industry interest is fueled by projected market size. The total revenue in 1994 for Video TeleConferencing (VTC) and DeskTop VTC was \$31.25M. Projections for 1998 are \$2,090M (Dickenson, 1994). "Intel's influence is significant In January Intel spearheaded the creation of the Personal Conferencing Specification group, a consortium of 14 heavy hitters in the PC and DeskTop Video TeleConferencing industry including AT&T, Compaq, and Novell" (Bort, 1994, p. 68).

Intel has also joined forces with Oracle, the database firm. In a teaming agreement, users of Intel's ProShare VTC will be able to access digital video data stored in Oracle 7 multimedia databases (Schroeder, 1995). Importantly, the companies have adopted standards from the International Telecommunications Union (ITU) as the basis for the agreement.

This effort has significance as a first use of standard telephone lines for distance education. Distance education systems based on satellite communications, cable, and other high bandwidth networks exist; however, no distance education system over POTS has been reported. Gomez, Judice, and Grady attested to this unavailability: "Until recently bandwidth has limited the instruction delivered by POTS" (Gomez et al., 1992, p. 772).

The reasons for this are: the recent emergence of video products that operate over POTS; the lack of courseware and education software for distance education over POTS; and the lack of equipment capable of networking a large number of video channels.

The dissertation is relevant at the local, national, and international levels. It is relevant at the local level because it supports NSU's project to improve its distance education system. The dissertation will benefit Nova Southeastern University by providing designs for an improved ECR or for additional study.

The dissertation is relevant at the national and international level because national leaders have embraced projects in distance education. Leaders such as the Chairman of the Federal Communications Commission, Mr. Hundt, have encouraged the use of emerging technology in support of education.

In summary, this dissertation is both significant and relevant. It is technically significant because major information systems corporations are making large investments in this emerging technology. It is technically significant because it is a first or early use of low cost VTC technology for distance education.

It is relevant because it includes designs, technology projections, and results that will assist others researching distance education. The dissertation adds knowledge to the distance education effort at NSU and to the research community.

Elements Investigated

The subject of this dissertation is the design of a distance education system based upon Video TeleConferencing technology. However, the system and network are only part of a total distance education program. For a complete distance education program, the three elements listed in Figure 3 needed to be addressed.

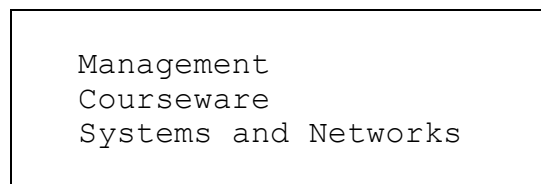


Figure 3. Elements to be Investigated

Proper management has been reported as an important element of a distance education program. Researchers at Purdue found that poor management severely hampered the use of distance education, and that strong management was required for distance education to be successful (Orczyk & Garrod, 1991). Findings at the University of Hawaii were surprisingly similar (Cleveland & Bailey, 1994). In this regard, researchers recommend the formation of a separate organizational entity to manage the distance education program.

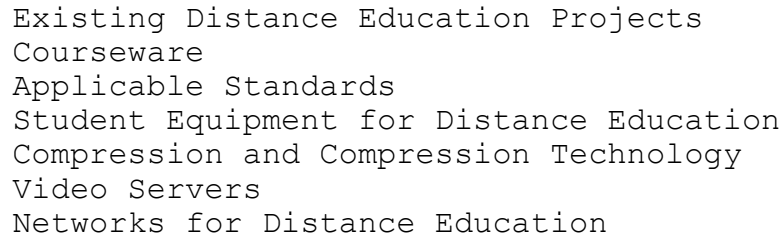
Siff, Kelley, and Maney (1991) pointed to the need for effective courseware for distance education and the difficulty in developing it. Marshman, Darnell, and Spikins (1992) published similar results. No matter how effective the delivery system, the success and long term viability of the distance education program will rest on quality courseware.

Courseware became an element of interest for this investigation because of its potential impact on the technical aspects of the system. Accordingly, the courseware and the networks used to deliver it are of interest for this effort.

Although they represent challenging problems, detailed studies in the areas of courseware and management were not included in this effort. These areas require educational and managerial studies that were beyond the scope of this effort. The areas are only addressed and reported to the extent that they impact the system and network design and tradeoffs.

While not the subject of this effort, these areas have been recognized as necessary for the successful execution of the NSU project. Under Dr. Levin's leadership, members of the MMECR project are working independently on projects in these areas.

The focus of this dissertation was systems and networks. Multiple related elements were studied in varying detail. The elements studied are given in Figure 4.



Existing Distance Education Projects
Courseware
Applicable Standards
Student Equipment for Distance Education
Compression and Compression Technology
Video Servers
Networks for Distance Education

Figure 4. System and Network Elements Investigated

Barriers and Issues

Data was collected over a period of approximately eighteen months, including preliminary research prior to the start of the dissertation process. After gaining an understanding of the technology, it was determined that the elements listed in Figure 5 were critical to the effort. These elements were thus accorded greater emphasis in the subsequent literature searches and attendance at technical conferences.

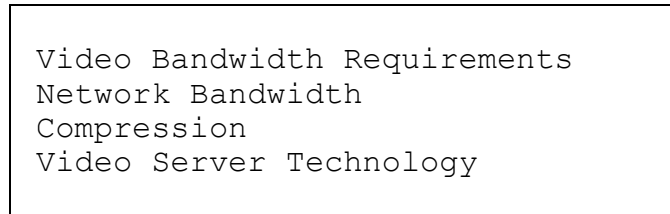


Figure 5. Critical Areas in Systems and Networks

The first critical element, video bandwidth, emerged in studying the requirements for the student's system. It became apparent that the amount of information required for video was an issue. If the amount of data overwhelmed the network, the system would not be feasible with today's technology. Further, it was known that tradeoffs could reduce the data, but the impact of the reductions on video quality was unknown.

The second critical element, network bandwidth, was related to the first element. Once the requirement for the total amount of information was known, it then had to be determined if the network could meet the requirement.

The third critical element is related to the first two elements. Compression can be used to reduce the amount of information required for transmission. This is because video information is "lossy"; that is, information can be lost without perceptible impacts. The degree to which the data could be compressed was not known, however, and this needed to be researched.

The fourth critical element, video servers, emerged as a barrier area. ISDN video servers had technical limitations, and multiple point connections could not be made with the POTS equipment. To overcome these problems, an extensive product search was conducted. It resulted in the identification of connection devices to support ISDN and POTS conferencing.

Each of the critical elements of Figure 5 emerged as a barrier to the attainment of the objective. Each of these elements required tradeoffs to achieve the system design. These tradeoffs are shown in Figure 6 and described below.

Area	Tradeoff
Video Bandwidth	Video Quality
Network Bandwidth	Cost
Compression	Processing Power
Video Server	Availability

Figure 6. Critical Areas and Tradeoffs

Regarding the first tradeoff, it was found that video quality was directly related to bandwidth. All other things being equal, the higher the video quality desired, the higher the bandwidth required. For a system operating over POTS, this became an issue that resulted in the decision to conduct a feasibility demonstration.

Second, it was found that the network bandwidth was directly related to cost. That is, the higher the bandwidth, the higher the cost. POTS at 28.8 kbps is the lowest cost network available for a distance education system. ISDN gives more bandwidth and better video quality, but at higher cost.

Third, it was found that higher compression ratios required greater processing power. That is, it takes a more powerful processor to attain a higher level of compression. This is due to the need to compress video on a real-time basis.

Lastly, it was found that the Video Servers for ISDN were available but expensive. The equipment necessary to display the required sixteen images for the POTS system have just emerged. However, the number of suppliers is limited, and the devices have yet to be used in a distance education system.

Limitations Of The Study

The objective of this effort was to design the system with its three components: student system, University host, and support system. The designs have been completed to the component and module level. The designs are limited to sixteen subscribers by current technology. Product projections show that a multi-session 2000 student system should emerge early in the next century.

While the design is complete, the actual development of the system is left for others. This is as proposed and approved.

Cost information is provided for completeness. This information should be updated prior to any major decisions. The reason for this is the nature of the industry and the newness of the products.

The components necessary to complete the design were first demonstrated in November 1995. Pricing information can be expected to change rapidly as the competitive environment changes.

Definition of Terms

Video TeleConferencing covers a number of technical areas that may be unfamiliar to the reader. To aid the reader, a Glossary and List of Abbreviations have been included at the end of the report. Also, an introduction to DeskTop VTC is offered in Chapter II. This simplified description of a VTC precedes the more technical aspects of the report.

As another aid to the reader, significant results have been summarized as Tables. The Tables begin in Chapter IV. The reader can gain an overview of the results by surveying the Tables.

Summary

The objective of this dissertation was the design of a low cost video system for NSU. The goal has been met, and the cost of the system for students with a multimedia system will be zero.

The NSU host system will enable multimedia electronic classrooms to be conducted with sixteen users including the instructor. The cost of the full system with CD ROM duplication equipment is less than \$100,000. Alternatives are proposed that lower that cost to \$11,000, and the system can be demonstrated for under \$2,000.

The effort has relevance at the local, national, and international levels. The effort is technically significant as an early--if not first--use of POTS systems for distance education.

The dissertation was completed as a part of the MMECR project. The MMECR project is an innovative initiative in the field of distance education. It has reinforced the commitment of the University to distance education and served as a focal point for distance education research.

Chapter II

Review of the Literature

Introduction

The findings of the literature search are presented below. The material is presented in the order of management, courseware, systems and networks. A review of recent dissertations, a thesis, and a text complete the section.

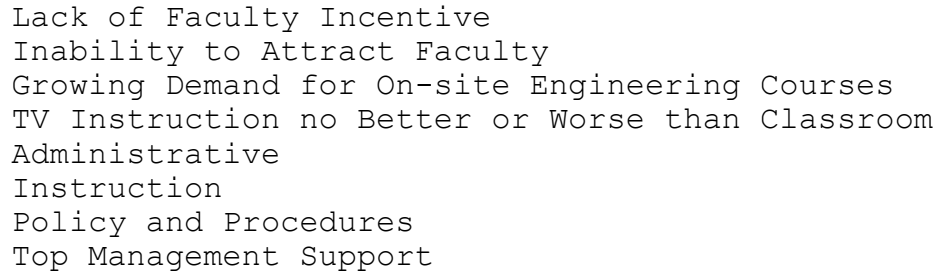
Management of Existing Distance Education Projects

At Purdue, Orczyk and Garrod identified issues associated with distance education (Orczyk & Garrod, 1991). Their article offered some valuable insights into structuring a distance education program.

The authors recommended a multilevel organizational approach to distance education. They offered the following observations: (i) at a research oriented University there is a lack of incentive to attract faculty to participate in distance education programs; (ii) there is a growing demand for on-site continuing education for engineers; (iii) the level of learning achievable by televised instruction is neither better nor worse than that achievable in the classroom; (iv) issues have to be addressed at the administrative, instructional, and policy and procedures levels; (v) top university management support is crucial to distance education; and, (vi) Purdue was unable to attract faculty to teach on TV due to the lack of departmental support or monetary incentives.

In the area of management, the experience at Purdue University is significant. In brief, the personnel involved in distance education at that institution recommended separate management procedures and incentives for distance education.

They found that the faculty policies at the institution favored the traditional educational policies, and that no faculty incentives existed for distance education. They also found that not all instructors were suited for distance education and the associated media, such as video. The Purdue experience is highlighted in Figure 7.



Lack of Faculty Incentive
 Inability to Attract Faculty
 Growing Demand for On-site Engineering Courses
 TV Instruction no Better or Worse than Classroom
 Administrative
 Instruction
 Policy and Procedures
 Top Management Support

Figure 7. Issues in Purdue Distance Education

Other findings at the management level involved the type of students and courses for distance education. It was found that engineering and computer courses were well suited for distance education, and that "mature" students did better with distance education than their counterparts. The market potential of distance education for continuing engineering in the corporate world was continually addressed.

The experience at the University of Hawaii is more recent, but remarkably similar to the experience at Purdue. In the spring of 1993, the University of Hawaii began offering MBA course work using a distance education system that connects the islands of Hawaii. In a comprehensive presentation of the technical, courseware, and management issues surrounding the system, the authors directly address the issues that NSU will face in a video based system including accreditation (Cleveland & Bailey, 1994).

The distance education program at the University is broadcast using the Hawaii Interactive Television System. The system connects six islands of Hawaii using point to point microwave links. From the microwave connections, feeder connections are made to remote classrooms using fiber and broadcast TV. The video is one way from the classroom, and audio is accomplished through a two way audio bridge.

Since its inception in 1987, the government financed broadcast system “. . . has served over 10,380 participants in 178 workshops and training sessions, 189 seminars, 137 teleconferences and interactive meetings and offers ten degree programs or portions of degree programs throughout the University of Hawaii” (Cleveland & Bailey, 1994, p. 135).

The authors found resistance to pedagogical change as experienced the Purdue developers. They state that this is partially due to lack of information on strategies to facilitate the process of change. They cite the need for a “. . . well organized support network to manage the complexity and scope of the technical and social interdependencies which define systems such as distance education” (Cleveland & Bailey, 1994, p. 135). “All too often, attention focuses exclusively on technical issues while overlooking the social impacts on existing tasks and working relationships or underestimating the amount of advanced planning, coordination, expenditure of resources and time needed for implementation” (Cleveland & Bailey, 1994, p. 135).

The need for advanced planning, accreditation, and dealing with personnel issues were highlighted. These and other management issues are summarized in Figure 8.

<p>Advanced Planning Essential High Technology Support Group Required Roles must be Defined and Coordinated Budget Commitment Required Service Providers needed for each aspect of system Accreditation must be planned Faculty Compensation Faculty Training Class Size</p>
--

Figure 8. Management Issues at the Univ. of Hawaii

Technical issues and requirements for distance education were also addressed by Cleveland and Bailey. The program was striving to achieve transparent course

delivery, or the equivalency of distance and traditional learning environments. The one way video restriction was cited as a technical limitation, and library access and support for remote students were highlighted as technical and accreditation issues. The authors believe that existing CD ROM systems can alleviate the problem of remote library access.

The findings at the University of Hawaii are shown in Figure 9. Despite the problems involved with the system, the advantages are significant. Most notable is the extension of education to locations with no other forms of education.

The last finding in Figure 9 deserves emphasis. The authors found that "Even a pilot project requires an investment in a complete system . . . Failure to plan ahead and invest properly will result in an ineffective, inefficient system which requires continuous moneys to upgrade and retrofit, wasting valuable resources" (Cleveland & Bailey, 1994, p. 140).

<p>Less Costly than Traditional Instruction Transparency Costs reduced Course Materials easy to maintain More Advanced Preparation for Class Required Class Briefing Material more important Delivery of Course takes longer Interpersonal Rapport difficult System and Hardware limitations bothersome Students at remote site enthusiastic Students at host site less active Complete system required even for Pilot</p>
--

Figure 9. Findings at the University of Hawaii

Capable management will become more important as the drives to reengineering education accelerate. Recent reports indicate that technology has already begun to impact education.

In a special report in Business Week, reporters found that "technology is reshaping education" (Armstrong, Yang, & Cuneo, 1994, p. 80). In companion articles, Eng found that teaching using high technology products was leading to higher test scores at the grammar school levels (Eng, 1994). Verity called for the need to empower the teachers and called for "The Next Step: Reengineer the Classroom" (Verity, 1994, p. 88).

Although it has begun, the reengineering and downsizing of education will be difficult. Civic leaders have begun to replace traditional programs with technology based, downsized programs. The tumultuous result in one case was reported by Larrabee: "Crowds of angry parents and teachers have shut down public meetings by jeering city officials and company executives" (Larrabee, 1995, p. 3A).

Despite these results, Larrabee reports that "High costs and poor results in public schools have many cities such as Hartford, Conn. experimenting with alternatives" (Larrabee, 1995, p. 3A).

The trend toward downsizing and the reengineering of education can be expected to continue. Larrabee identified the municipalities contracting to downsize and restructure public education in Figure 10. The firms competing for these efforts are all using technology based solutions and see the schools as an attractive market.

<p>Mount Clemens, Michigan Wichita, Kansas Wilkinsburg, Pennsylvania Baltimore, Maryland Miami, Florida</p>

Figure 10. Efforts at Restructuring Public Education

The trend toward technology based education can be expected to grow. In a recent stock market forecast the Fidelity investment company projects that ". . . the for-profit education companies offering 'electronic education' or the 'virtual university' could potentially be industry leaders" (Reynolds, 1995, p. 7).

Drake University began a distance education program in 1991. The system utilizes a fiber optic network in Des Moines to offer college courses to high school students and non-traditional students at seven high school sites connected by the network. Drake is also awaiting connection to the fiber based Iowa communications network (Fellers, 1994).

The system utilizes a modified broadcast teaching method, and maintains continuous audio throughout the sites. An interesting feature of the system was its ability to scan the high school sites at regular intervals so the instructor could detect students with their hands raised. This feature has been adapted to the design presented here.

Two important considerations in distance education are course suitability and course leveraging. Leveraging denotes the reuse of existing course material for other markets. At the University of Bradford in England, expertise in distance education is used to provide engineering courses for industry.

The University is involved in the project DELTA, "Developing European Learning through Technological Advances". This effort is attempting to provide open courses through a combination of media, including video and telephone. The University uses distance education for only the project portion of its courses (Alder, Chandler, & Loomes, 1993).

The DELTA project is looking at ISDN as a means of providing interconnection for distance education. Since ISDN is also available in major portions of the United States, ISDN is a viable network for international distance education.

In addition to providing distance education, the Memorial University of Newfoundland system provides telemedicine. The system provides one way video and two way audio over satellite to Canada, Africa, and the West Indies. "The emphasis at Memorial has been in the application of inexpensive and cost effective technologies with the involvement of a large user consortium to assure economic viability" (House & Keough, 1989, p. 10.2.1)

House and Keough, 1989, supplement traditional courses with radio, audio tapes and live TV. The authors summarize the alternative networks in use for distance education. They state:

There has been a continuing debate on the question of the best techniques to provide distance health and educational programs. There are those who strongly believe that live two-way television is necessary. Others advocate one-way television and two-way audio, while others point to the high cost of television and claim that interactive voice-only systems provide highly effective results. (p. 10.2.1)

Memorial tested one-way video with two way audio. "While the project demonstrated clearly the effectiveness of one way live TV and interactive audio, it was concluded that most of the educational material could have been delivered by audio alone." The authors continued: "Audio teleconferencing is an effective and economic method of supporting and delivering telemedicine and distance education services. A consortium of users will make a teleconferencing system more economic than with a single user group" (House & Keough, 1989, p. 10.2.3).

The Memorial effort is noteworthy because of its global span: "In 1985 the International Satellite Organization (Intelsat) and the International Institute of Communications established the Satellites in Health and Rural Education (SHARE) project to celebrate the 20th anniversary of the establishment of Intelsat" (House & Keough, 1989, p. 10.2.3). Memorial used Intelsat to connect Nairobi and Kampala with Canada. The project was subsequently expanded to include the six Caribbean countries of the West Indies Distance Education Teleconference System.

In a series of articles, du Plooy, 1992, described a university completely structured for distance education. The University of South Africa was established as a distance education facility and conducts no traditional classroom instruction. The University uses postal delivery as their "network" and is now moving to the public telephone system. Their approach to courseware development is based on an artificial intelligence expert teacher. The system provides the capabilities listed in Figure 11.

<p>Advise On Courses And Prerequisites Answer Administrative Inquiries Assist Students With Programming Languages And Other Software. Act As A Tutor Evaluate Assignments Provide Fast Feedback To Students Act As A Technology Driven Education Management System For The Department.</p>
--

Figure 11. Expert Teacher Functions

du Plooy considered distance education an exciting area of research. The author saw the expert teacher and its network as integrating the entire University, including the library, administration, lecturers, and courseware generation facility.

On courseware and Computer Aided Instruction (CAI), the author claimed: "We have proved that CAI is viable in a distance education situation and that a multimedia approach could go a long way towards alleviating the teacher and lecturer shortage and enhancing the quality of distance education and training" (du Plooy, 1992, p. 27).

On the negative side of the University of South Africa experience, Villiers and du Plooy, 1992, addressed some of the difficulties in distance education. They stated: ". . . the University has been struggling with the twin problems of lack of staff and a difficult subject to teach . . . " (Villiers & du Plooy, 1992, p. 8). Another problem with distance education was: ". . . the feeling of isolation due to the lack of interaction with lecturers and other students" (Villiers & du Plooy, 1992, p. 8). On a more positive note, they stated: "Computer science lends itself to animation, simulation, and improved ways of presentation to students, which makes it an ideal subject to teach via CAI" (Villiers & du Plooy, 1992, p. 10).

The telecommunication issues of distance education mirror those of health care and education. Kindred and Harley, 1992, described the medical telecommunications system used in rural Saskatchewan.

Using a 1.5 Mbps telecommunications network among the areas' hospitals, Canada was successful in exporting specialized medical knowledge to the rural areas of Saskatchewan and 134 hospitals. The system enables Canada to distribute the latest in medical knowledge which "doubles every seven years" (Kindred and Harley, 1992, p. 138).

Mary Walker and Joseph Donaldson reported on the distance education efforts at the University of Illinois (Walker & Donaldson, 1989). Their educational system is similar to Nova Southeastern University's. They augment their Electronic Blackboard System with one way video and audio. Separately, they also use studio videotaped courses for the delivery of off-campus courses in continuing engineering education.

In their article, they compared student performance using the various systems. The results of a seven year study are presented. The authors concluded that on-campus grades are higher in Electronic Blackboard courses.

The authors made the following additional observations. They claimed their results are consistent with the results obtained by other researchers.

They found that engineering students performed substantially better than other students using the electronic blackboard. Additionally, they stated that older students with corporate sponsors did better than average; thus, ". . . suggesting the importance of maturity and experience in the profession as contributors to performance in off-campus credit programs" (Walker & Donaldson, 1989, p. 445).

At the University of Texas, researchers studied the effectiveness of the electronic blackboard in their "Nick Summer Experiment". They found that the electronic blackboard "helped to increase group focus and attention on completing the task" (Ellis, Rein, & Jarvenpaa, 1989, p. 359). Similar to the original Nova Southeastern University system, their electronic blackboard was text based.

The corporate world is interested in distance education as indicated by Gomez et al., 1992. The authors stated that their firm, Bellcore, believes: "Advances in video compression, digital channel coding on copper loops, and multi-rate switching fabrics have made it possible to bring affordable, interactive video into the classroom and home" (Gomez et al., 1992, p. 770).

The authors identified the various media in use for distance education efforts: "While radio has been used to deliver instruction in the third world, the primary delivery media in the United States has been educational television via standard satellite broadcast, and to a lesser extent, cable" (Gomez et al., 1992, p. 771).

"The most common distance learning mode of operation is to broadcast a 'teacher' to a remote location . . . Student interaction with the teacher is provided via some secondary channel" (Gomez et al., 1992, p. 771). The need for the secondary channel is to overcome the time delay associated with satellite transmission.

Regarding satellite transmission, the authors observed: "The most severe disadvantage (of satellite) is the cost of the antenna . . . with digital broadcast satellite technology driven by entertainment applications, the cost is likely to see rapid decline" (Gomez et al., 1992, p. 771). In terms of satellite cost, Gomez et al. stated: ". . . this style of instruction depends on a relatively large number of people being interested in the same thing" (Gomez et al., 1992, p. 771).

The authors found that the transmission delay in a satellite TV's broadcast make it unacceptable as a single media for interactive distance education. Those systems that do use satellite as a part of their network augment it with a second network such as telephone to achieve student teacher interaction. Even with this approach however, there is still time latency between the channels.

Gomez et al., 1992, reached a major conclusion related to this effort:

We believe some of these (educational) problems can be better solved by instructional delivery based on the public switched telephone network augmented with video technology. Furthermore, we feel this technology can cost-effectively extend the reach of the classroom directly into the home in the near term. (p. 771)

The authors highlighted three areas that they believe are barrier areas in POTS delivery of distance education. These areas are listed in Figure 12.

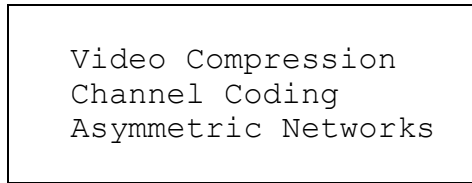


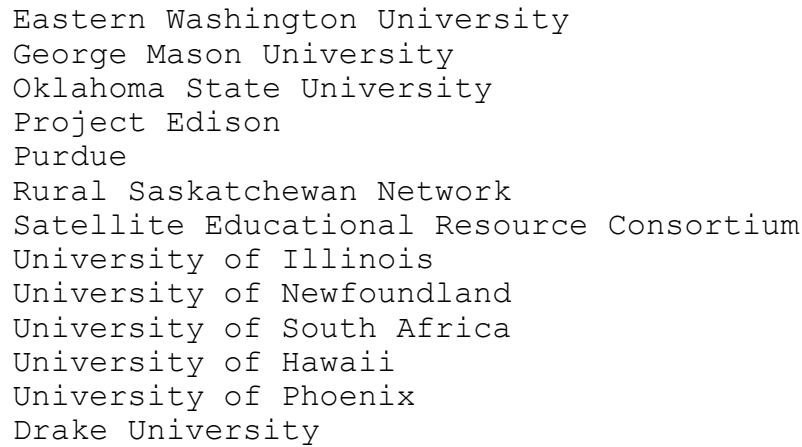
Figure 12. Enabling Technologies

Asymmetric use of the network bandwidth is an important consideration in the design of the network. The asymmetric use means that the bandwidth does not have to be shared equally between two end points on the net. As an example, the network bandwidth could be prioritized to favor high quality, full motion video for the teacher and low motion (portrait) video of the student.

Gomez et al. concluded with a description of two systems: the North Dakota High School Net, a distance education system connecting local schools using T1 networks; and a more technologically current effort, Project Edison. Project Edison is a joint venture of Bell Atlantic and a local school district to develop a multimedia distance education system. It is a major effort to "privatize" the schools.

Project Edison offers to teach students in grades k - 12 (Kindergarten through twelfth grade) for less than municipalities pay in taxes for education. The project uses modern management and technology. It has stimulated major discussions on the best way to revitalize schooling in the Northeast United States (Larrabee, 1995).

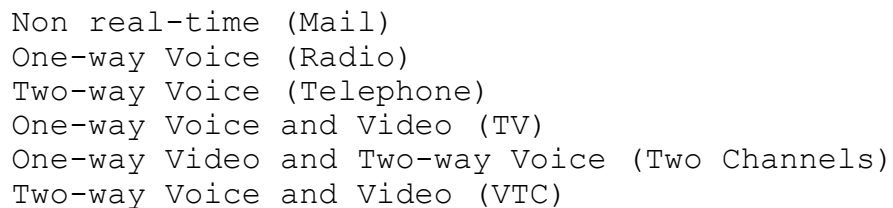
The existing distance education efforts identified as a result of this study are summarized in Figure 13.



Eastern Washington University
 George Mason University
 Oklahoma State University
 Project Edison
 Purdue
 Rural Saskatchewan Network
 Satellite Educational Resource Consortium
 University of Illinois
 University of Newfoundland
 University of South Africa
 University of Hawaii
 University of Phoenix
 Drake University

Figure 13. Existing Distance Education Projects

Although a number of network media for distance education were found, the existing systems all reflect one of five possible approaches shown in Figure 14. Even though VTC is listed, today's connections are primarily point to point. That is, conference room to conference room.



Non real-time (Mail)
 One-way Voice (Radio)
 Two-way Voice (Telephone)
 One-way Voice and Video (TV)
 One-way Video and Two-way Voice (Two Channels)
 Two-way Voice and Video (VTC)

Figure 14. Alternative Types of Networks

Courseware

Peltason, 1993, offered some definitions that are useful in describing the various distance education options. The author refers to the following three concepts: (i) Interactive Distributed Learning; (ii) Interactive Remote Tutoring; and (iii) Interactive Teleteaching.

Interactive distributed learning is based on an n-m communication path that enables conference like communications among the participants. Two of the n participants could be the instructor and the Library, for example, while the m are the students. Interactive remote tutoring is based upon a direct 1-1 connection between the tutor and the learner. Interactive teleteaching is a "virtual classroom" 1-m concept.

Peltason's work was done in Europe on the previously referenced DELTA project. The article pointed out the advantages of ISDN as an international standard.

The development of concepts and applications, such as courseware, can be hindered by the hardware in use. In the case of distance education, bandwidth is certainly a limiting factor. One approach to develop systems for distance education is to eliminate the constraining variables and concentrate on the remaining issues. Building a laboratory environment for just courseware and concept development is a valid approach to distance education.

Bugos, 1991, described such an approach in an article on an "Interactive Video Laboratory System". By providing a high quality video platform, the courseware and other design issues could be worked out before attempting to solve the bandwidth problem. The system proposed by Bugos would handle full motion video and could be based on Intel's Digital Video Interactive system. The system compresses 720 kb frames to 4.5 kb frames achieving a compression ratio of 160 to one.

Bugos pointed out that a single CD ROM can hold up to 44 hours of audio, 650,000 pages of text, 40,000 still video images, or 72 minutes of full motion video or some combination of the above. For programming, the author recommends using "C" or special purpose routines.

There is no question, the CD ROM capability now available on the current PCs offers the ability to create multimedia courseware with massive amounts of information. Additionally, this media can be used to distribute large non-proprietary software packages. This information can be distributed cheaply and effectively to students.

Bugos identified several barrier areas in digital video including: (i) reducing the cost of compression; (ii) reducing the amount of hardware and special software required; (iii) improving the quality of images; and (iv) smooth motion sequences. The author concluded: "Applications, courseware, and software for interactive laboratory systems must be extremely well planned and prepared. . . . The time to begin research and development of interactive video laboratory systems is now" (Bugos, 1991, p. 962).

Jurgen, 1992, would agree that the time is now: ". . . video compression, optical-fiber networks, digital recording, digital high definition television--are already in hand" (Jurgen, 1992, p. 24). Jurgen related some of the characteristics that are needed in solutions: scalable, extensible, and open architecture.

The author defined scalability as: ". . . the ability to use a variety of resolutions, temporal rates, colorimetry, and intensity dynamic ranges. In other words, displays designed for one set of those parameters should be able to do a reasonable job of showing images produced at higher or lower values of resolutions, rates, colors, and so forth" (Jurgen, 1992, p. 25).

The author described the existing standards for still-picture compression (JPEG), video-teleconferencing (ITU px64), and full motion compression (MPEG). The author stated the need for a universal header to make any video stream recognizable by any device.

Marshman et al., 1992, pointed out that "The cost of using a distance learning package . . . is very low compared with attending an external course with the added advantage of having the training material permanently available for new staff or revision purposes" (Marshman, Darnell, & Spikins, 1992, p. 272). They also observed: "As authoring packages--such as Authorware, chosen by IEEE for its proposed Software Engineering Multimedia courses--become better known, course presenters will be able to structure courses and transfer them to disk at less cost than the current systems which require the skills of several people in a multi-disciplinary team" (Marshman, Darnell, & Spikins, 1992, p. 272).

Siff, Kelley, and Maney, 1991, addressed the problem of "Engineering a Software Environment for Distance Education". Summarizing their test results with a Datel software package at the George Mason University, the authors stated: "Distance education has always been a poor relation to the real thing" (Siff, Kelley, & Maney, 1991, p. 1009). In their formal evaluation, English students: (i) missed the opportunity for interaction; (ii) found the lecture less motivating; and, (iii) simply wished that there had been more meetings (Siff, Kelley, & Maney, 1991).

The authors summarized the positive aspects of the product: "This concept is not CAI, not expensive and makes maximum use of the effectiveness of information technology for what it does best, communications" (Siff, Kelley, & Maney, 1991, p. 1010).

Alexander and Pistorius addressed courseware at the University of South Africa in 1992. A design model for courseware development is presented that describes the following phases: (i) preparation for the project; (ii) predesign; (iii) design; (iv) programming and formative evaluation; and (v) summative evaluation.

De Villers, Pistorius, Alexander, and du Plooy (1992) described some constraints on courseware and CAI in a distance education environment including the observation: "It is very time-consuming and costly to develop CAI software" (De Villers, Pistorius, Alexander, & du Plooy, 1992, p. 11).

The article included survey results on a 1991 hardware survey of their students. It reinforced the importance of the student end instrument in the distance education problem. In their case, 50% of the first year students had an IBM machine with a 20 Mbyte hard disk. Only 50% had a color screen. This necessitated the requirement to produce low resolution graphics packages for the courseware. The course material was distributed on 5 1/4" disks.

Also in the area of courseware tools, Alder, Chandler, and Loomes, 1993, reported on distance education approaches in the United Kingdom. Marshman et al., 1992, detailed the development of courseware for distance education in electronic engineering.

Miller, Merrill, and Cole, 1988, believed that the graphical capability of the computer can "revolutionize" the learning and teaching experience. They stated that: "Dynamic visual aids can promote the development of more intuitive understanding, tie the abstract mathematics to concrete physical processes, and provide the motivation to learn" (Miller, Merrill, & Cole, 1988, p. 67).

At Lawrence Livermore Laboratory, the authors procured a \$130,000 movie generation system to assist in the development of graphical material for college engineering courses. They brought together representatives from six institutions to build the courseware (Air Force Academy, University of Arizona, University of California, Howard, Michigan Technical University, and the University of Nevada). In the process of building the courseware, they found the production of the material was "painfully slow". They concluded, however, that computer graphics has a role to play in education and ". . . we assume that is accepted as a given" (Miller, Merrill, & Cole, 1988, p. 60).

In the area of courseware, the literature indicated that distance education courseware is extremely difficult and time-consuming to develop. It was also found that the basic electronic blackboard did contribute to learning and collaboration.

In terms of learning, the results indicated that audio is as effective as the combination of video and audio. It was also stated that distance education is "no better or worse" than traditional methods of learning (Orczyk & Garrod, 1991).

Systems

An Introduction to DeskTop VTCs

Prior to presenting the literature search results in Systems and Networks, a brief explanation of a DVTC is offered. Readers familiar with the technology can continue with the discussion of Applicable Standards, immediately below.

During the discussion, the terms coder, decoder, and codec will be used. A coder is an algorithm that takes data, such as an image, and transforms it into an alternate form. The alternate form in this case is a reduced size representation of the original. In some coders, the decrease can be as much as 10,000 to 1 in terms of bits or bytes.

A decoder reverses the process. The coder and decoder algorithms can be implemented in hardware or software. The process of coding and decoding results in the loss of data, as will be described later.

To code the data and decode it back to its original form, the coder and decoder must be matched. That is, the algorithm used in one must be based on the algorithm used in the other. Accordingly, coders and decoders are typically found together, and can reside on the same processor chip.

Codec is an abbreviation used to denote a coder and decoder pair. The term codec is used throughout the industry and in this report. It can denote either the coder, the decoder, or both.

Figure 15 is a simplified block diagram of a DVTC. The system will be described starting at the camera and working down to the network. The flow is one way from the camera to the user display and to the network. The thread is the conversions that must be made at each stage. That is, the transformation of the input to the output at each component.

Starting with the camera, the Video Card accepts the analog camera input in a format such as NTSC. It outputs the same information in a digital form. In other words, the video card performs the analog to digital conversion from the camera to the processor's graphics card.

Once converted by the video card, the graphics card will display the digital image in VGA or SVGA format. If the image is to be transmitted, the codec compresses the image and sends the compressed form over the network.

The video card interfaces internally with the graphics card. Graphics cards that accept NTSC directly and output VGA are now available, eliminating the need for the video card (Ozer, 1995).

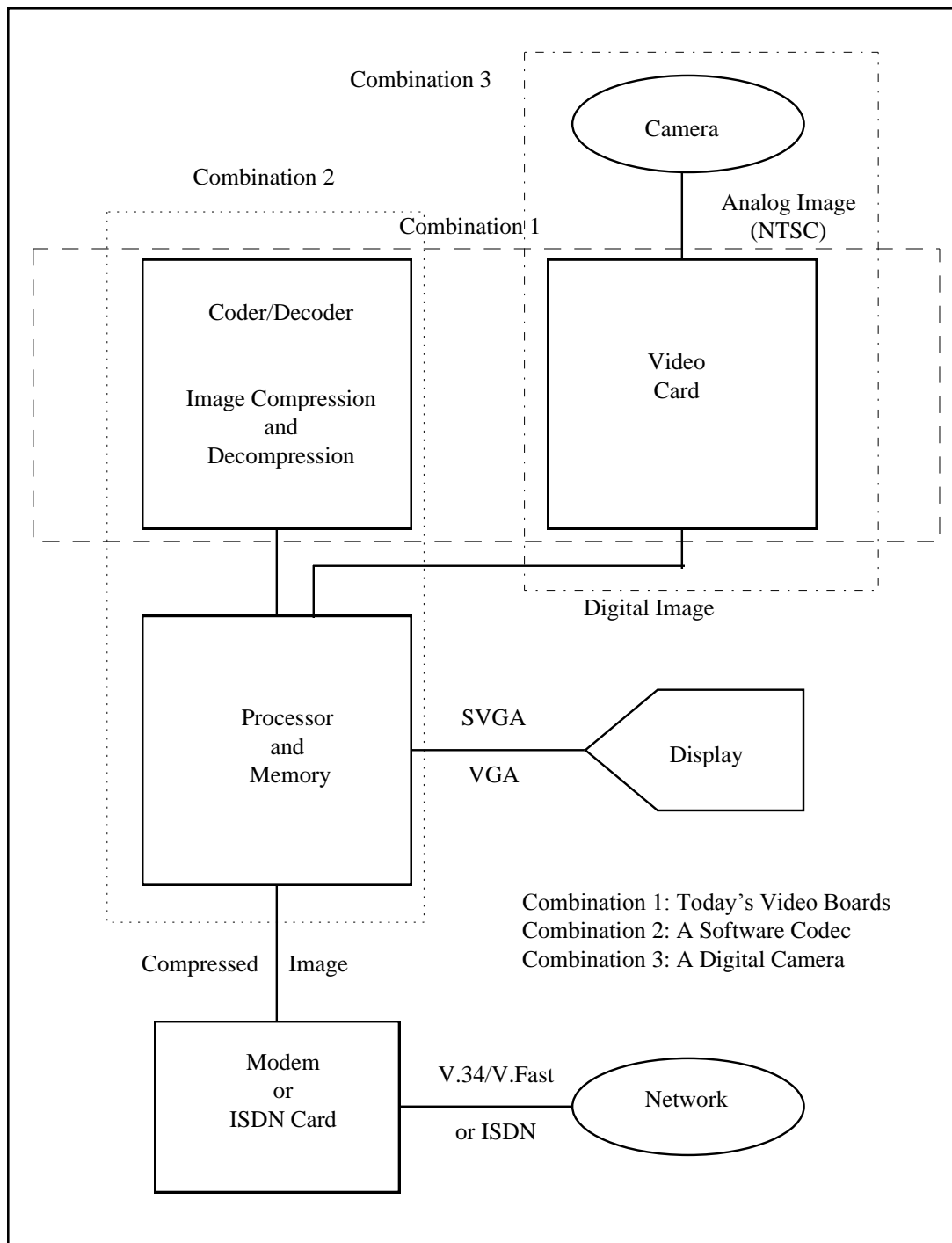


Figure 15. A Simplified VTC

The codec can be implemented in hardware or software. If it is implemented in hardware, the components required are typically located on the video board. This is shown as Combination 1 in the figure.

Combination 1 is quite common, and special purpose video chips are used. Combination 2 shows a software codec running in the processor. Combination 2 does not require a camera nor video board.

Systems that only receive video and have no requirement to generate an image can use combination 2. If the application only needs an incoming image, combination 2 with a software codec is a low cost approach. The incoming image is received over the network, decoded, and displayed to the user. No camera, video card, or outgoing image is required. This is the approach recommended later in this report.

Combination 3 involves the camera. The most common DVTC cameras have an analog output--NTSC or the European standard, PAL. Cameras are now emerging that directly output a digital signal. These digital cameras are currently expensive, however, they eliminate the need for a video card.

In brief, video transformations take place between the camera input and the two outputs of the system: VGA or SVGA for the display; and V.34 or another network protocol. When the output is directed to the network, it is first compressed using hardware or software.


Audio adds a microphone, audio card, and speakers to the system. The audio storage and transformations are similar in flow to the video; that is they are a series of analog to digital conversions and compression.

By replacing the camera with a microphone, the video card with an audio card, and the display with speakers the reader will readily grasp the process. Once both the video and the audio are transformed, they are combined with the control information and merged prior to transmission over the net. There are standards specified for this merging or multiplexing, as addressed later.

Many variations are possible for audio, video, and the multiplexing. There is no technical solution that is universally accepted. Different vendors offer different approaches to the transformation problem, and product improvements are emerging rapidly in the components of the system.

Applicable Standards

When it comes to video and compression, the industry seems to have voluntarily recognized the need for standards. A selected list of applicable standards is given in Figure 16.



T.120 - ITU Standard: Collaborative Computing
 H.320 - ITU Standard for ISDN Video
 H.261 Video compression
 G.711, G.728 Audio compression
 H.221 Multiplexing
 H.323 - ITU Standard for LAN Video
 H.324 - ITU Standard for POTS Video
 H.263 Video compression
 G.723 Audio compression
 H.223 Multiplexing
 Indeo
 JPEG Joint Photographic Experts Group
 M-JPEG Motion JPEG
 MPEG (1, 2, and 4) Motion Picture Experts Group
 V.34, V.Fast - Modem Standards (28.8 kbps).

Figure 16. Standards in Video TeleConferencing

T.120 is the ITU standard for collaborative computing. It contains a series of communications and applications protocols and services that provide support for real-time, multipoint data communications. The standard has broad industry support.

T.120 is a very important standard in the evolution of data communications. It provides a vendor supported series of specifications for communications and applications that support real-time, multipoint data communications. The standard has been established by the ITU and has the support of over fifty key international vendors. Apple, AT&T, British Telecom, Intel, MCI, Microsoft, and PictureTel have committed to the standard (Starkey, 1995).

T.120 is also important because it specifies levels of interoperability for the client terminal (Starkey, 1995). These are listed in Figure 17. The related T.124 standard specifies the meeting control features that are important to the instructor. The features include access control, and the ability to add and drop participation at any time.

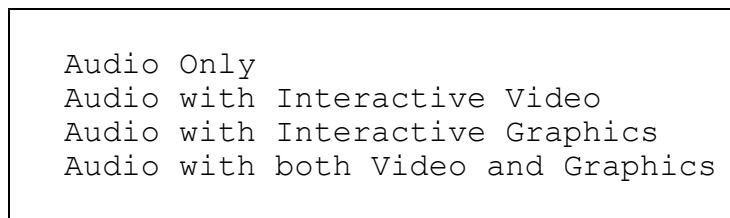


Figure 17. T.120 Terminal Capabilities

A block structure for T.120 is shown in Figure 18 (Starkey, 1995). The structure supports the various levels of terminal capabilities and allows operation over the network ports using ISDN, POTS, or LAN.

T.120 was produced by the "International Multimedia TeleConferencing Consortium". Major vendors have joined the consortium and are working toward a "Standards First!" philosophy. The group has established a World Wide Web site and has made the T.120 documents available on-line (Starkey, 1995). The site addresses are listed in Appendix A.

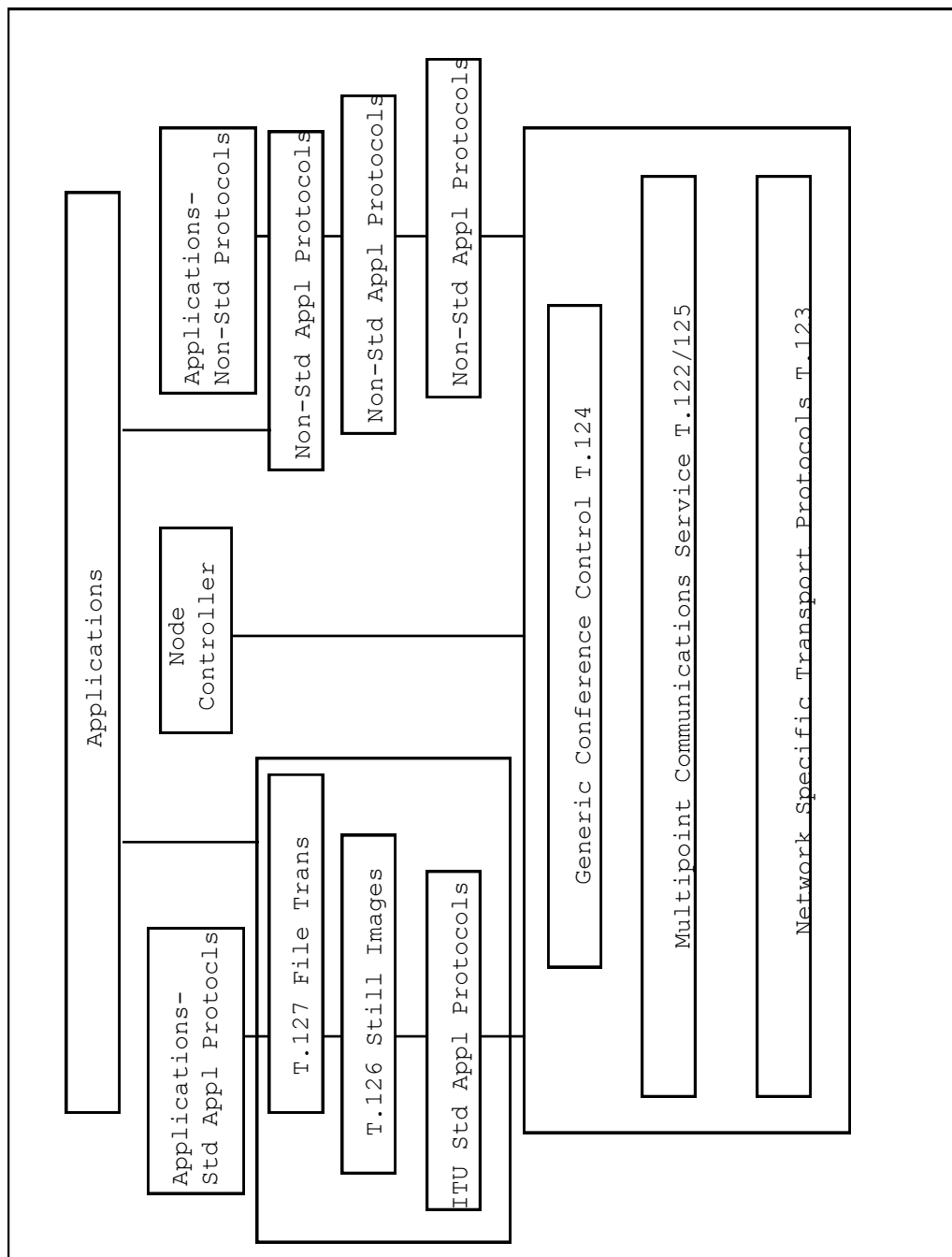


Figure 18. The T.120 Model

The important element of T.120 for this effort is the T.123 Standard for specific protocol stacks. T.123 supports ISDN, POTS, TCP/IP (Internet), and SPX/IPX. The latter is used in Novell LANs. By tying these communications media together, T.123 provides a seamless interface for video conferencing over diverse communications media. For example, T.123 will enable subscribers with a modem to participate in a VTC with a subscriber on the Internet using TCP/IP.

In a study of design approaches for teleconferencing prepared for the European Union, Schindler recommends the "Standards First!" approach. In particular, the author recommended the adoption of H.320 and T.120 for multipoint systems. The author recognizes the shortfalls in the standards listed in Figure 19, however, the author contends that the adoption of the standards will promote the development of tools and toolsets to aid in the creation of teleconferencing applications. Indeed, vendors including Intel have announced developer's kits to meet such requirements.

<p>Complexity and Ambiguities Lack of LAN Features Lack of Application Sharing Features Not Secure</p>

Figure 19. Shortfalls in the H.320 and T.120 Standards

The H.320 group of standards in Figure 16 are the ITU "px64" standards. They are based on the 64 kbps channels of ISDN. The H.320 standard includes: H.261, a compression algorithm based upon Digital Cosine Transformation (DCT); G.711, and G.728 for audio compression; and H.221 for multiplexing or framing (Klenke, 1994).

H.323 and H.324 are the equivalent LAN and POTS standards to H.320. These standards provide for the interoperability of LAN and POTS based systems. Both standards support T.120, and thus T.120 becomes a common interface for POTS, LAN, and ISDN systems.

Indeo is a proprietary Intel standard for compression. It already has a number of chips designed to support it. Its advantage is performance. It was highlighted as a possible defacto standard by Beck, Severson, and Lee in 1994, however, the company has recently announced acceptance of the ITU standards (Maney, 1995).

The next group of standards also come from the ITU. They are: JPEG, the Joint Photographic Experts Group standard for still images; M-JPEG, a Motion version of JPEG that employs compression on frames; and the MPEG Moving Pictures Experts Group. The MPEG standard is used to store motion pictures on CD ROMs. It has a transfer rate of 1.5 Mbps and uses bi-directional prediction, that is, it compresses from both previous and future frames.

The ITU has renamed MPEG to MPEG-1 and is working on MPEG-2, a toolbox of compression techniques. They are also working on MPEG-4 (Beck, Severson, & Lee, 1994).

The H.320 group of standards is based upon the Digital Cosine Transformation (DCT), a compression technique that has been widely adopted. The H.261 compression algorithm supports two resolutions: Common Intermediate Format (CIF) with 352x288 pixels; and QCIF (Quarter CIF) with 176x144 pixels. The H.324 POTS standard supports QCIF and a reduced pixel Sub-QCIF.

The H.261 compression algorithm reduces the information content in a screen by dividing the screen into 16 x 16 blocks of pixels. It then treats the blocks as I blocks or P blocks. An I-block does not depend on a previous block, while a P-block is determined from a previous block. "By considering temporal redundancy in addition to spatial redundancy, the use of P-blocks results in frames that can be encoded with fewer bits". MPEG adds B blocks to H.261 that are bi-directionally predicted blocks (Klenke, 1994).

The color information in the standard is transmitted as YCbCr where Y = luminance, and Cb and Cr represent the chrominance (or color). Due to eye characteristics, Y, Cb and Cr are sampled at different rates. This "4:1:1 sub-sampling" enables a further reduction in the information content of the frames (Klenke, 1994).

The "G" group of standards in Figure 16 support the compression of the voice associated with the picture. G.711 addresses 64 kbps compression; G.723 addresses 5.3 to 6.3 kbps compression; and, G.728 covers 16 kbps compression. The remaining V.34, V.Fast standards are modem standards.

The importance of industry standardization is reflected in the development of a special purpose audio and video processor for H.320 (ISDN) and H.324 (POTS) applications. In a very informative presentation, Ahimovic of AT&T presented the processing requirements for the standards and the processing power available from existing processors. Ahimovic points out the CPU processing power is more expensive than special purpose processors, and they dissipate more power. The AT&T special processor (AVP-III) should promote standardization by putting software functions into hardware. Ahimovic's data is shown in Figure 20.

The AVP-III will enable the complete H.320 processing requirement to be met on a single chip at an estimated cost of \$78.00. Using the special purpose processor will enable higher quality systems, as well as freeing processing power for collaborative software.

AT&T is not the only vendor providing special purpose video processors. Integrated Information Technology also is pursuing the same approach, and Intel has a "i750" chip family (Ozer, 1995).

<u>VTC Required Pentium MIPS (P-MIPS)</u>	
QCIF Video (H.263@2+FPS)	25-75
Audio (G.723)	0
Control (H.223)	10

H.324 (POTS) Total	35-85
CIF Video (H.261@15 FPS)	1000
Audio (G.728)	120
Control (H.221)	10

H.320 (ISDN) Total	1130
<u>Available P-MIPS</u>	
486DX33	20
486DX66	40
Pentium - 100 MHz	100
P6 Pentium - 133 MHz	200
AVP-III	1800

Figure 20. VTC Processing Power Required and Available

The chip vendors appear to be following the ITU standards to the degree that they cover the technology. The compression algorithm, or codec, was an area where the vendors had used proprietary designs. However, most are now adopting a dual approach offering both the standard and the proprietary capability.

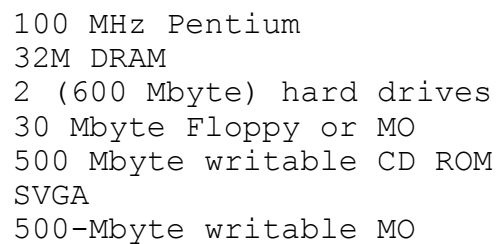
Users of VTCs are insisting on equipment based on standards. DOD is one of the largest users of Video TeleConferencing (Brundage, 1994). A series of articles on DOD VTC systems struck a common theme in the lack of standards among the providers of Video TeleConferencing equipment. Kelley, 1991, cited the need, and other later articles supported the contention (Mooney, Newport, & Schroeder, 1994; Chadderdon & Schroeder, 1994; Deville and King, 1994; and Brundage, 1994).

In summary, the industry seems to be responding to user demands for a standards based approach. T.120 has been widely adopted by the vendors, and chip suppliers are developing products that reflect the new standards. As an umbrella standard, T.120 provides both network and application interoperability requirements. The standard will facilitate collaborative computing and seamless operation over a variety of networks including POTS, ISDN, and the Internet.

Student Equipment

The equipment available to the student has been a major consideration in designing the distance education system. The cost and performance of the student equipment are critical to the effectiveness of the entire network. In this section, the cost and performance of the student's system are addressed.

Bernard Cole (1993) laid out the emerging hardware "Technology Framework" with a quantification of the personal computer capabilities projected to be available to the student. This laydown is summarized in Figure 21.



- 100 MHz Pentium
- 32M DRAM
- 2 (600 Mbyte) hard drives
- 30 Mbyte Floppy or MO
- 500 Mbyte writable CD ROM
- SVGA
- 500-Mbyte writable MO

Figure 21. Projections for Personal Computers

Cole's projections on the Pentium processor were correct, and there is no end in sight for the chip. Intel, the chip manufacturer projects that the 133 MHz P6 chip will soon be widely available, and that a 200 MHz P6 chip will be available in the first half of 1997 (Davey, 1995).

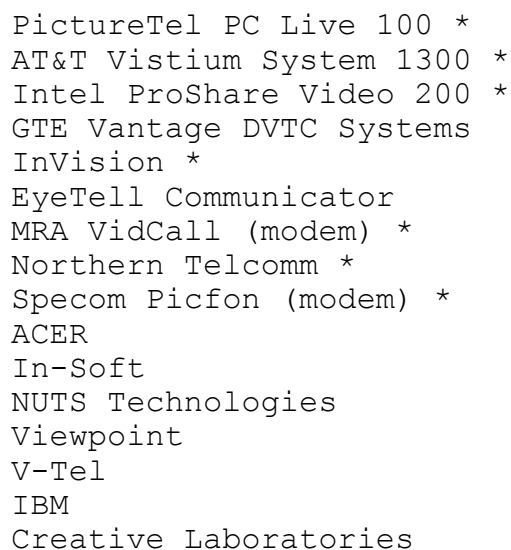
Heider (1995) from Intel stated that the processor technology continues to follow Moore's Law. That is, the transistors per die will double every eighteen months. Heider projects a P7 Intel chip before the turn of the century. The CEO of Intel, Andrew Grove, also projects the continued rise in processing power: "In 1995, Intel hopes once again to double processor performance at key personal computer prices (Anon, 1995a)."

While these projections did not cover video and associated network technology, Machrone covered these areas in a 1994 market survey and test of Desk Top Video TeleConferencing systems (Machrone, 1994). A listing of known systems is given in Figure 22. (Those with an * appear in the article; the list has been augmented based upon other literature.)

The systems in Figure 22 all run on an Intel 486 or equivalent. The typical system consists of two PC cards (Video and Sound), a camera, and associated software or groupware. Many of the systems are available for less than \$1,000.

Based upon the tests, Machrone selected the AT&T Telemedia for \$5,000 that operates over ISDN. The AT&T system offers a good picture and perfect audio at 352 x 240 pixels and 15 Frames Per Second (Machrone, 1994). Machrone tested the units on the configuration listed in Figure 23.

The computer system in Figure 23 could be procured for less than \$2,000 using New York pricing as a base (Anon, 1995c, 1996). Adding a \$1,000 video system would bring the price for a video based terminal to about \$3,000. The design presented here replaces the \$1,000 video system with a \$100.00 camera and NSU provided software. Accordingly, any student with a multimedia Intel 486, or better, can participate in the MMECR at no additional cost.



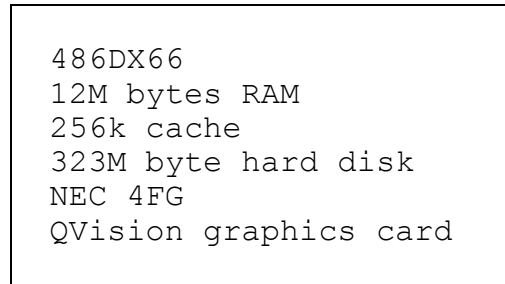
PictureTel PC Live 100 *
 AT&T Vistium System 1300 *
 Intel ProShare Video 200 *
 GTE Vantage DVTC Systems
 InVision *
 EyeTell Communicator
 MRA VidCall (modem) *
 Northern Telcomm *
 Specom Picfon (modem) *
 ACER
 In-Soft
 NUTS Technologies
 Viewpoint
 V-Tel
 IBM
 Creative Laboratories

Figure 22. Desk Top Video TeleConferencing Systems

A more recent test of PC based VTC systems was conducted by Taylor and Tolly, 1995. The tests compared the performance of five systems against eight weighted criteria including frame rate, audio, and synchronization factors. The results showed the PictureTel with a score of 7.15 of a possible 10. The Intel ProShare was rated significantly lower at 5.73--next to last.

The authors were not impressed with even the best systems. They note: "Choppy video and out of sync audio give today's PC based video products a low rent look and feel" (Taylor & Tolly, 1995, p. 64).

The latest, most comprehensive list of VTC products has been compiled by North Carolina State University as a part of its "SUCCEED" project. The list is available over the Internet. One hundred products have been identified, and product descriptions are included. The Internet address is listed in Appendix A under VTC Equipment.



486DX66
12M bytes RAM
256k cache
323M byte hard disk
NEC 4FG
QVision graphics card

Figure 23. Video Test Configuration

At the 1995 DeskTop Video Conferencing convention, Creative video claimed market leadership in terms of total volume. Creative Video claimed to have outsold all other products by selling 17,000 "PC 3000" units in the first quarter of 1995. The company claimed 30,000 units in 1994, and indicated that many of the buyers of the POTS based system were evaluating VTC using the low cost Creative product (Crilley, 1995).

In the area of user interface, security was a concern. A number of references on video security were reviewed on video network security and efforts to scramble analog and digital video. The security material is aimed at the scrambling of broadcast video and pay for use TV.

After reviewing the material, the topic was found to be extraneous to the design of a controlled access net, such as the Nova Southeastern University network. Accordingly, existing network access and password protection will be used to provide security for the system. The articles reviewed include: Christiansen and Hvidsten, 1988; Kubota, Morikura, Kato, and Hayashi, 1990; Griesshaver, 1991; and Kelkar, 1992.

Compression And Compression Technology

"The first picture phone was publicly introduced by AT&T in 1964 at the New York World's Fair . . . the original picture phone required the analog equivalent of 90 Mbps to transmit" (Goleniewski, 1995, p. 614). Using compression technology, today's systems can operate at 7.2 kbps, a 10,000:1 reduction.

In this section, this reduction and its impact on quality is addressed. The focus is the amount of information that has to be passed, the amount of information that can be passed, and the resultant compression ratios.

Based upon the compression ratios, the state of the art is studied in terms the ability of processors to achieve these compression ratios and the resulting picture quality. Articles that deal with video, video compression, and video quality are reviewed.

Video data is "lossy". That is, data can be lost and still have acceptable quality to the human eye. How much data can be lost depends upon the application. To determine acceptability, it is necessary to understand the application and determine an acceptable level of quality for the application, in this case, distance education. The importance of the application is demonstrated by the following example.

To fight credit card fraud, Kodak developed a system that will store an individual's photo on the magnetic strip of a credit card (Bell, 1995). Storage of a VGA image on the card with no compression would have required about 7 megabits of data (see Figure 24). Using Kodak's technique, the image can be stored in 400 bits--a 20,000 to 1 difference. Photos accompanying Bell's report show that the image is poor, but adequate for identification purposes.

While not as dramatic as the Kodak system, video teleconferencing systems demonstrate impressive reductions in the amount of information required. Variables in video compression are summarized in Figure 24.

Commercial TV (full motion video) broadcasts 30 frames per second. Reports from the National Research and Education Network stated that 1 to 10 Mbps of compressed video is adequate for video teleconferencing, twenty times less than the uncompressed requirement (Anderson, 1992).

Lefebvre, 1994, and Heish, 1994, identified some of the accepted standard requirements necessary to support the various forms of video and voice. They stated that a rate of 1.5 Mbps could support high quality video using compression techniques, and that 64 kbps would yield speech quality audio.

The authors identified other network parameters of interest in addition to quality. These are latency between voice and data, and jitter--the variability in latency. Lefebvre and Heish stated that low grade video may be acceptable in some applications, however, video must be of high quality for Video TeleConferencing. Further, the amount of bandwidth set aside for audio must be sufficient to eliminate jitter.

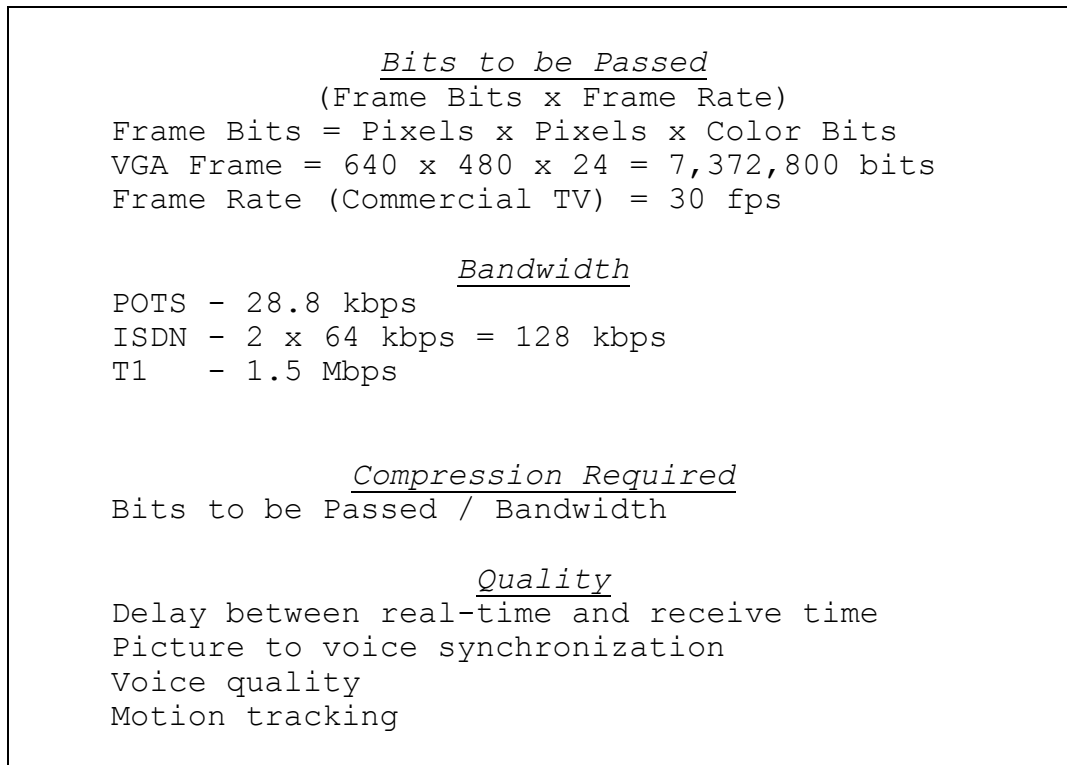


Figure 24. Variables in Video Compression

In a detailed description of compression requirements and techniques, Zieniewicz and Flatt, 1994, noted that for a VGA display, 640 x 480 pixels are used with 24 color bits. This equates to 7,372,800 bits of raw data to be transmitted (Goleniewski, 1995). The authors stated that lossless compression techniques are capable of reducing the data by up to 3:1, and that lossy compression techniques fall into four categories: Digital Cosine Transform; Vector Quantization; fractal; and wavelet.

The first two techniques can give compression ratios up to 20:1. The latter two techniques can give compression ratios of "2000:1". To achieve these compression ratios, ". . . times of ten seconds to two minutes are typical in a PC based environment" (Zieniewicz & Flatt, 1994, p. 253). This information is summarized in Figure 25.

Lossless - 3:1 Digital Cosine Transform - 20:1 Vector Quantization - 20:1 Fractal - 2000:1 Wavelet - 2000:1

Figure 25. Compression Techniques and Ratios

How much bandwidth is actually required for quality video? Beck, Severson, and Lee, 1994, presented test results that indicate that the most bandwidth needed for Video TeleConferencing is 384 kbps for 352 x 288 pixels at 15 frames per second. The authors stated that quality was acceptable down to 100 kbps. Their result shows barely adequate performance at 56 kbps. "At lower bit rates, it is better to drop to lower resolution" (Beck, Severson, & Lee, 1994, p. 304).

Creative Laboratories offers a PC based video teleconferencing system that operates over standard telephone lines (Anon, 1994a). The product supports an image of 160 x 120 pixels at frame rates up to fifteen frames per second. Other vendors are also claiming operation at less than 28.8 kbps (Wilson, 1994).

The difference between the results shown by Beck et al. and the POTS capable systems, such as the Creative, lies in four areas. These are the number of pixels, the number of color bits per pixel, frame rate, and the compression ratio.

The frame rate used in some systems approaches portrait speed. Bandwidth is traded-off for the loss of motion tracking inherent in fewer frames per second. The POTS capable systems work at a low frame rate, 7 - 10 frames per second, and at a high compression ratio: "Typical image performance is 7 - 10 fps on a 486DX66 and up to 20 fps on a Pentium 100 with a 160x128x16 resolution" (Wilson, 1994, p. 242).

The frame rate and the size of the picture are drivers, but compression ratio and processing power to run the compression algorithm are also factors. Heish, 1994, foresees compression ratios as high as 200 - 500:1 with the current family of PCs.

It is important to note that while video is lossy, not all multimedia information is lossy to the same degree. As a case in point, the video transmission of a presentation typically requires better quality video than a conversational video. The reason is that the viewgraph material can not be read at lower resolutions. Additionally, X-ray imaging is a classic example where high resolution is an issue.

Thom, 1994, provides the summary of compression ratios required for the various types of data given in Figure 26 For Video TeleConferencing, the author found: "Low resolution pictures of only 176 x 144 pixels with medium frame rates of 7.5 frames per second or greater and a low delay of 2 seconds or less is necessary for conversational integrity" (Thom, 1994, p. 235).

The author went on to state that: "Compression techniques available today provide compression ratios in excess of 200:1 depending on picture quality. . . . work being done in the areas of fractals and wavelets and analysis/synthesis coding is showing promise in achieving compression ratios in the 1,000:1 to 10,000:1 range" (Thom, 1994, p. 236).

Application	VTC	Multimedia
Resolution (Pixels)	176 x 144	256 x 256 plus
Frame Rate (Per Sec)	7.5	15 - 30
Latency	<2 Sec	<<2 Sec
Raw Data Rate	4.6 Mbps	47.2 Mbps
Compression (9.6 kbps)	479:1	4,917:1
Compression (64 kbps)	72:1	738:1

Figure 26. Compression Requirements

Sloan substantiated Thom's findings with test results. In the 1994 paper, Sloan documented a fractal compression system that was used to pass 160 x 128 video over 9.6 kbps networks with frame rates as high as 24 for 8 bit gray scale images. The system was witnessed by the researcher. It had utility, but not as a video teleconferencing capability. The system demonstrated compression ratios of 544:1.

The compression and decompression algorithm used in Sloan's demonstration was run on a standard Intel 486DX66 with 8 Mbytes of RAM. The results are consistent with the Creative Laboratories system; it provides up to 160 x 120 pixels at 15 frames per second over a 28.8 kbps link (Anon, 1994a).

The Proof of Principle demonstrations conducted for this effort verified the Creative Laboratory claims and showed that a video system could operate at rates between 28.8 kbps and 7.2 kbps. This is a reduction by a factor of ten thousand from full frame, normal motion video. Creative claims the system achieves a 350:1 ratio using a Intel 486DX33.

It should be noted that a key variable in these systems is the amount of color information that is passed. In Sloan's system eight bit gray scale was used. The commercially available PictureTel 100 supports 15 or 24 color bits per pixel. The Connectix camera recommended for the system proposed can send 4 bit per pixel black and white images.

The calculations in Figure 27 were used by the researcher to provide a degree of assurance that the claims of POTS operation were legitimate prior to the purchasing the Proof of Principle equipment. The figure depicts the various tradeoffs in picture quality that reduce the information content to reach the required bandwidth.

Referring to Figure 27, the number of pixels, the number of color bits per pixel, and the frame rate were used to determine the amount of data that needed to be passed over the network.

Tradeoffs in the number of pixels, color bits, and frame rate drastically reduce the information to be transmitted. As shown in Figure 27, reducing the pixel size to 160 x 112, the color bits to 16, and the frame rate to 5 reduces the amount from 200 Mbps to 1.5 Mbps, a factor of 133 reduction. Further, compression techniques can take the 1.5 Mbps and reduce it by an approximate factor of 50 to 1. This leaves an amount of data that is transmittable at 28.8 kbps. Subsequent reductions in the frame rate allow the systems to operate at 9.6 kbps, a rate widely in use and available to most students.

The calculations for the Connectix black and white camera require special emphasis. By using the lowest pixel settings, 4 bit color, and one frame per second images, the bit stream (19.2 kbps) can be sent over a 28.8 kbps modem without compression. Adding 5.6 kbps of G.723 compressed audio gives a total VTC requirement of 24.8 kbps, still within the modem capability.

Regarding the audio, the literature supports the feasibility of 4.8 kbps for voice range data. Audio in this range of transmission is referred to as "Low Bit Rate Voice" (LBRV).

Video = Frame Bits x Frame Rate per Second

Frame Bits = Pixels x Pixels x Color Bits

Frame Rate per Second (Commercial TV) = 30

VGA (30 FPS): $640 \times 480 \times 24 \times 30 > 200$ Mbps

PictureTel (15 FPS): $320 \times 240 \times 16 \times 15 = 18.4$ Mbps

Creative (5 FPS): $160 \times 112 \times 16 \times 5 = 1.5$ Mbps

Connectix (1 FPS): $80 \times 60 \times 4 \times 1 = 19.2$ kbps

Audio

Compressed (12:1) CD Quality = 128 kbps

Compressed (4:1) Voice Range (7 kHz) = 8 kbps

G.723 = 5.6 kbps

Creative = 4.8 kbps

Network Bandwidth

POTS = 28.8 kbps

ISDN (2 x 64 kbps) = 128 kbps

T1 = 1.5 Mbps

Compression Required

Bits to be passed / Bandwidth

VGA / T1 = $200 \text{ Mbps} / 1.5 \text{ Mbps} = 133$

PictureTel / ISDN = $18.4 \text{ Mbps} / 128 \text{ kbps} = 143$

Creative / POTS = $1.5 \text{ Mbps} / 28.8 \text{ kbps} = 53$

Figure 27. Compression Calculations

The most definitive literature found on the quality of LBRV was an article reporting testing by the British Columbia Telephone Company. Their results used a rating scale from 1 to 5. In results compiled for a 1990 article, they found that pulse coded modulation at 64 kbps received a score of 4.3. They found that: "LBRV implementations at 8 kbps can achieve scores on the order of 3.7. Given a reasonable cost incentive, the vast majority of users will find state of the art 8 kbps LBRV technology acceptable" (Bindley, 1990, p. 953).

In a more recent article, Wylie overviewed the standards for voice and compression, including ITU G.711 and G.722. The author reviewed the data requirements of CD quality audio and voice as well as the available compression ratios. The author stated that current audio systems exhibit a 4:1 compression ratio and indicated that emerging audio compression techniques at a 12:1 ratio can deliver CD quality audio (1.411 M bps) over a single ISDN line (Wylie, 1995). More importantly, Wylie observed: ". . . the art of compressing the data stream into narrower and narrower digital pipes will continue" (Wylie, 1995, p. 10).

Based on these findings and the relative magnitudes of the raw data streams (video = 200 M bps, audio = 1.4 M bps), the researcher concluded that the video quality was a far greater issue question than the audio problem.

Regarding picture quality, Contin and Battista tested two different compression algorithms, MPEG and H.261. They found no appreciable difference in quality. The authors also noted that at low bit rates, improvements within the frame were more important than movement reproduction. The tests were conducted subjectively using twenty-four subjects (Contin & Battista, 1994).

In terms of compression techniques, Lodge's 1992 article is widely quoted. The author cited the fact that the first digital transmission of a picture occurred in 1922 between London and Halifax, Nova Scotia. The author went on to list some of the factors involved in the compression of video signals, and described the DCT compression technique in depth.

The author, head of the Standards and Technology Commission in the United Kingdom, also addressed the topic of testing low bit rate television. The author made the important observation that not all frames are equally critical. For example, the author cited frame research that indicated that sports sequences and pop video sequences have frames of differing priority. At this time, there is no compression technique available to adapt to this unequal frame criticality. All the current techniques treat the frames equally.

In 1992, Yates and Ivy, 1992, described a pyramidal video compression technique that allows a moving image to be gracefully degraded with reductions in bandwidth. The goal of the effort was a VLSI implementation of the coder and decoder that can run on a single chip. The algorithm sends only changed data between frames. Only moved portions of the frame are transmitted, and the amount of information is dependent upon the amount of motion between the frames. That is, the algorithm detects motion and takes it into account in the algorithm.

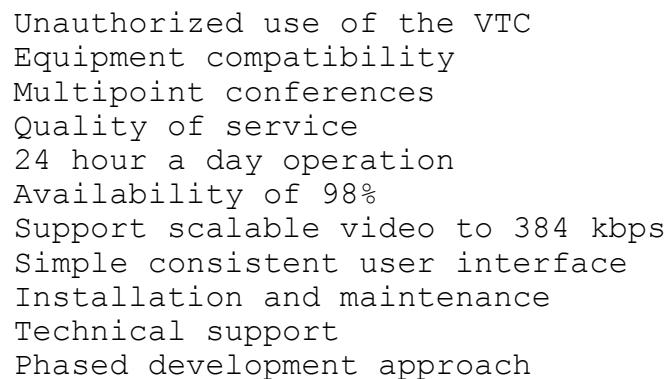
Other chip efforts have been reported to accomplish compression algorithms and techniques. Ang, Ruetz, and Auld, 1991, reported that a firm in Irvine California had a real-time chip capable of 500:1 compression. The authors stated that: "Video data, even after compression at ratios at 100:1, can be decompressed with close to analog videotape quality" (Ang, Ruetz, & Auld, 1991, p. 16).

The Ang et al. article has a good presentation of compression techniques, particularly the Digital Cosine Transform. Compression is an important area, however, because as pointed out by Ang: ". . . a color image with resolution of 1000 by 1000 pixels at 24 bits each will occupy 3 Mbytes (24 Mbits) of storage in an uncompressed form" (Ang, Ruetz, & Auld, 1991, p. 16). The authors stated that lossless compression techniques exist that can reduce data by 3:1, however, these techniques are not usable in certain video applications such as medical X-rays.

In addition to discussing chip development, Ang et al. gave a good description of the three color systems currently in use: R - G - B in the computer industry; Y - U - V in the Television industry; and C - M - Y - K in the printing industry. (Legend: R - red; B - blue; G - green; Y luminance, brightness; U, V color differences of Y - R and Y - B; C - cyan; M - magenta; Y - yellow; K - black).

Goto, Ando, Inoue, Yamahina, Yamada, and Enomoto, 1991, reported on a NEC effort to develop a super speed video chip. The chip utilizes Ultra Large Scale Integrated technology. AT&T and Cyrix are also developing chips for video.

A number of articles were reviewed on the subject of network architecture for VTC. These include: Akinpelu, Deacon, and Shieh, 1988; Mooney, Newport, and Schroeder, 1994; DeVille and King, 1994; Chadderdon and Schroeder, 1994; Brundage, 1994; and Fitzpatrick and Hargaden, 1994. While the articles were not found to be directly applicable to this paper, a number of peripheral considerations were identified. They are summarized in Figure 28.



- Unauthorized use of the VTC
- Equipment compatibility
- Multipoint conferences
- Quality of service
- 24 hour a day operation
- Availability of 98%
- Support scalable video to 384 kbps
- Simple consistent user interface
- Installation and maintenance
- Technical support
- Phased development approach

Figure 28. Miscellaneous VTC Considerations

The test results on video quality reported by Beck et al. were subjective. Schaphorst and Bodson dealt with the objective testing of video equipment. In their 1991 work, they attempted to correlate an objective quality measurement standard for compressed video against a subjective standard. The work focused on measuring the motion distortion between frames. The authors used three overall measures: temporal frequency response; scene cut response; and transmitted frame rate.

Schaphorst and Bodson highlighted the fact that no objective measurement techniques exist for motion video: ". . . no standards have been established to measure the ability of a TV system to reproduce motion" (Schaphorst & Bodson, 1991, p. 1771). This issue is important, because the ITU video standards do not specify: (i) the strategy to be employed by the encoder; (ii) which blocks will be transmitted; (iii) what type of code; and (iv) the coding precision. These techniques are being considered by ITU to measure the quality of still video. Additionally, the authors highlighted an underlying difficulty in the testing--the test image.

The subject of video testing was addressed in a series of articles from the Department of Commerce including: Voran, 1991, and Quincy, 1990 and 1991. These articles commented on the difficulty in arriving at an objective standard that correlates with subjective human results.

Quincy's 1991 work showed that techniques based on Laplacian and Sobel gradient operators increase monotonically with the transmission rate. The measures have been proposed to ITU for adoption as a standard test technique. It is clear from reviewing the articles that the objective testing of video quality is an area that will support additional research.

In summary, it was found that systems exist that can produce a recognizable image from as little as 400 bits of information. The variable is the quality required for the application. Regarding the quality, it was found that video quality is subjective and that efforts to make it objective have not been successful. CCIR Rec. 500 is a standard for subjectively evaluating picture quality (Anon, 1990).

An important consideration in the design of the network for distance education is the asymmetric use of the network bandwidth. The asymmetric use means that the bandwidth does not have to be shared equally between two end points on the net. As an example, the network bandwidth could be prioritized to favor high quality, full motion video for the teacher and low motion (portrait) video of the student.

A very important point for distance education video was made relative to allocation of the bandwidth. Both Contin and Battista (1994), and Beck et al. (1994), found that improvements within the frame were more important than the number of frames. In the system proposed, student movement has been traded for bandwidth allocated to the teacher.

In general, it was found that video quality will improve as more bandwidth is added or as compression techniques improve. Fractal and wavelet compression ratios of 2,000:1 are being projected, and some authors use the figure of 10,000:1 (Thom, 1994). At 10,000:1 rates, a high quality 640 x 480 pixel frame with 24 color bits/pixel can be transmitted at a full motion 30 frame rate per second rate over 28.8 kbps lines.

These compression ratios take up to 10 seconds of processing power on current 486DX66 MHz systems. However, as the processing power of the PC continues to improve, or as special purpose video processors emerge, these times are expected to decrease to levels required to support higher quality video.

Video Servers

For a distance education system, multiple student sites must be connected to a single teacher site. The devices necessary to connect multiple video sites to the network are known as video servers or multipoint controllers. The video server is a crucial element in the design of a distance education system.

This section includes information on the following areas: video server vendors; design approaches; and important features. The results of the video server product survey are included later in the report.

Figure 29 is a list of video server suppliers identified from the literature and from exhibits at technical conferences. The literature sources were: Natarajan, 1995; Bulkeley, 1995; and Starkey, 1995.

The video server market is marked by reselling. Major vendors offer products manufactured by another company, and some vendors recommend products offered by others. This environment is believed to be due to the lack of a dominant supplier, uncertainty on the potential size of the market, and the lack of a patent position by any of the suppliers.



AT&T
C-Phone
ConferTech
Hewlett-Packard
IBM
Microsoft
MultiLink
PictureTel
Quadraplex
Silicon Graphics
Starlight
Teleos
VideoServer

Figure 29. Video Server Suppliers Identified

For example, PictureTel video servers are built to specifications and can be supplied by anyone capable of meeting the requirements. The original PictureTel server was designed by Harris Corporation who sold the rights to PictureTel. Future PictureTel video servers ("Montage") will be supplied by VideoServer and possibly others (Semanite, Personal Communication, October 10, 1995).

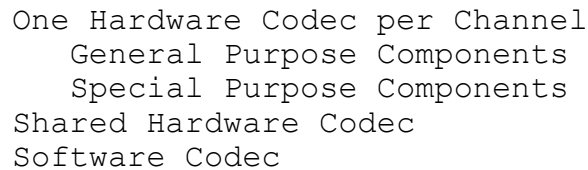
Creative Laboratories--a POTS VTC supplier--has decided to rely on AT&T instead of providing its own video server (Crilley, Personal Communication, September 29, 1995). Meanwhile, AT&T is in the process of manufacturing a video server, but is procuring VideoServer systems in the interim.

Video servers have demanding technical requirements. These include processing and timing constraints: “. . . the exacting nature of the requirements is compounded by the isochronous nature of the video output--the fact that real-time video must be delivered in a constant data rate” (Natarajan, 1995, p. 66).

A basic understanding of the technical constraints can be obtained through a simplified example. Visualize a network with sixteen incoming video lines. Assume the incoming video lines are coded and compressed. Further assume that we wish to build a composite frame showing all the inputs.

To build the composite frame, the video server has to decode the sixteen inputs, make the composite frame, recode the composite frame, and transmit it to all sixteen sites. This must be accomplished within the specified frame rate.

In studying video servers, four distinct design approaches to this problem were found. These approaches are summarized in Figure 30.



One Hardware Codec per Channel
 General Purpose Components
 Special Purpose Components
 Shared Hardware Codec
 Software Codec

Figure 30. Design Approaches in Video Servers

The first approach, a single general purpose codec per channel is reflected in systems such as the Creative Laboratories, Intel ProShare, and other point to point systems. Each system comes with a video board that contains a codec fabricated from general purpose processor chips. In the example with sixteen inputs, one codec would be used to decode each input, and the video server would have a total of sixteen codecs.

The second approach simply replaces the general purpose codec with a special purpose codec. AT&T Microelectronics is pursuing this approach with their AVP III chip previously described (Ahimovic, 1995).

Cryix, a major chip supplier, has also announced plans to offer a video chip that will eliminate the need for audio and video boards. The chip is the 5GX86 and is expected to be available early next year (Davey, 1995).

Ahimovic, 1995, claimed very attractive cost performance characteristics for the special purpose processor approach. According to Ahimovic, one AVP III processor at a cost of \$78 will have the equivalent processing power of twelve Pentiums operating at 100 MHz and costing over \$4,000 each. If these cost and performance estimates materialize, all video servers could converge to the special purpose processor approach.

The third approach is to time-share the codecs. Under this approach, each input receives a pro-rated fraction of the codecs' time. The advantage of this approach is cost, and the obvious disadvantage is performance. For a sixteen user system with only one codec, each input would receive only one-sixteenth of the codec's processing power. This approach is being pursued by the C-Phone company (Flohr, 1995).

The fourth approach is to use a software codec. Proponents of this approach argue that the continuing increase in processing power will generate sufficient excess processing power to perform the codec function without the need for dedicated hardware. Green presented results that show ". . . our software codec, running on a tuned Pentium running Windows 3.1 has been able to sustain 14 frames per second over POTS . . ." (Green, 1995, p. 604).

Rubery supports the software codec approach. The author finds that they are the cheapest solution and downloadable (Rubery, 1995). Wilson presents results using the InVision conferencing package running on a Pentium 90 with the National Semiconductor software based codec. The author claims the CPU load varied from 10%-15% (Wilson, 1995).

Wilson notes that the current family of processors have the power to support real-time compression for two way video at a cost below hardware based systems (Wilson, 1995).

The use of a software codec has been adopted for the system proposed here. The solution includes a polling feature with half-duplex transmissions to ensure quality equivalent to a single point to point VTC.

The codec design approach has an impact on the user interface. As an example, consider the PictureTel Model 8816 video server. The system supports multipoint conferences but only displays one participating location at a time. The reason for this is that the system can not process the multiple inputs at the frame rate used by PictureTel. By displaying only one input at a time, the processing requirements (and thus cost) for the video server can be limited. The system selects the active input and needs only one codec for that specific input.

PictureTel is introducing a new product line named "Montage" designed to display four sites simultaneously. The Montage system will directly accept up to 48 direct inputs and up to 2000 cascaded conference end points. The system will display four sites simultaneously (Semanite, Personal Communication, October 10, 1995).

Vendors refer to the ability to display all inputs simultaneously as "continuous presence". Products containing the "continuous presence" feature are just being released and have been demonstrated at the technical conferences. The systems in use today display one site selected from operator selectable options. The available options include: display one site (broadcast), browse (chair controlled); display all sites cyclically, and display the active speaker's site.

The importance of the "continuous presence" feature for distance education is highlighted by VideoServer. In a marketing brochure, they quote Don Peters, the Planning Engineer for the Washington Higher Education Telecommunications System. According to Mr. Peters: "Continuous presence will add a whole new dimension to our distance learning application Now the instructor will be able to see the entire class, including all the remote classrooms simultaneously" (Anon, 1995d, p. 3).

Video servers are expensive to procure and maintain. Accordingly, it is believed that the communications carriers will be a significant force in the video server market. These vendors can share the equipment and costs among their network users, much as audio conferencing equipment is shared today.

Networks For Distance Education

In surveying the existing distance education projects, networks were found that ranged from the postal service of the University of South Africa to the intercontinental satellite network of Saskatchewan. The most technically capable networks for distance education are those based on fiber optic connections. Fiber optics offer the best network connections for distance education because of their capacity and response time. Eventually, fiber will usher in a new age of connectivity and interactive services (Anon, 1994b).

While fiber optics are being deployed throughout the long haul switching networks, the connections to the home are almost universally made using copper twisted pair wiring. This massive set of connections is referred to as "the Copper Loop".

The Copper Loop

"A few years after inventing the telephone, Alexander Graham Bell patented twisted pair wiring in 1881" (Waring, Wilson, & Hsing, 1992, p. 1743). The twisted pair wiring used in this network is called the Copper Loop. It has been improved and expanded since its invention in 1881. It is important here because the Copper Loop is used to connect the student to the telephone network.

Using the Copper Loop, either analog or digital signals can be sent to the telephone network. VTCs with POTS use analog modems to send the signal; VTCs using ISDN send a digital signal directly.

"For the US Public network, there are over 140 million subscriber access lines, representing an investment of over \$80 billion" (Waring et al., 1992, p. 1743). Knowledge on the composition of the US Copper Loop is limited to a dated study conducted in 1983. The study was conducted before the breakup of AT&T, and no similar study has been conducted since. The Bellcore report was published in 1987 (Bellcore, 1987).

The study is important because it addresses the line length and construction of the 140 million subscriber lines. For very long lines, a load coil is sometimes placed in the twisted pair subscriber link. This affects the performance of the line at frequencies above the voice band (3000 Hz). "To service rural customers, load coils are placed on long loops to add inductance to the pair which in turns flattens the voice channel response" (Waring et al., 1992, p. 1744).

Waring et al. found that "About 75% (100 million customers) of the loop plant is nonloaded" (Waring et al., 1992, p. 1745). This 75% number is important because it becomes a limit on the connectivity of any system based on high speed modems or digital adapters.

Seventy-five percent equates to one hundred million subscribers--a large market. To provide digital service to these customers, in particular video service, Bellcore developed digital techniques to improve the bandwidth into the home. Gomez et al. believed that the bandwidth necessary to send video to the home was possible: "Very Large Scale Integration (VLSI) based signal processing techniques seem to be able to boost the transmission capacity of the standard copper plant to 1.5 Mbps" (Gomez et al., 1992, p. 772). Hsing, Chen, and Bellisimo also used that figure (Hsing, Chen, & Bellisimo, 1993).

Waring et al. chronicles the developments toward the 1.5 Mbps Copper Loop figure. "The Digital Subscriber Line (DSL) was developed for ISDN Basic Rate Access and transmits 160 kbps over the non-loaded copper plant" (Waring et al., 1992, p. 1744). DSL, a digital as opposed to analog transmission technique, can be transmitted over a 18k foot twisted pair loop. Accordingly, it covers virtually all the nonloaded loop plant (Waring et al., 1992).

This finding on coverage is important, because it implies that any subscriber that can use a high speed analog modem can use ISDN. Based on this finding, the barriers to ISDN appear to be the willingness of the Regional Bell companies to install the switching equipment and the cost to the subscriber. Waring et al.'s information means that ISDN coverage is not a technical issue. Virtually all subscribers that can use a high speed V.34 modem can use ISDN. The limitations are their willingness to pay and service availability.

Subsequent to DSL, High Bit Rate DSL (HDSL) and Asymmetric DSL (ASDL) were developed. ASDL will support analog and ISDN usage over the same line into the home (voice and data). These techniques enable subscribers with the proper terminating equipment to achieve 1.5 Mbps over their existing copper phone lines. Service rates up to 10 Mbps are possible on 55% of the lines using these technologies (Waring et al., 1992).

Kyees, 1995, attributes the concept for ASDL to Joe Lechleider, a researcher at Bellcore. Kyees notes that "In less than three short years, the focus has progressed from work on ASDL with 1.5 Mbps payloads in 1993 to 6 Mbps payloads in 1994, and now 50 Mbps in 1995. The author notes that "if the proposed 50 Mbps ASDL systems prove practical and economical, the life of the embedded Copper Loop base could be extended even longer and allow capital investment in advanced transport to be spread out (Kyees, 1995)."

A minor drawback of the DSL technologies is that they require power. Accordingly, the POTS capability of the copper link will be maintained so the customer has telephone operation during power outages.

Analog Modems and ISDN Adapters

Researching the decreased modem performance during the Proof of Principle demonstration, the researcher discovered the "Spiraling Death" syndrome among high speed modems. This problem was reported by Navas, 1995.

The syndrome is a bug in the operating firmware of the modems. The modems check line quality periodically to determine the highest throughput that can be achieved. If the line quality drops during the connection, the modems step down to the lower frequency. A spiraling death modem continues to step lower regardless of whether it has already adjusted for the degraded condition. Accordingly, the modems degrade in speed until the connection is lost. This is the condition that occurred in the Kileen, Texas Proof of Principle demonstration. This problem has now generally been recognized and corrected by modem developers.

Modem developments have emerged rapidly. A review of the development of modems was performed by Read in 1994. He reviews the developments in terms of ITU standards (Read, 1994).

Read starts with the 1964 V.21 standard for transmission at 300 bps, and continues to 1994 with the V.Fast standard that supports 28.8 kbps. V.Fast is the standard that was used in the Proof of Principle Demonstrations.

V.Fast was a vendor by vendor interpretation of the V.34 standard that was about to be issued by ITU. The V.34 standard has subsequently been issued and is the current industry standard for 28.8 kbps.

Read's article is important because the author calculates a maximum throughput for analog modems at 32 kbps. Using Shannon's noisy coding Theorem, the author states that a typical POTS line with a bandwidth of 3200 Hz (300 - 3500 Hz) will be bounded at 10 bps or 32,000 bps. (The author assumes a typical signal to noise ratio of 30 dB.)

The V.34 modems were tested by Hall in late 1994, and also by Fowler in the same year. Hall's tests were interesting because they were conducted in accordance with the Telecommunications Industry Association's Standards for modem environments. Those tests lay out the type and percentages of connections to be used to simulate the local loop.

Hall found that the four top modems delivered at least 19.2 kbps over all test cases. These cases represent 78.33% of the Copper Loop, corresponding to the percentage of non-loaded Copper Loop lines.

The Motorola V.34 modem delivered no less than 26.4 kbps. Additionally, with compression, these modems achieved up to 113.8 kbps. The author concludes "Unless you have unusual local telephone lines, a limited PC or a truly poor connection, you can expect to get 24 kbps fairly regularly. On relatively poor lines, you can expect to get 19.2 kbps. At worst, you'll only get about 14.4 kbps" (Hall, 1994, p. 64).

On a first hand basis, the US Robotics Courier V.34 modem has been installed at the researcher's installation. Connections of 20 kbps and more are common over lines where 14.4 kbps was difficult to achieve. Fowler tested the US Robotics modem and achieved results similar to Hall's.

Angus, 1994 has similar results for the V.Fast modems, and the author also addresses compression. Using compression at 4 to 1, a modem could theoretically pass data at four times the advertised rate. However, not all data is compressible. Fowler's results address this and the author shows the degree of compression achieved for various types of files. The author shows a 28.8 kbps modem achieving 80 kbps on a dBase file and 30.9 kbps on a previously compressed "zip" file. For multimedia, 28.8 kbps must be used for the throughput calculations since the video and audio are compressed for transmission.

Read states that a significant number of lines in Europe have more than the 3500 Hz bandwidth found in the United States. Accordingly these lines could support higher rates. This is supported by a 1992 Motorola study that logged 400 test calls throughout Europe. The authors found that error free connections were established for most connections at 21.6 kbps or 24 kbps (Brown, 1992). They also found that transatlantic connections were limited to 14.4 kbps or 16.8 kbps.

In a related vein, Cooper measured the performance of cellular networks in 1992. The author found that these networks would only support 1200 bps.

The V.34 modems can be used with the existing network with no changes or additional charges. A V.34 connection is treated and billed as a telephone call. The telephone company does not need any special equipment, and the V.34 can be used almost anywhere there is a telephone connection.

ISDN is more complicated. The user requires ISDN equipment and so does the telephone company. It needs an ISDN switch. The need for the telephone companies to invest this switching has limited its availability, and ISDN only has about 60% US availability. Some Regional Bell Operating Companies such as Southwestern Bell are not interested in it at all because of lack of demand (Derfler, 1994).

Difficulty in obtaining ISDN from Southwestern Bell has lead Texas to begin building its own ISDN network (Messmer, 1994). "There is not only a problem in getting ISDN Basic Rate Interface service in Texas, but also in obtaining simple digital private lines in general" (Messmer, 1994).

The digital capability universally available from all United States telephone companies is "Switched 56 kbps". Those areas of the country that do not have ISDN use two switched 56 kbps channels for VTC.

ISDN gives a speed advantage of four or five to one over V.34, but at a higher cost. V.34 modems are available for under \$200; ISDN line adapters are now as low as \$400. The ISDN equipment cost does not include operating fees. "Users can expect to pay about \$150 for the (ISDN) installation fee, plus \$40 per month for leasing ISDN. . . . a one hour point to point call will cost about \$20" (Bort, 1994, p. 68).

The cost of ISDN can be expected to decrease. An Ad Hoc Coalition on Low Cost ISDN has been formed to lobby for low cost telephone rates. They have established an Internet list to discuss the proposed amendments to HR 1555, the Communications Act of 1995. The site is listed in Appendix A under ISDN Rates.

In the home, the user would see little apparent physical difference between an analog V.34 "modem" and an ISDN "line adapter". The differences lie in performance, cost, and availability.

POTS and ISDN

Read reported that the analog modem has reached its limit. This is echoed by Frankel, 1995. In a comprehensive article, Frankel explains the relationship of analog modems and ISDN:

While modem technology converts digital signals into an analog format compatible with traditional telephone service, ISDN instead gives end users direct access to the 64 kbps channels used in the digital telephone network. And, unlike direct digital access, ISDN is switched, allowing connections to be made to any other node on the network for only as long as required by the application. (p. 20)

Frankel sees ISDN at the beginning of its life cycle. "It offers the best, or only, solution to a number of today's communications challenges, and is unlikely to be displaced by emerging technologies until they are equally ubiquitous, perhaps a decade from now" (Frankel, 1995, p. 25).

In a balanced presentation, however, the author points out the problems with ISDN. The author includes regional coverage, cost of the equipment, connect and line charges, and setup problems. "Setting up ISDN equipment can be a daunting task, with the user expected to set up numerous cryptic parameters" (Frankel, 1995, p.24).

Frankel points out that ISDN users beyond 5.5 km from a digital switch will require additional equipment. The author notes that the overall cost trend is clearly down, despite recent adverse FCC rulings. Overall, the author clearly believes ISDN is a major technology for those requiring higher bandwidth than analog modems can provide.

Pettersson, writing in the same journal agrees with Frankel's projections on ISDN. "With a toehold in specialized applications, ISDN is poised for takeoff as the all digital telephony service affordable by everyone" (Pettersson, 1995, p.26).

To determine current industry thinking on ISDN, the researcher attended the August 22, 1995 DeskTop Video Teleconference in Secaucus, New Jersey. This conference included the major suppliers in the industry and featured a keynote VTC by Dr. Richard Baker, the Chief Scientist at PictureTel.

Speaking from Boston, Dr. Baker indicated that the industry is currently being driven by three factors: standards, networks, and applications. The major standards were H.320, H.323, and H.324. These represent the ISDN, LAN, and POTS network standard stacks respectively. The applications are showing the merging of real-time information, stored information, and information sharing.

Regarding recent developments, the author opted that Mbone, the technique for broadcast over the Internet was not ready yet. He added that Windows 95 "Plug and Play" for multimedia was also not ready.

Baker noted that the drivers for the multimedia hardware were not yet installed in Windows 95, a fact also noted by the Intel representative, George Heider, and Neil Starkey of DataBeam. DataBeam has been working closely with Microsoft, and stated that Microsoft wants a user interface that includes a "one button connect" and seamless integration with network services. Starkey claimed that Microsoft will build their solution using DataBeam's T.120 products.

Dr. Baker noted that 70% of all PictureTel applications use ISDN, and that the ISDN call from Boston to New Jersey cost \$30.00 an hour. The author did indicate, however, that ISDN costs approximately \$200 to \$300 an hour in Europe, and applications in Europe wanted a 64 kbps solution as opposed to the 128 kbps ISDN solution to lower line costs.

Baker projected a rapid growth in POTS based systems as prices decline and H.324 is adopted. At the other end of the bandwidth question, the author indicated that quality conscious users are turning to 384 kbps channels (ISDN-PRI).

Computer Shopper discussed POTS versus ISDN for their readers. In a review of PC based video system they noted that: "POTS systems are especially attractive because there are no additional monthly charges and you don't have to make any special arrangements with the phone company. . . . it's no surprise that the majority of video conferencing newcomers are POTS based systems (Quain, 1995). Quain also noted the continued unavailability of multi-point solutions.

George Khater from PictureTel compared the POTS versus ISDN approaches. In a balanced presentation, the author found that POTS systems had acceptable latency but low quality video. The systems have high network availability. Conversely, the author found that ISDN had video quality and low but growing domestic network availability (Khater, 1995).

The researcher believes the issue of POTS versus ISDN is irrelevant so long as the student--and not NSU--pays the bill. The decision should be left to the student based upon the cost and the students personal judgment of video performance versus cost. The system that has been proposed will support either network approach.

The Internet

One network that has to be considered for distance education is the Internet. DOD started the Internet in the early 1970's during the Cold War between the United States and Russia. It was designed for the reliable transmission of text information (Krol, 1993). Since its initiation, it has grown into a world wide network of computers.

The Internet uses Transmission Control Protocol (TCP) and Internet Protocol for packet transmission. The Internet Protocol (IP) controls the transmission of the message.

IP does not guarantee speed of service, a key requirement for video and voice. The Internet has been used in these applications, and the reported results have not been totally satisfactory. Since the Internet would be ideal for distance education the performance issue was addressed in depth.

On May 24, 1993, the Internet was used for the first time to transmit a full length movie. As reported in the NY Times by Markoff, the reduced frame rate of two frames a second vice twenty four ". . . gave it a surreal quality. . ." and, "The soundtrack came through haltingly, frequently broken up by what engineers called 'packet drop out' when the Internet became too congested with other data traffic." But, "Come back in six months, and all this stuff will be working flawlessly" (Markoff, 1993, p. D8).

An enhancement to the protocol called "MBone" is being pursued to improve the real-time performance of the Internet. MBone stands for the Multicast Backbone over the Internet. It is a feature that provides one to many addressing. That is, a sender can broadcast a message once to multiple subscribers. In a review of MBone, researchers found that the routing protocols for MBone are still immature. Further, they found that the use of the Internet Protocol for MBone ". . . can have a major impact on network performance. . . . We have found that bandwidth capacities of lower than T1 will result in network crashes and thus appear unsuitable for MBone (Brutzman, 1995)."

MBone was used for a major Internet demonstration in distance education at North Carolina State University. Although the researchers were pleased with the results, speech delays of up to 5 seconds were reported with T1 lines in use (Rettinger, 1995). This demonstration is addressed in more details below under "Recent Dissertations and Research".

The reason for the Internet's poor real-time characteristics are attributed by Zhang to a ". . . combination of bandwidth shortage and inadequate traffic control (Adam, 1995)." Zhang is a member of the Internet Architecture board.

Stephen Deering, the lead designer of the latest Internet Protocol, IP Version 6, is more optimistic on the use of MBone for video. The author states that the new Internet protocol will meet the requirements add additional addressing capability (Adam, 1995). Huitema, the former chairman of the Internet Application Board added that:

IPv6 is more friendly for multimedia transmission. For instance, it prioritizes bits, which enables time sensitive data to find a path through the network even though areas may be congested. A video stream is broken up into a narrow channel for low-definition video and supplemental wider channels for higher definition. . . . If congestion occurs, then channels are dropped graceful, so the video, even though it may be of poorer resolution, still gets through. (p. 28)

Deering projects that IP Version 6 will be available within three years. "A number of workstation companies--Sun, Digital, HP--and router vendors are working on it. Some beta releases are expected by the end of the year (Adam, 1995)."

Despite Deering's optimism about MBone and IP Version 6, Brutzman's data indicates that the protocol should be extensively tested before adoption. More significantly, the results from North Carolina State indicate that "tuned" T1 links using the Internet and MBone will not provide satisfactory results. The availability of T1 links to the students is not deemed feasible in the foreseeable future.

Local Area Networks

Turning to the Local Area Network (LAN), connections within the University need to be addressed. Considering the current industry offerings, the LAN options are 10 Base-T, 100 Base-T, or fiber.

The 10 Base-T and 100 Base-T operate over twisted pair wiring. The 10 Base-T network provides speeds of 10 Mbps, and the 100 Base-T yields speeds to 100 Mbps (Lowe, 1995).

The results on using the Ethernet for video are mixed. Nichols, 1992, found that a moderately loaded 10 Mbps Ethernet can handle video. Wortendyke and Butler, 1991, also found that Ethernets could handle video depending on the motion characteristics, voice latency, and voice jitter that were acceptable.

Worsley did not agree. The author found that existing Ethernet 802.3 based LANS do not meet the speed of service requirements necessary to provide synchronized voice and data (Worsley, 1995).

The issue appears to be acceptable performance, and IEEE 802.9a "Isochronous Ethernet" or "IsoEthernet" was proposed by National Semiconductor, IBM, and Apple in 1992 to improve LAN performance. It is an extension to IEEE 802.3 that enables multimedia to be added to existing LANs without replacing existing equipment or wiring.

Isochronous Ethernet uses existing twisted pair wiring to carry two independent networks. The equipment that is added to the LAN controls the network timing and adds 6.144 Mbps (96 x 64 kbps channels) to the net while preserving its basic 10 Mbps capability (Worsley, 1995).

"Currently, ISO-Ethernet is the only completely standardized LAN capable of providing the quality of service real-time video conferencing. Unfortunately, it is not available from any of the dominant LAN vendors (Weissberger, 1995)."

ITU efforts are underway to produce a standard for LAN based video (H.323), however, efforts are just beginning. "H.323 is still in its early stages (Khater, 1995)."

The issue on LAN connections is simply cost. If the funding is available, the University should adopt 100 Base-T or fiber as soon as possible. Although it is expensive because of the interface cards into the PCs, the use of fiber for the LAN will support the eventual transition to ATM.

Depending upon the quality desired, 10 Base-T and 100 Base-T can handle the current requirements for video. As imaging requirements emerge, however, the fiber optic LAN will become more commonplace. The reason for this is that video can be heavily compressed. Imaging information can not.

Shimizu and Maesako, 1988, described a fiber link for video between two university campuses in Japan. The system was found to be entirely satisfactory as a lecture system.

Other Networks

Cable TV is an interesting network alternative. According to Riccomi, 1994, Zenith, DEC, and Intel provide VTC systems that connect to cable TV outlets. The systems provide a 19.2 kbps downlink and a 10 Mbps uplink to the subscriber. Using the cable link, subscribers such as libraries and schools can route information and data over the links. "According to industry sources between 5 - 6 million subscribers are connected to such two-way cable plants today" (Riccomi, 1994, p. 161).

The reason behind this large base is TeleCommunting. "The introduction of two way video-teleconferencing over cable TV plants could quickly lead to many businesses becoming cable TV subscribers. They may do it for no other reason than to provide collaborative computing and Video TeleConferencing between their central offices, their executives' homes, and the TeleCommunters that work from their home offices" (Riccomi, 1994, p. 162).

The cable used for Cable TV will give 10 Mbps service or higher, depending on distance. This media may have merit in metropolitan areas, however, for a nationwide system, the Copper Loop is the most widely available network, and it is capable of handling the rates necessary for distance education. Further, as the projections of 1.5 Mbps on the Copper Loop materialize, the performance of the network will improve.

A very important emerging network possibility is Very Small Aperture Satellite (VSAT). Rash, 1988, described the use of VSAT for distance education. This broadcast network is dedicated to math, science, and language education. The system is a two channel system with the satellite used for TV broadcast, and telephone used as the secondary channel for real-time interaction.

These satellite systems have recently been introduced for commercial TV distribution and are selling rapidly to home users. Additionally, the Hughes Corporation has announced an Internet gateway using the technology (DirecPC). The system uses the satellite as a high speed downlink and a terrestrial link for the interface to the Internet.

In operation, the user can request a large file over the terrestrial link, and have it sent at high speed through the satellite link. The system costs about \$30 per month, and the satellite dish is under \$1,000. Unfortunately, the satellite dish can not be used for both the Internet system and commercial TV. However, at \$30 per month, it is cheaper than ISDN.

Another network alternative is Switched Megabit Data Service (SMDS). This is a Bellcore network that is separate from the existing long haul Bell communications network (Stallings & Van Slyke, 1994). However, SMDS has less coverage than ISDN, eliminating it from consideration.

ATM is the direction of the future. It couples the speed of its fiber optic media, with a protocol that guarantees speed of service. The fiber media will offer seamless transmission capabilities in the Gbps range (Davidson & Muller, 1992). Sprint offers ATM across the United States, and AT&T offers it in Southern California (Cochran, 1995).

North Carolina announced a "North Carolina Information Highway" based on ATM. The plan was announced in 1993 as a consortium project with BellSouth, Carolina Telephone, and GTE.

The system is currently operational, and has forty-two sites operating, mostly at educational facilities. The system was launched by the state to develop education and business opportunities. Industry is using the system for distance education (Rockwell, 1995).

Stallings and Van Slyke, 1994, gave a comprehensive treatment of the current and emerging network capabilities. Their projections for the various networks are shown in Figure 31. The Figure includes the throughput of the various network services as well as the percentage of the market that the network is expected to capture by year. Note the capacities projected for ATM and B-ISDN using fiber optic media.

Service	Throughput	1993	1998	2003
Frame Relay	20 Mbps	94%	38%	1%
SMDS	150 Mbps	5%	37%	4%
ATM	600 Mbps	1%	4%	60%
B-ISDN	600 Mbps	-	1%	35%

Figure 31. Current and Projected Network Capabilities

Bellcore supports ATM as the direction of the future. The organization projects the use of the existing twisted pair connections directly from the home to the local network containing fiber networks. At the network switch, they see ATM switches (Hsing, Chen, & Bellisimo, 1993).

The latest January, 1995 IEEE projections on networks endorse ATM. They come from IEEE's annual Technology Forecast. In the section on Data Communications, Sue Lowe stated: ". . . for broadband services . . . Some industry analysts predict an industry shakeout, on the assumption that there will be a seamless ATM network linking local to wide area networks" (Lowe, 1995, p. 28).

Lowe went on to forecast: "In 1994, . . . the widespread deployment of frame relay based service was a precursor to a general shift away from private networks toward commercial nets supplied by carriers. When ATM supplants frame relay--connecting the subscriber directly to the service--we'll see a network management metamorphosis" (Lowe, 1995, p. 29).

The deployment of ATM is a difficult undertaking, however, requiring large investment and construction activities. ATM requires fiber optic cable to be deployed in addition the installation of ATM switches. "For all the sweat and effort, a good crew can lay just 500 feet of (fiber optic) cable a day. . . . It's labor intensive, but there is no other way to do it (Cauley, p. 1, 1995)."

In a featured front page article, the Cauley finds that the Bells have vastly underestimated the difficulty of bringing in the new technology necessary to support network upgrades. Writing in the Wall Street Journal, Cauley observes that the "Phone Giants Discover the Interactive Path Is full of Obstacles" (Cauley, 1995, p. 1).

The article quotes Bell representatives as stating: "None of us realized the complexity of building interactive networks . . . We all wish it was easier to do, but it is rocket science at this point" (Cauley, 1995, p. 1). Cauley notes that the sweeping deregulation of telecommunications is surprisingly changing Bell plans: "Sweeping deregulation . . . may further detour the much hyped highway. The Bells would have to focus on defending their hold on local phone service, which still provides 90% of their profits."

Bill Gates of Microsoft indicated that communications is now the barrier in information systems. Like Cauley, the industry leader does not see ATM as emerging rapidly. Gates spoke at the 1995 COMDEX Trade show attended by over 250,000 attendees including the researcher. At that show, Gates and Lou Gershner of IBM presented their views of the industry future. Both recognized the importance of networking in the future of the industry (Manes, 1995).

The incentive for fiber networks is the distribution of video to the home. The RBOCs believe they have the technology to supplant cable TV in this high profit application. Cohen and Heyman, 1993a, reported on a Bellcore simulation of video traffic over ATM networks. Reibman and Berger, 1992, also studied the problem. Their efforts are directed at the best algorithm to handle video information and its impact on the ATM network.

The 1995 telecommunications reform bill will accelerate efforts by the RBOCs to achieve their 1.5 Mbps rate over the Copper Loop (Andrews, 1996). The deregulation in the bill allows the RBOCs to compete with the cable TV operators and distribute video using the Copper Loop. By providing a 1.5 Mbps capability to the home, the telephone companies can deliver VCR quality video using MPEG compression techniques. Conversely, the cable video plant can now be used to offer telephone service.

A network consideration for NSU is whether to use private or leased lines (Stallings & Van Slyke, 1994). NSU currently meets its nationwide connectivity requirements using AT&T. If the University decides to upgrade the speed of its leased lines, it has to ensure that the services provided are consistent with its overall architecture.

Another consideration is the use of a service such as Prodigy, American On-line, CompuServe, or the recent Windows 95 network. The services provide excellent, user-friendly interfaces and Internet browsers. It is projected that 12% of all US homes will have an on-line service, and 47% will have computers by December, 1995 (Boeck, 1995).

During this effort, Prodigy was used in the review of HTML documents and for document retrieval over the Internet. It offers an excellent browser and access up to 14.4 kbps. The more technically current Microsoft network offers 28.8 kbps, ISDN, and T1 service. The cost of Prodigy is \$8 per month for five hours of use. Other services offer unlimited Internet access for \$15 a month.

Network Summary

Reviewing the literature on the wide area networks for distance education, it is concluded that POTS is the closest to a "universally" available network. ISDN provides better video quality, but it is expensive and suffers availability problems.

Further, delays in installing ISDN have been lengthy (Bsales, 1995). This is a consideration for students who may attend the University for a single course or a short time.

The use a single type of network for distance education appears unnecessary. Some students will have access to ISDN and will be willing to pay the premium for that service. Accordingly, the University should plan for a heterogeneous solution and plan to upgrade as developments continue to emerge.

The designs in Chapter IV will accept POTS, ISDN, or switched 56 kbps inputs. The connection to the Internet should await the successful demonstration of the new Internet Protocol, Version 6.

For the LAN, the issue is cost. If the funding is available, a low impact upgrade to 100 MHz is recommended. This can be followed by the adoption of fiber at the earliest financial opportunity. Any new plant cabling should consider fiber lines in addition to the twisted pair.

ATM is the direction of the future, and it should be considered when it is available. Full availability of ATM will be paced by fiber optic cable deployment.

Recent developments in VSAT represent an exciting new network opportunity for NSU. The systems are too new to be included here, but the concepts demonstrated by the new Hughes Internet system should be closely watched in the future. Competition will surely emerge.

Recent Dissertations and Research

A search was conducted on recent dissertation efforts. The search was conducted at the abstract level using the March, 1995 Dissertation Abstracts of the United States. Eighty-nine abstracts were retrieved and eighteen were reviewed for applicability.

Most of the reported dissertation work is directed toward comparisons of traditional and distance education methods. Favored approaches include: the comparison of male versus female students in a distance education environment; comparisons of effectiveness for different courses; opinion surveys of students and faculty; and status reports of distance education in selected school districts.

In the comparisons, it was repeatedly found that distance education was as effective as traditional methods, even for non-technical subjects such as psychology (Burkman, 1994). No gender differences were reported, however, an interesting finding was a correlation between satisfaction with distance education and hours worked. Those working more than thirty hours a week were more satisfied with distance education than those who worked less (Price, 1993).

The attitude of educators was reported in a variety of dissertations. The findings reflected those reported at Purdue University and the University of Hawaii. Hamilton, 1994, found a significant difference in the opinions of administrators, deans, and faculty regarding budgeting for distance education and product marketability.

Tsai, 1994, completed work on distance education at NSU. The paper is titled "A Strategic Plan for NonTraditional, Off-Campus, Bachelor's Degree Completion Programs at the World College of Journalism and Communications". Tsai makes the following points: (i) the development of distance education programs requires strong institutional support; (ii) faculty resistance and reluctance should be considered in planning; and (iii) the key for restructuring is strategic planning. The effort investigated the use of distance education at the World College of Journalism and Communication in Taipei, Japan. The effort is organized around administrator and alumni surveys.

At the University of Phoenix, Goodwin reports that students perceive they have a comparable academic product to traditional products (Goodwin, 1994). However, she also reports the need for increased student support and salary problems due to the increased work-load with the system.

Few efforts at the hardware or design level were reported. Those reported utilized satellite or two channel systems to overcome the satellite time delay. No multimedia efforts were found.

Although no doctoral dissertations were found that were directly applicable to this effort, an important Master's Thesis was found at North Carolina State University (NCSU). The work, "DeskTop VideoConferencing: Technology and Use for Remote Seminar Delivery", reports on tests at the University utilizing MBone for video based distance education over the Internet (Rettinger, 1995).

As a part of the demonstrations, an audio experiment with a video broadcast was reported on the May 23, 1995, "Good Morning America". During the demonstration, three questions were successfully posed by the MBone audience (Rettinger, 1995).

The work at North Carolina is part of the "Southeastern University and College Coalition for Engineering Education (SUCCEED)" project. The project has established a home page that can be reached using the Internet address shown in Appendix A.

The North Carolina State University site is important for three reasons: (i) Rettinger's thesis results on the Internet video with MBone; (ii) the availability of open architecture audio and video Internet software tools that can be used for experimentation (See Figure 32); and (iii) Rettinger's supporting survey of Video TeleConferencing products at the site.

Rettinger's results are consistent with other reported results using the Internet. Rettinger reports that audio over the Internet was delayed by one to five seconds. She concludes: "Circuit switched channels such as ISDN offer dedicated bandwidth and predictable timing of data delivery but do not easily support multipoint communication which is required Packet switched channels, either a local or wide area, more easily support multipoint communications but do not provide predictable timing of data delivery" (Rettinger, 1995, Chpt. 5, para. 2).

Product	Name	Description
sd 1.14	Session Director	Main Tool
nv 3.3	Network Video	VTC Tool
vat 3.4	Video/Audio Tool	Audio Conferencing
wb 1.59	WhiteBoard	Shared Whiteboard
imm 3.3	Image Multicaster	Multicast Images
ivs 3.5	VTC System	VTC
ivsd 3.5	ivs Daemon	Answer Calls
vic 2.6	VTC	VTC

Figure 32. OSI Products for Solaris 2.3 at NCSU

A Text on TeleConferencing and Distance Learning

Until recently, the researcher was unable to locate any texts that deal directly with the subject matter of this dissertation. That limitation was overcome with the discovery of "TeleConferencing and Distance Learning" by Portway and Lane.

The sixteen chapter, 448 page work is a compendium of articles on various technical and educational aspects of the subject. A cursory review of its contents indicated that it is a worthwhile purchase for those in the field. An index is not provided.

The Glossary is extensive, and the book appears suitable for course readings on the subject. Ordering details are included in the citation (Portway & Lane, 1994).

Summary

The literature review has resulted in the identification of over 190 references. Reflecting the nature of the effort as a study of emerging technology, approximately one-hundred of these references have been published in the last three years.

Detailed results and recommendations based on the literature review will be presented later in the paper, however, certain major findings in each of the study elements are apparent.

First, in the area of management, the literature review supports the establishment of a separate entity, or department within NSU for distance education. The experiences at Purdue and Hawaii support that conclusion.

Second, in the area of courseware, it is reported that the development of multimedia courseware requires special skills and is time consuming. Developing the courseware in the proposed separate department appears warranted. Further, an independent, specially selected, and specially compensated staff should be considered.

Third, in the area of systems and networks, the VTC technology is moving very fast. There are currently two main problems: the availability of video servers and hubs; and the current Internet Protocol. The protocol cannot support the real-time requirements for an effective distance education system. It is believed that the hub problem has been overcome. The Internet problem must await improvements in the network.

The efforts at the University of Hawaii and North Carolina State University deserve emphasis. The Hawaii system uses a combination of satellite and ground networks, and is operating successfully. The ground links enable the University to meet the real-time audio requirements, a necessary element for successful video teleconferencing.

The SUCCEED project at NCSU utilizes the Internet and appears to have strong financial support. This effort is interesting for two reasons. First, the NCSU effort demonstrates the timing difficulties with Internet solutions. Second it offers OSI products that can be used for experimentation. These products can be used with the NSU Sun system with its Solaris operating system.

Chapter III Methodology

Introduction

A task methodology was used to complete this dissertation. Goals for the effort were identified and tasks were defined to meet the goals. The tasks were then executed to ensure attainment of the goals and the objective.

In this chapter, the goals, barriers, and tasks are described. The methodology used for each task is then given. This chapter deals primarily with the methodology; the results are given in Chapter IV.

The Goals, Barriers, and Tasks

Four specific goals were identified for this dissertation. Each goal was analyzed to determine what barriers had to be overcome to accomplish the goal. The goals and their barriers are summarized in Figure 33 and discussed below. The goals are in Roman numerals; the twelve barriers are in Arabic.

The first goal was to forecast distance education technology. The barriers to this goal involved understanding the related technology and how it was used in distance education. Understanding three technology areas was necessary to design the system.

The first technology area was video equipment and associated software. Available video equipment varies greatly in price and capability. These ranges, associated capabilities, and trends had to be understood to make product recommendations.

The second technology area was networks. Researchers projected that every home will be capable of communicating at 1.5 Mbps in the near future (Hsing, 1993). Understanding the current communications capability and trends was necessary to project the cost-effective use of video across the network.

Video compression was the third technology area. Understanding compression and processing requirements was crucial to understanding the system tradeoffs.

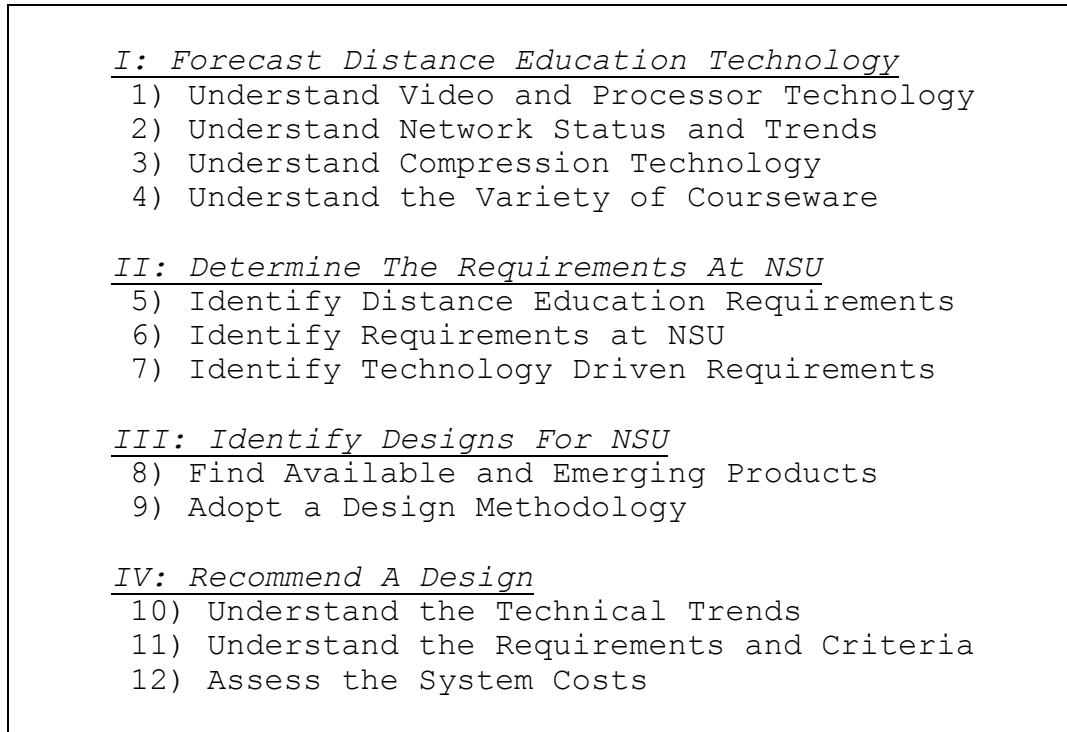


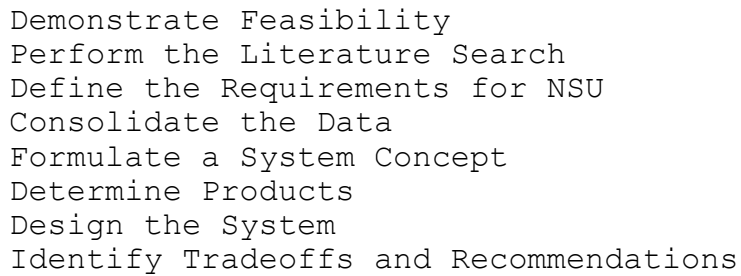
Figure 33. Dissertation Goals and Barriers

The second goal was to determine the requirements for Nova Southeastern University. The requirements came from three sources: the literature search, Nova Southeastern University, and the technology. The requirements were augmented using the NSU faculty and the MMECR group.

The third goal was to identify design alternatives. This required an understanding of the available products and design tradeoffs. From the beginning of the effort in January 1995, information was gathered on available and projected products. Additionally, multiple conferences were attended to complete this task.

The fourth goal was to recommend a design. Success in achieving this goal required an understanding of the technology and the requirements. Once the potential products, availability, and costs were known, it was possible to arrive at a recommended design.

To overcome the barriers, the tasks listed in Figure 34 were identified. These tasks have been successfully accomplished, and the goals have been achieved.



- Demonstrate Feasibility
- Perform the Literature Search
- Define the Requirements for NSU
- Consolidate the Data
- Formulate a System Concept
- Determine Products
- Design the System
- Identify Tradeoffs and Recommendations

Figure 34. The Dissertation Tasks

Task 1: Demonstrate Feasibility

The first major task was to demonstrate the feasibility of the effort. The researcher believed that VTC over POTS was possible based on the review of the literature and the calculations on the amount of data that had to be transmitted. Nevertheless, serious questions remained regarding the quality of a system that operated at 9.6 kbps.

The skepticism on quality was based on the amount of data represented in a broadcast of digital video. It was reinforced by the fact that all VTC systems other than the Creative Laboratories system required 128 kbps service (ISDN).

To assess quality, direct experience with the system was deemed necessary. Accordingly, a Creative Laboratories PC 3000 was obtained and used to conduct Proof of Principle demonstrations.

The Creative Laboratories system cost approximately \$1200. It installs on a standard 486DX33 or better Intel machine. The system supports multiple pixel size images and varying modem rates, making it ideal for experimentation.

While the researcher used a Creative Laboratories PC 3000 in all demonstrations, Creative is not the only low cost system for video. Other vendors claim operation at 28.8 kbps, and the Creative Laboratories system reflects a technology that is just emerging (Wilson, 1994).

In an initial demonstration, the Creative system was used over standard telephone lines between Toms River and Fort Monmouth, New Jersey, a local call over an approximate distance of thirty miles. The Creative Laboratories settings for pixels, color, and frame rate are shown in Figure 27 for the Creative-POTS example. The video parameters were dynamically controlled by the system to maintain the required bandwidth limit. The system was installed on an Intel 486DX33 with 8 M bytes of memory.

During the demonstration, the quality of the video and audio was subjectively judged to be less than the ISDN based VTCs. These had been previously used by the researcher. However, the overall performance of the Creative system was judged adequate for certain applications including distance education.

This initial demonstration convinced the researcher that a POTS system was a viable basis for the design of a distance education system utilizing low cost video systems. To confirm this opinion and to begin the requirement definition process, arrangements were made with Dr. Levin to demonstrate the system at the 1995 Summer Institute in Ft. Lauderdale, Florida.

Two demonstrations were conducted at the Summer Institute: one for Dr. Levin, and one for the Dean and interested members of the NSU faculty and staff. The demonstrations were conducted in the Marriott at Ft. Lauderdale, Florida.

For the demonstrations, an Intel 486DX33 at the researcher's facility was connected to a Piccolo computer at the Summer Institute. The Piccolo is a transportable--as opposed to portable--computer. The researcher had desired to use a portable computer at NSU for ease of transport, however, the system uses two full sized boards that do not fit in a portable computer. Accordingly, the compact Piccolo with its full size chassis was used.

The Piccolo is about the size of a carry-on bag, and has an integral 10" VGA display. The complete system is described in Figure 35.

Piccolo 486DX33 (8 MB) Creative Laboratories PC 3000 Creative Laboratories 28.8 V.Fast modem Sound Mate 3 PC Speakers
--

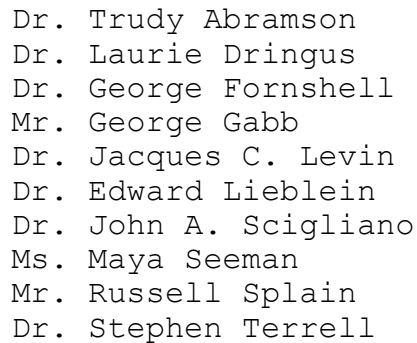
Figure 35. NSU Demonstration Configuration

The first demonstration at the Summer Institute was solely for Dr. Levin. The features of the system and the proposed screen concept were explained. Subsequent to the explanation, an attempt was made to connect to Ft. Monmouth, New Jersey.

An initial connection attempt was made from a conference room at the Marriott to the Ft. Monmouth location. In the interest of cost, an AT&T 800 access number was used under the researcher's mistaken assumption that a 9.6 kbps connection could be readily attained.

After one abortive attempt to connect the systems at 9.6 kbps, a second attempt resulted in a connection at 7.2 kbps. Video and audio were briefly exchanged, however, the Creative Laboratories system indicated that the line quality was poor and terminated the connection.

Although the demonstration was truncated, Dr. Levin decided to demonstrate the system to a larger audience of educators and interested NSU staff. The staff members included those knowledgeable in the area of VTC. The attendees are listed in Figure 36.



Dr. Trudy Abramson
Dr. Laurie Dringus
Dr. George Fornshell
Mr. George Gabb
Dr. Jacques C. Levin
Dr. Edward Lieblein
Dr. John A. Scigliano
Ms. Maya Seeman
Mr. Russell Splain
Dr. Stephen Terrell

Figure 36. Attendees at the NSU Demonstration

In a brief presentation for the attendees, the underlying technology of the system was explained and the system features were described. The briefing chart is depicted in Figure 37.

After completing the briefing and explaining the system, a phone call was made from the Marriott conference room to the New Jersey location. The system established communications at 7.2 kbps, and the connection was maintained while the operational features were described.

The snapshot feature of the system was demonstrated, and a high quality (320 X 240 pixel) image of the New Jersey participants was received. The whiteboard sharing was demonstrated, and application sharing was attempted by the operators on a first time basis.

During a demonstration of the file transfer capability the system locked up. The demonstration was then concluded. The malfunction was attributed to operator error on the part of the researcher.

After the demonstration, five of the faculty and two of the staff members who witnessed the demonstration were contacted. They were individually polled to determine their opinions on the system and its overall utility. Additionally, this opportunity was used to brief the observers on the system concept that was included in the Dissertation Proposal.

The seven individuals were visited independently. During unstructured discussions, they were shown the initial screen concept and briefed on significant highlights of the proposed effort.

The consolidated inputs from the faculty were sent to them for comment using E-mail. No additional inputs were received. The comments are listed in Chapter IV. The comments were used in the evolution of the original concept to the final design.

Another demonstration of interest was conducted between Killeen, Texas and Ft. Monmouth, New Jersey. The demonstration is interesting for two reasons. First, the area is not served by ISDN, and second, the POTS connection degraded from 14.4 kbps to under 7.2 kbps. In this demonstration Intel 486DX33 systems were used.

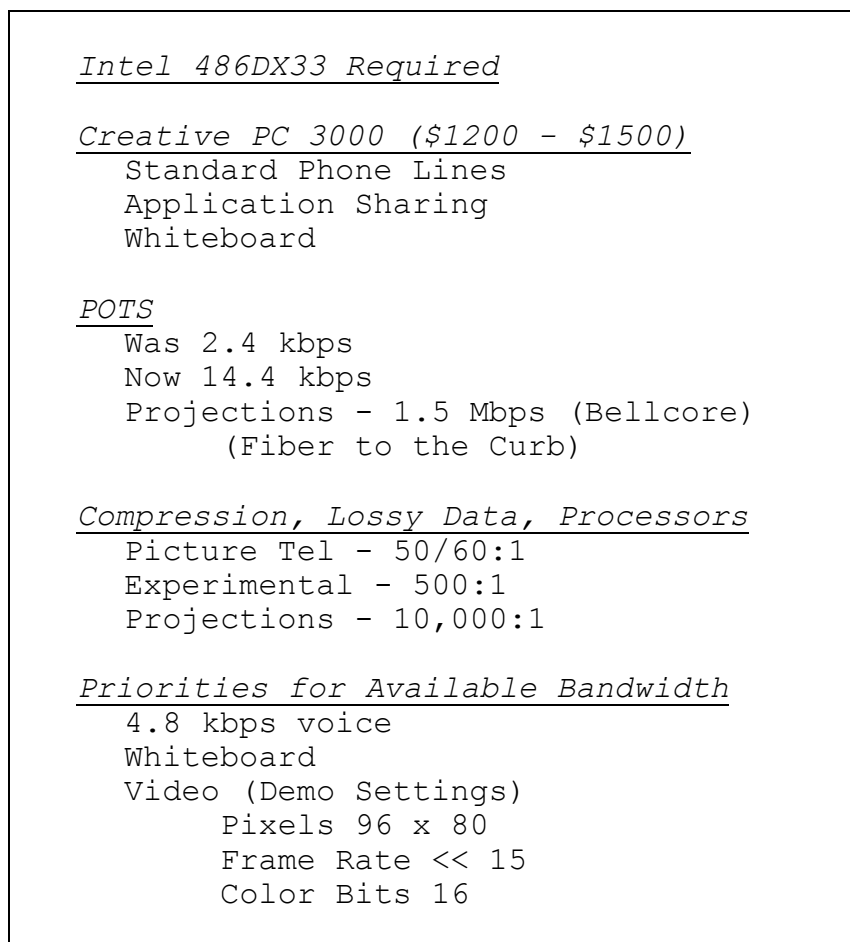


Figure 37. Faculty Briefing Chart: July 12, 1995

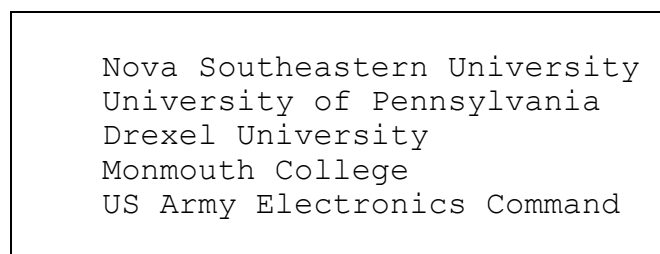
The failure of the system to maintain 7.2 kbps operation caused concern over the performance of the analog modems and the Copper Loop. It resulted in an extended search on material on Modems and the Copper Loop. The material was highlighted as a separate section of the literature review.

Completing the Proof of Principle Demonstration was invaluable. The knowledge gained contributed directly to the dissertation by providing: a starting basis for the technology requirements; a demonstration product that can be used for research; a baseline for measuring technical progress in the products; and, a cost baseline.

The installation and operation of the Creative Laboratories system provided first hand experience in the video tradeoffs of a VTC. More importantly, the operation and observation of the system gave the researcher direct experience with the video and audio quality of a POTS based system.

Task 2: Perform The Literature Search

The literature search was conducted using the technical libraries shown in Figure 38. Appendix A gives the CD ROM information sources by library.



Nova Southeastern University
University of Pennsylvania
Drexel University
Monmouth College
US Army Electronics Command

Figure 38. Technical Libraries Used

The intent of the literature search was to study the areas of management, systems and networks, and courseware in the context of distance education. During the search, selected articles were reviewed in depth while others were simply truncated during the process.

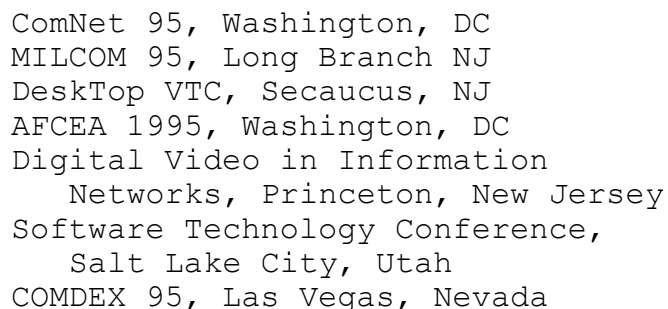
Security is an example. In the original concept, it was believed that video security would be a major barrier area. However, after formulating the systems concept, it became apparent that existing network security and password techniques could be used. Conversely, video compression and compression technology were found to be key elements of interest.

It was recognized during the initial literature searches that the material available through traditional sources lagged the leading edge of the technology. Even major technical periodicals, such as the Institute for Electrical and Electronic Engineers (IEEE), were found to be three to six months behind product announcements.

Accordingly, weekly periodicals, newspapers, conferences, and the Internet were used to obtain the latest information. This data was combined with updates of the literature search.

Technical conferences were found to be a particularly worthwhile source of information. It was only by attending the technical conferences that leading edge results could be obtained. The conferences attended in 1995 are listed in Figure 39. Each of these conferences yielded up to date technical information and products related to the effort.

An unexpected source of information was the national newspapers. Since information technology is currently of interest to the financial markets, the New York Times, Wall Street Journal, and USA Today were excellent sources of information. The effort could not have been kept current without this daily source of information.



ComNet 95, Washington, DC
MILCOM 95, Long Branch NJ
DeskTop VTC, Secaucus, NJ
AFCEA 1995, Washington, DC
Digital Video in Information
Networks, Princeton, New Jersey
Software Technology Conference,
Salt Lake City, Utah
COMDEX 95, Las Vegas, Nevada

Figure 39. Major Conferences Attended in 1995

The Internet was a major source of current information. It was used to download programs, review other University efforts (Stanford University, North Carolina State University), and to join relevant News groups. As an example, the researcher entered the Adult Education Distance NETWORK (AEDNET) newsgroup and received information on education issues from around the globe. The link was used to download Mosaic, Internet Assistant for Microsoft Word, and a variety of other software items.

To support Internet activities, the researcher used the Prodigy on-line service. This 14.4 kbps twenty-four hour link was used to augment NSU access available only between seven o'clock in the morning and seven in the evening.

Record keeping was an important part of the literature search. A three ring binder system was used to maintain the references. This is a system used by the military for key reference material. The system works quite well in stress situations, and was worth the minimum degree of discipline required. Over time, it was found to be superior to a simple file system because of the reliability of retrieval. Product information consisting of glossy brochures and non-uniform size material was organized by product type and placed in file folders.

Regarding the dissertation effort as a whole, the literature search was perhaps the most contributory of all the tasks. It impacted almost all of the barrier areas and was the basic enabler for the proposed dissertation.

Task 3: Define The Requirements For NSU

Introduction

The third task was to define the requirements for Nova Southeastern University. During the effort, requirements were identified for the three components of the system: the student system; the Nova host system; and the support system.

The first step in the requirement definition process was to definite the capability of the original ECR. This was quickly accomplished, and the ECR as of July, 1995 is described in Figure 40.

<p>Student: Text based VT100 access NSU Host: DEC 5900 Network: Tymnet at 2.4 kbps Security: Central Logon Features: Text Based Utilities: E-mail, ECR</p>
--

Figure 40. ECR as of July 1995

To augment the knowledge about the July 1995 system, the researcher joined the bi-weekly ECRs conducted by Dr. Levin. The researcher had used the ECR, but had not analyzed its interface capabilities and features.

Although it is text based, the interface of the ECR was found to be functionally complete. Further, it was known to be an acceptable interface for use at the University. The investigation of the ECR was important in determining the initial concept for the upgrade system.

Knowledge of the NSU system made it easier to identify requirements for the upgrade of the system. The knowledge also aided in controlling the scope of the literature search. Once the characteristics of the ECR were identified, this information was used as an aid in directing the literature search. During the literature search, requirements that appeared applicable to the various components were noted.

Student System Requirements

Initial requirements for the student system were generated from product announcements and advertisements found during the literature search. Multimedia systems with a sound board and CD ROM were found for under \$2,000. They could be upgraded with the Creative Video system for an additional \$1,200. Based upon the Proof of Principle results, this hardware combination was known to be adequate for the student's system.

A baseline for the student system was postulated and sent to the MMECR members for coordination. Difficulty was encountered in determining the recommended processor--486 or Pentium. Some of the members felt the recommended processor should be a Pentium. This processor was readily available, but many students already possessed an Intel 486--a system that is totally adequate for the student's needs.

During the debate over the processor, the researcher found that there was a large degree of agreement at the operating system level. All members agreed on a Windows approach. Recognizing this consensus, the requirements for the student's system were structured around the operating system, as opposed to the processor. Agreement was then quickly reached.

The revised equipment and software requirements were then sent to all MMECR members and comments were requested. Concurrence was obtained. In an ECR conducted by Dr. Levin on August 20, 1995, the requirements were approved as a baseline.

The requirements for equipment did not include the video segment. The members of the MMECR were not working in this area, and these were determined by the researcher. The requirements for this element came from the literature search, product survey, and the Proof of Principle Demonstrations.

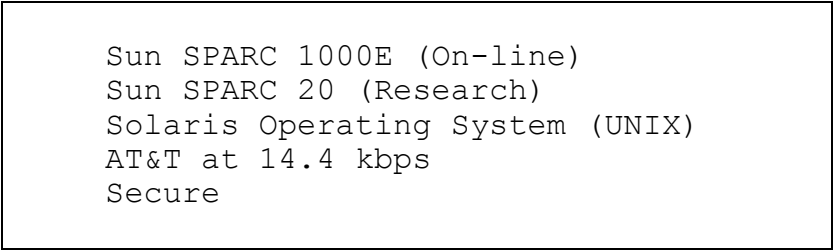
Operational requirements for the student were provided by Dr. Levin. These completed the requirement definition for the student system.

NSU Host Requirements

The platform requirements were based upon the NSU information architecture. The University had procured Sun workstations for its use, and was committed to open systems architecture based on UNIX. The Sun system runs Solaris, a version of UNIX. Sun claims that Solaris “. . . brings together over 80% of the installed UNIX systems” (Goodman, 1993, p. lix).

The target configuration for the NSU host system is shown in Figure 41. The system is based on Sun SPARC workstations and the AT&T network. A Sun SPARC 20 workstation had been procured and was available for research; after evaluation this was the system selected as the baseline for the NSU host.

The Sun products were found to be state of the art equipment with excellent interface capabilities. The emerging product line for Sun, the SPARC Ultra series, was also investigated. The Ultra series was claimed to have video and interface capabilities designed for multimedia. The Ultra system utilized a 64 bit processor running at 167 MHz, an improved high speed SCSI interface, and extensive use of cache memory in a visual computing subsystem.



Sun SPARC 1000E (On-line)
Sun SPARC 20 (Research)
Solaris Operating System (UNIX)
AT&T at 14.4 kbps
Secure

Figure 41. Target NSU Host Systems

For the operational requirements, Dr. Levin provided functional requirements for a graphics based MMECR system. These are listed in Chapter IV. These requirements were used to augment the requirements compiled from the literature search.

System requirements were discussed with members of the faculty and staff following the Proof of Principle demonstration at the NSU Summer Institute. The requirements were discussed in the context of a video based system. These inputs were also used to augment the requirements prior to the design of the system.

Support System Requirements

For the support system, it was decided to use the Sun SPARC 20 in a dual capacity. The system was available and complied with the NSU information architecture.

The system could be used for courseware development and recording when not in use as the host. If necessary, an additional system could be procured, maintaining the information architecture.

The functional requirements for the support system came from Dr. Levin, the literature search, and the product search.

Summary

In the proposal phase, requirement definition was identified as a risk for the effort. In execution, it was found that the MMECR group greatly facilitated the process. Platforms and functional requirements were identified for all system elements. They are listed in Chapter IV.

The benefits of the ECR as a collaborative tool were clearly demonstrated during the requirement definition process. The ECR was used to gather knowledgeable opinion from the members, and differences of opinion were quickly resolved. Furthermore, Dr. Levin provided guidance that was necessary to complete the designs.

Task 4: Consolidate The Data

The fourth task was to consolidate the data. The effort addressed a number of interrelated areas, and there was a risk in losing the focus of the effort. To maintain focus, the dissertation committee recommended a clear statement of the problem and the goals of the effort. The recommendations were well founded. By maintaining a focus on the defined problem and goals, the effort was successfully completed.

In Chapter IV, the results of this consolidation process are given. The Chapter lists the key findings from the literature search, Proof of Principle Demonstrations, and the requirement definition. The consolidated results are then used to structure the design, product selection, and recommendations.

Task 5: Define a Systems Concept

To perform this task, the functionality for an initial concept was derived from the text based ECR. The ECR was known to possess an acceptable level of functionality, and its functionality was used as the starting point for the system concept.

An initial concept was developed that duplicated all of the functionality of the July 1995 ECR. The features of video and voice were added to that capability.

The initial concept and screen layout reflected only the thinking of the researcher. However, it was believed that presenting an initial concept to the NSU faculty would facilitate the concept definition process. Accordingly, the initial concept was created, and it was used as the starting point in the discussion of design concepts.

The researcher's initial concept was included in the Formal Dissertation Proposal and briefed at the 1995 Summer Institute. As hoped, the concept generated significant interest and specific feedback.

The feedback was used to modify the initial concept and to arrive at the final concept. The major modifications involved instructor control of the initialization process and display area. The initial concept, the consolidated feedback, and the resulting concept are given in Chapter IV.

Task 6: Survey and Select Components

Introduction

To build the MMECR, both hardware and software components were required. The hardware was selected from marketing information and trade shows offerings. The support software was selected by evaluating products that would support the MMECR.

The methodology used to select the hardware and support software is detailed below. In addition to these components, an operational software package was required. For that major component, a module level design is presented in Chapter IV.

Hardware Components

To identify appropriate components for the MMECR, applicable trade publications and catalogs were surveyed for performance and price information. These were excellent sources of information for some items, such as the PC equipment.

Specialized components could not be found from these sources, however. As an emerging technology, PC video equipment was not widely advertised in the trade publications.

To determine pricing and availability of the specialized equipment, the trade shows listed in Figure 39 were attended. The DeskTop VideoConferencing Symposium, and COMDEX--a trade show with over 280,000 attendees and 2,000 vendors--were particularly good sources.

In surveying the available products, it became apparent that the developers were all providing quality equipment at competitive prices. At the DeskTop Video Conference virtually every booth demonstrated a high quality video conference.

"Auctioning" was the method used to determining the recommended products. Baseline components were compared with possible alternatives. The product was replaced if a more capable product was found. This process was used over the length of the dissertation effort.

As an example of the product methodology, the original video product for the student was the Creative system used in the Proof of Principle demonstrations. This system added \$1200 to the cost of the PC. However, in attending the trade shows, a black and white system at \$100 was found that became the recommended student product. It had not been previously found in the literature.

Additionally, as the product identification process proceeded, a "receive only" video approach emerged. This approach was based on a software codec approach separately recommended by Green (1995), Wilson (1995), and Flohr (1995).

While searching for a video system for the student's system, the researcher considered the use of a software codec. If software compression and decompression were used, it would lower the system cost to zero for those students with a multimedia system. The student's system could use the software codec to decode the image broadcast from NSU.

The University of Hawaii system was a "receive only" system. The significance of this fact had eluded the researcher because it was based on broadcast TV and had a secondary audio channel. However, during the Wilson 1995 briefing at the DVTC Convention, it occurred to the researcher that the Hawaii approach could apply to POTS as well. That is, only the image and audio of the instructor needed to be broadcast. The students merely need to decode the incoming broadcast signal, and provide audio.

In the University of Hawaii system, the teacher could not see all of the students, but could hear them. The students can see and hear the instructor. This "receive only" approach to video, coupled with the software decoder resulted in the base case "zero cost" student's system solution.

The approach was indirectly involved with the faculty comments at NSU. Many of the faculty interviewed did not want to see the students during the class. Accordingly, a student image that was infrequently refreshed--or a photograph--emerged as a design alternative.

The baseline host configuration was the Sun SPARC. During the product survey, it was found that Sun was introducing an "Ultra SPARC" product that has better processing and networking capabilities. The evolution to this system is included in the recommendations.

During the product survey, the network interface equipment involved the most effort and research. The necessary equipment is referred to as a video server or network hub. It was known that existing video servers could meet some of the system requirements for ISDN, however, no equipment was available to network the POTS connections.

This problem was finally resolved at the November 1995 COMDEX convention where new POTS interfacing equipment was displayed. The equipment was so new that final pricing was not yet available.

There was no specific MMECR guidance on components for the support facility. The researcher's intent for the support system was to find equipment that could be used in the preparation of courseware. To keep the cost of the system low, it was decided to use the Sun SPARC 20 in a dual mode. It would be used as the support system when it is not being used as the host. Equipment and designs were selected to support courseware development and recording.

For the support system, selected peripherals were investigated. For example, a device to support CD ROM copying and a projection display were recommended in the design.

For the peripherals, technical feasibility was not an issue. Accordingly, the methodology was simply to select components with adequate functionality and cost. The recommended devices are acceptable alternatives, however, they were the subject of a subjective selection process. In the event NSU decides to procure the devices, they should be subjected to a more rigorous cost and performance evaluation.

Support Software

The MMECR group uses HTML in support of its efforts. Early in the MMECR project, the requirement emerged for a HTML viewer. The MMECR group was using Lynx as a viewer, however, Netscape was reported to have superior features including a point and click interface and graphical display capability.

In support of the MMECR, an evaluation of Netscape with Beame and Whiteside PPP software was undertaken. In conducting the Netscape with PPP review, however, the researcher needed products that supported the preparation and off-line viewing of HTML pages. The scope of the effort changed into the identification of the support software a student would required to participate in the MMECR group.

First, a viewer and communications package were necessary to enable the student to see the HTML code. Second, a tool was necessary to facilitate the preparation of HTML code. Lastly, a graphics package was necessary to enable the conversion and insertion of graphics images into HTML pages.

The researcher investigated the products shown in Figure 42. The products were installed and operated on three different systems used by the researcher. The systems were typical of those that might be used by a student. These systems were the researcher's desktop at home (486DX66), desktop at work (486DX33), and laptop (486SX33).

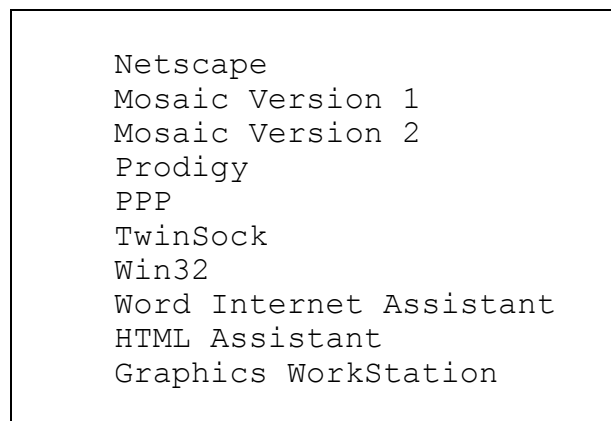
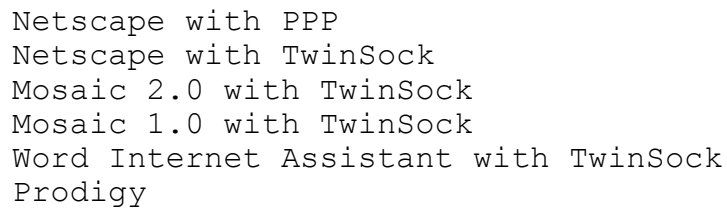


Figure 42. Support Software for the MMECR Student

With the exception of Netscape and Prodigy, the products shown in Figure 42 were selected for review because they were freeware. They could be used by students and the MMECR group at no cost.

The evaluation effort was conducted over an approximate three months period as a background task to other efforts. In all, twenty-seven different software installations (nine products x three systems) were required to arrive at the recommendations. Prodigy had been previously installed and was not counted in the installations. The installations were time consuming and troublesome--a potential problem for new students.

The combinations were evaluated for presentation quality, speed, and setup ease. Six product combinations were tried as viewers. They are shown in Figure 43. The researcher tried the following editors: Internet Assistant for Microsoft Word 6.0, and HTML Assistant. Both are freeware (if one owns Word 6.0). The effort yielded a freeware support software package that could be used by students in support of the MMECR and other NSU activities. The results are given in Chapter IV.



Netscape with PPP
Netscape with TwinSock
Mosaic 2.0 with TwinSock
Mosaic 1.0 with TwinSock
Word Internet Assistant with TwinSock
Prodigy

Figure 43. Viewer Configurations Investigated

Summary

The hardware product survey was conducted using a combination of marketing information and attendance at conferences. Support software for the system was selected based upon the researchers evaluation of the products listed above.

The survey was laborious and expensive. However, the process resulted in the identification of products that completed the design. The components enable a POTS or ISDN based MMECR to be developed now. The components selected and the designs are in Chapter IV.

Task 7: Design the Operational Software

The design methodology was in general accordance with Whitten, Bentley, and Barlow's text on system design (1994). The process is shown in Figure 44.

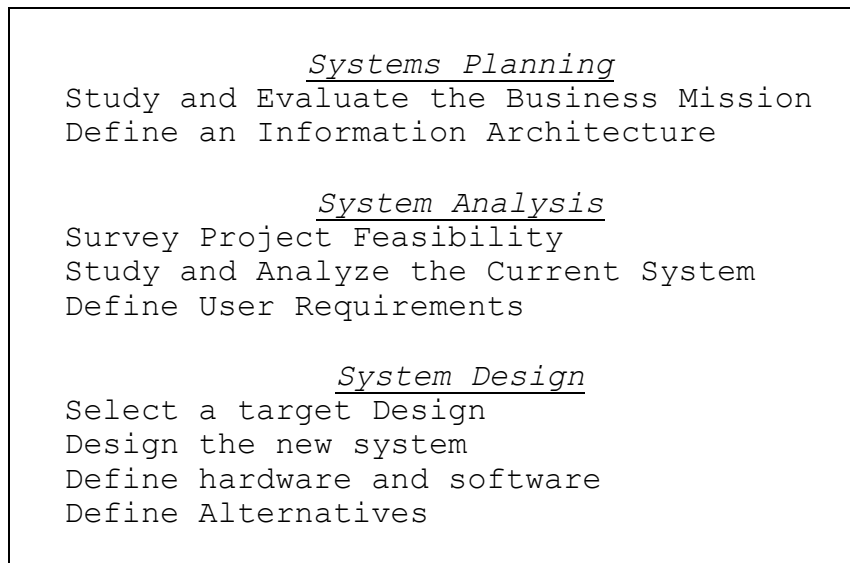


Figure 44. The System Design Process

Some considerations recommended by Whitten et al. were deleted, while others have been added. For example, design alternatives were added. These alternatives provide the University with approaches to lower the risk and cost of the development.

Whitten et al. suggested the design process be documented addressing the topics shown in Figure 45. The design addresses these areas throughout the report. Key locations are listed for reference.

Topic	Location
Business Mission	Chapter II (Existing Projects); Tables 3 & 7
Current System	Figure 1, 40, and 51
Requirements	Tables 4, 5, and 6
Information Architecture	Chapter III, IV (Task 6)
Project Feasibility	Chapter III, IV (Task 1)
Tradeoffs	Table 17
Recommended Design	Chapter V

Figure 45. Documentation of the Design

Using Whitten et al. as a guide, the system was designed in accordance with recognized standards. The process was adopted for this specific effort, and the report addresses the documentation recommended by Whitten et al.

The areas of video teleconferencing and distance education are rich in potential studies and experimentation. Accordingly, the system was designed to enable research in addition to operation. Flexible components and designs were used whenever possible. Specifically, video quality, network options, and user interfaces were structured to enable comparison.

Task 8: Issues and Recommendations

The dissertation involved an extensive literature search, product search, and design effort. During these activities, alternatives, tradeoffs, and recommendations were considered and tabulated for this report. The resulting tradeoffs and recommendations are offered along with advantages and disadvantages in Chapter IV.

Summary

In this chapter, the methodology used to accomplish the dissertation tasks were described. The tasks have been completed and the goals of the effort have been met.

The Proof of Principle Demonstrations were conducted using low frame rate video equipment. This demonstration was an invaluable learning experience. Further, it showed the potential of POTS video to the NSU faculty.

The literature search was the heart of the learning effort. It covered a broad range of topics related to distance education and technology. The knowledge acquired during this process was used to support the entire effort.

Requirements were defined using an innovative approach involving the MMECR. Initial requirements were determined using the literature search and technology evaluations. These were augmented with MMECR and University inputs. The MMECR was used to coordinate results.

The product search was extensive. It involved the use of technical conferences and trade publications. The resulting list of products supports the design proposed.

The system design was conducted in accordance with accepted practice. The effort resulted in alternative designs that can be implemented now.

The system will support multimedia electronic classrooms at NSU with a minimum of equipment. It will enable students to participate in classes using standard telephone networks or ISDN. The system was designed to support additional research in distance education and video technology.

In reviewing the tasks, the Proof of Principle and the literature survey were the enabling tasks. These efforts provided the knowledge base to perform the design. The product survey also contributed to the knowledge base, but not to the same degree.

In reviewing the methodology and the tasks, it was found that all of the tasks were necessary for a complete effort. Each of the tasks contributed to the reduction or elimination of the barriers. Further, no one task could have eliminated a barrier independently. The contribution of each task to the resolution of the barriers is depicted in Figure 46.

The task organization of the dissertation has met the needs of the researcher. By defining the goals and barriers, the researcher was able to structure and manage the effort. The task organization provided a means for conducting the research, communicating the scope of the effort, and organizing the final report.

<u>TASKS</u>	
1-----	Demonstrate Feasibility
2-----	Perform the Literature Search
3-----	Define the Requirements for NSU
4-----	Consolidate the Data
5-----	Formulate a System Concept
6-----	Survey and Select Products
7-----	Design the System
8----	Identify Tradeoffs and Recommendations
<u>BARRIERS</u>	
12 56	1) Understand Video Systems/Processors
2 56	2) Understand Network Status and Trends
12 56	3) Understand Compression Technology
23 56	4) Understand the Types of Courseware
23	5) Search for Distance Education Efforts
1234	6) Define Requirements at NSU
12 6	7) Search for Technology Requirements
12 456	8) Search for Available/Emerging Products
567	9) Adopt a Design Methodology
12 456	10) Understand the Technical Trends
1234567	11) Understand Requirements and Criteria
1 45678	12) Assess the System Costs

Figure 46. The Tasks and the Barriers They Address

Even with well-defined tasks, the effort was not completed within the proposed schedule. In retrospect, this was attributed to over-optimism. The schedule was simply too aggressive for the scope of the effort.

Chapter IV Results

Introduction

The results are presented in this chapter. They are organized by task; Tables are used to summarize the major findings. A Summary is included at the end of the Chapter.

Task 1: Demonstrate Feasibility

Introduction

A series of demonstrations was conducted throughout the United States using the Creative PC 3000 system with its V.Fast modem. They were conducted to determine the feasibility of low frame rate video for distance education. The demonstrations were conducted between the locations shown in Figure 47 and Ft. Monmouth, New Jersey. They are shown in the order in which they were conducted.

Toms River, New Jersey Ft. Lauderdale, Florida Ft. Lauderdale, Florida Kileen, Texas

Figure 47. Demonstration Locations

Demonstration Results

In the initial demonstration, the Creative system was used over standard telephone lines between Toms River and Fort Monmouth, New Jersey, a local call over an approximate distance of thirty miles.

During the demonstration, the POTS connections varied in speed from 16.8 kbps to 9.6 kbps. While the system is supplied with a 28.8 kbps modem, connections above 16.8 kbps could not be attained due to phone line quality. This is a limitation that had been encountered previously on the phone lines used; the highest rate ever achieved over these lines was 21 kbps.

Audio quality was maintained during the demonstration at the 9.6 kbps rate, confirming the results reported in the literature. The audio was subjectively rated good to excellent.

The performance of the integral whiteboard software was considered outstanding at the 9.6 kbps rate. The video was judged to have poor motion tracking capabilities, but judged adequate for some applications.

After investigation, it was found that the systems under study prioritize voice over video. This tradeoff is supported by studies that show high quality voice is more important than video.

The results on the quality of the voice, whiteboard, and video reflected the priority algorithm in the system. The system utilized 4.8 kbps of bandwidth for audio and prioritized the remainder. Audio was top priority (during periods of speech); the whiteboard was second priority; and, video was the lowest priority. Since the system was not designed to operate below 7.2 kbps, it will always provide the required 4.8 kbps for quality voice.

The finding on audio priority was significant. It indicates that a video conferencing system will be adequate for voice conferencing if a data rate of more than 4.8 kbps is maintained--almost a certainty. Further, the adequate performance of the audio was confirmed in the demonstrations.

The second and third demonstrations were conducted using a link between Ft. Monmouth, New Jersey and Ft. Lauderdale, Florida. The communications results were similar to those reported for the initial demonstration. All communications at Ft. Lauderdale were conducted at 7.2 kbps, the lowest operating setting of the Creative System.

A final trial of the Creative system was conducted between Kileen, Texas and Ft. Monmouth, New Jersey. During the trial, the POTS connection degraded from 14.4 kbps to less than 7.2 kbps in less than two hours.

The Kileen Findings

The Kileen results led to an extension of the literature search in two areas: the performance of the Copper Loop; and, the status of analog modem design.

As a result of the supplemental literature review, it was found that the major limiting factor in the performance of the network is the line length from the user's home to the telephone company's equipment. It was found that only 85% of the U. S. homes would be able to use ISDN or V.34 due to the line length or loading coils in the line.

The reason ISDN is subsequently limited to 60% of U.S. homes is the refusal of certain RBOCs to provide the switching equipment for ISDN service. Although there are percentage differences, this means that a user who cannot employ ISDN for technical reasons will probably not be able to use a high speed modem. The user's line length is simply too great for either.

Two other findings resulting from this demonstration and supplemental literature review are: (i) V.34 modems provide outstanding performance, unlike the V.Fast modems that preceded them; and, (ii) the 28.8 kbps performance of the V.34 modems is the limit for analog modems. Higher speeds will require digital line adapters such as ISDN.

Observations on Networks

The Proof of Principle demonstrations and the research on the Copper Loop, modems, and ISDN adapters led to a series of observations on networks. They are presented in Table 1 from three perspectives.

First, from the student perspective, V.34 modems with their 28.8 kbps rates are at the limit for analog transmission over the Copper Loop. Greater throughput requires the use of the ISDN adapters in lieu of the modems.

<p style="text-align: center;"><u>Student Perspective</u></p> <p>V.34 Modems: Maximum Performance for POTS Analog and ISDN Converging ISDN line cost high ISDN Installation Delays</p> <p style="text-align: center;"><u>RBOC Perspective</u></p> <p>Line Length is a limiter Switch Cost vs. Market for ISDN ATM Emergence</p> <p style="text-align: center;"><u>NSU Perspective</u></p> <p>Cost of Multiple ISDN Lines Availability of POTS vs. ISDN ISDN Installation Delays to Student</p>

Table 1. Network Observations

In that regard, the price of the best analog modems and the ISDN adapters are converging. Although there are cheaper models, a top rated (US Robotics Courier) V.34 modem costs about \$400.00; the lowest cost ISDN adapter (Motorola Bit Surfer) can be brought for about the same price. Therefore, the only student consideration on ISDN should be the operating cost, and the installation delays.

The installation delays should be taken seriously. Bill Machrone of PC Magazine had an ISDN line installed. The well known industry journalist used Intel, Bell Atlantic, and other senior industry officials to expedite the process. Machrone noted "it took almost a year from the time I ordered the line to the time I got it working" (Machrone, 1995, p. 83).

From the RBOC perspective, the key issues are the line length and the switches. Based upon the 1983 Line survey (Bellcore, 1987), virtually all the students who can use V.34 over their line can use ISDN. However, switch cost is a different issue, and the RBOCs are in control on this issue.

Based upon the literature review, it appears that not all of the "independent" RBOCs are willing to make the investment in the ISDN switches. Further, the emergence of ATM and its equipment investment may further cloud this issue.

From the NSU perspective, three things have to be considered. First, NSU is looking at major communications expenses if all students use ISDN. Either the University pays the cost, or it will have to pass the cost on to the student. Second, because of the decisions of some RBOCs not to deploy ISDN, it will not be available to as many students as POTS. Third, ISDN takes time to install, and this has to be considered in course and program planning.

The Faculty Comments

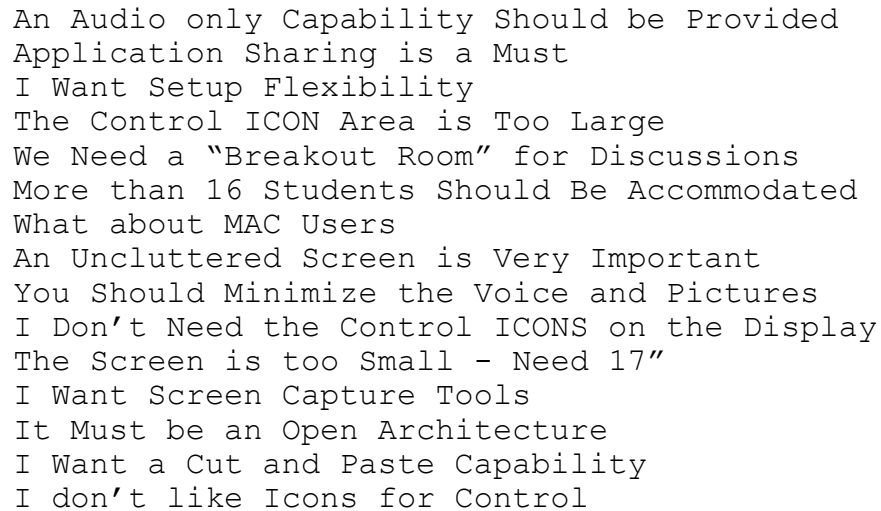
After the Ft. Lauderdale demonstrations, the Faculty and staff attendees were individually polled to determine their comments on the system and its overall utility. They were also briefed on the initial system concept that was included in the Dissertation Proposal.

Consolidated comments from the discussions are listed in Figure 48, Figure 49, and Figure 50. They are loosely grouped into comments on the Whiteboard, the System, and the Images. They are given independent of the source, although that information is available upon request.

<p>The Whiteboard is Key Three Whiteboard Areas are Necessary I Need Two Whiteboards Whiteboards Must be Quick and Easy to Change The Briefing Material is Crucial The Whiteboard Needs Emphasis</p>

Figure 48. Faculty Comments: Whiteboard

From a design point of view, the discussions made it clear to the researcher that instruction was situational. That is, different approaches were used by different instructors in different situations. The conclusion from this was that the screen setup and concept must be flexible.

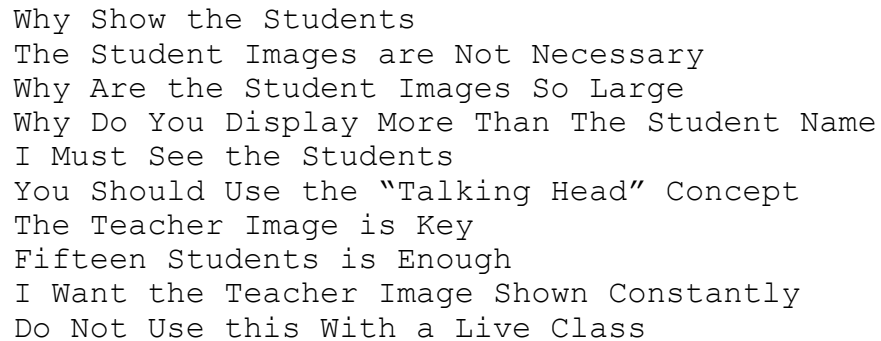


An Audio only Capability Should be Provided
Application Sharing is a Must
I Want Setup Flexibility
The Control ICON Area is Too Large
We Need a "Breakout Room" for Discussions
More than 16 Students Should Be Accommodated
What about MAC Users
An Uncluttered Screen is Very Important
You Should Minimize the Voice and Pictures
I Don't Need the Control ICONS on the Display
The Screen is too Small - Need 17"
I Want Screen Capture Tools
It Must be an Open Architecture
I Want a Cut and Paste Capability
I don't like Icons for Control

Figure 49. Faculty and Staff Comments: System

To meet the flexibility requirement, the instructor must be given the capability to setup the system to meet the need of the particular teaching situation faced. This consideration was factored into the system design.

The group of comments in Figure 50 on the student images were very important. Note that the instructors did not state a requirement for quality student images. In fact, some instructors were not interested in seeing the students at all. This was a major contributing factor in the resulting design.



Why Show the Students
 The Student Images are Not Necessary
 Why Are the Student Images So Large
 Why Do You Display More Than The Student Name
 I Must See the Students
 You Should Use the "Talking Head" Concept
 The Teacher Image is Key
 Fifteen Students is Enough
 I Want the Teacher Image Shown Constantly
 Do Not Use this With a Live Class

Figure 50. Faculty and Staff Comments: Images

The demonstration of the Proof of Principle system to the faculty and the subsequent discussions on the proposed concept were invaluable. The input enabled the researcher to revisit the baseline concept and determine how to meet the flexibility requirements posed by the diverse group.

Overall, the reaction to the demonstration and system was favorable. More importantly, detailed comments emerged from these educators based upon their individual teaching styles. The effort was particularly worthwhile because the researcher is not an educator, and the faculty group possessed years of experience in education. The requirements stated by the group were used to arrive at the final system concept and design.

Summary

Three aspects of the Proof of Principle Demonstrations are considered very important. First, the demonstration revealed network limits in the Copper Loop. Prior to the demonstrations, it was believed that the existence of 28.8 kbps modems meant that operations at that speed were easily and reliably obtained. They were not with the V.Fast generation of modems.

The emerging V.34 modems have demonstrated superior communications capability and should be adopted in any design. They are the basis for the design presented here.

Second, the demonstrations showed that POTS has utility as a distance education network, even at speeds down to 7.2 kbps. In the case of the first demonstration link, 14.4 kbps was the practical limit for the system. It performed briefly at 16.8 kbps and satisfactorily down to 9.6 kbps. The demonstrations at the Summer Institute had to be conducted at 7.2 kbps. Nevertheless, even at very low rates, the system was capable of passing voice, video, and application sharing data.

Third, the successful demonstrations at the Summer Institute served to generate new ideas from members of the NSU faculty and staff. As a result of the demonstration, major changes were made to the system concept and were reflected in the final design.

The Proof of Principle demonstrations showed that POTS could provide the required multimedia bandwidth for the MMECR. Only those cases where 9.6 kbps cannot be achieved will pose a problem. Since the wiring length is the most likely problem in these cases, ISDN is not a solution either.

Some students will desire better quality than POTS can provide. They should be allowed to adopt ISDN at their discretion, and the University should support the connection, but not pay for it.

In summary, the Proof of Principle demonstrations showed that low frame rate video can be used as the basis for a distance education system. These systems demonstrated a low cost video and application sharing capability. The results from this Proof of Principle Task are listed in Table 2.

Management

ISDN Cost is an Issue
 ISDN Coverage is less than V.34
 The "Independent" RBOCs
 ATM Switch Deployment Costs
 ISDN has Installation Delays
 Fiber Installation Paces ATM

Courseware

Instruction is Situational
 Student Images Not Essential
 Instructor Control Key
 Instructor Flexibility Essential
 Multiple Whiteboards Required

Systems and Networks

POTS System Has Utility to 7.2 kbps
 Audio is Good
 Whiteboard Outstanding
 Video Recognizable
 V.Fast Modems Unreliable
 Replace with V.34
 9.6 kbps not always achievable
 14.4 kbps could not be maintained
 Video System Negates Need for Audio Only
 Analog Modems limited to 28.8 kbps
 Operator Interface Non-forgiving
 Installation Difficult
 Hardware Reliable

Table 2. Proof of Principle Results

The POTS based systems can only be expected to improve as the technology progresses. As the V.34 modems are deployed and more powerful processors are made available for the compression algorithms, these systems will gain widespread utilization. Based upon the experience with the demonstration system, it is projected that the number of these systems will dramatically increase in the near term.

Task 2: Perform the Literature Search

The literature search in Chapter II is current. There are over 190 references; over one hundred were published in 1993 or later. The major findings are listed in Table 3.

Management

Distance education requires separate management
Distance education is a growing business area
Distance education can not be done in parts
Multiple research opportunities exist

Courseware

Courseware is a key long term consideration
Multimedia courseware is difficult to develop
Multimedia courseware requires unique skills

Systems and Networks

Multimedia PCs are available for less than \$2000
Video at 28.8 kbps is available
ISDN provides good quality video
Processor advances will improve video quality
ATM is the communications of the future
Network advances are paced by fiber optics
Deployment of fiber optics is labor intensive

Table 3. Major Findings from the Literature Review

Regarding management, the need to centralize the management of distance education has been established by efforts at Purdue University and the University of Hawaii. The need for this has also been reinforced by recent dissertations involving the attitudes of administrators and educators toward non-traditional education (Hamilton, 1994; Tsai, 1994; and Goodwin, 1994).

If this researcher were to list recommendations in priority order, the top recommendation would be to manage distance education as a separate activity. Quality courseware and technology issues pose unique staffing and funding requirements.

The establishment of the organizational entity as a "profit center" might be appropriate. This would enable NSU courses to be leveraged with short course business opportunities. Further, the specialized and expensive equipment and maintenance makes separate funding advisable to eliminate priority disputes.

Regarding systems and networks, the industry has equipment and networks under development that will provide the hardware needed for distance education. Additionally, the technology developments will provide very capable networked video systems early in the next century.

Courseware is an area that members of the MMECR are addressing in separate efforts. These studies are important to NSU's position as a supplier of quality distance education.

Task 3: Define the Requirements for NSU

Introduction

In this section the results from the requirements definition activities are presented. As described under the Methodology, requirements were collected from an analysis of the existing ECR, the MMECR group, and the Proof of Principle Demonstration.

The requirements from the faculty interviews were presented in Task 1. The remaining requirements are addressed here; they are then allocated to system component.

Requirements from the ECR Analysis

To determine the requirements from the ECR, the existing system was reviewed and the functional capability was examined. The requirements from this investigation are listed in Figure 51.

<u>Student</u>
Know who is in the Class
Prepare Questions
Ask Questions
Know the questions asked
Use existing computer
Participate at no cost
Get Help
<u>Instructor</u>
Know who is in the Class
Conduct the Class
Control the Class
Record the Class
Store and retrieve files
Get Help

Figure 51. Requirements from the ECR Review

Requirements from the MMECR Group

At an ECR conducted August 20, 1995, the MMECR group adopted the requirements for the students system shown in Figure 52. Note that the baseline hardware is recommended but not required. It was agreed by the MMECR group that a variety of systems could be used so long as they were capable of running a Windows environment.

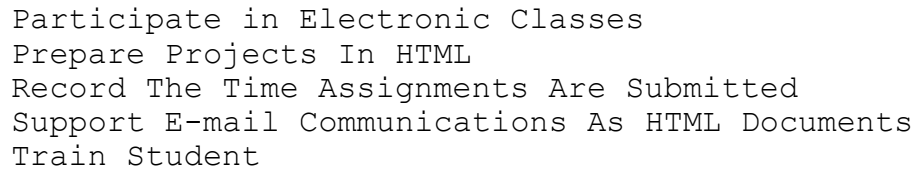
<p style="text-align: center;"><u>Baseline Hardware (Recommended)</u></p> <p>Multimedia 486DX66 with 8 MB or Pentium SVGA 14" Display 14.4 kbps modem Sound Card, Speakers and Microphone CD ROM</p> <p style="text-align: center;"><u>Baseline Software (Required)</u></p> <p>Windows 3.1, Windows 3.11, or Windows 95 Viewer: Netscape or Mosaic Communications (Student's Choice) Point to Point Protocol (PPP) Twinsock Kermit ProComm for Windows or Equivalent HTML (Student's Choice) HTML Assistant Word 6.0 Internet Assistant Word Perfect Internet Assistant Graphics WorksStation</p>
--

Figure 52. MMECR Requirements for the Student System

The software requirements spanned multiple functions, including operating system, viewer, communications, and HTML preparation. There was agreement that Windows was the required operating system for the student, and that either Netscape or Mosaic could be used as a viewer.

The discussions on communications software resulted in a list of acceptable packages. So did the HTML preparation software. In these cases, it was decided to let the student make the selection from the alternatives listed in the figure.

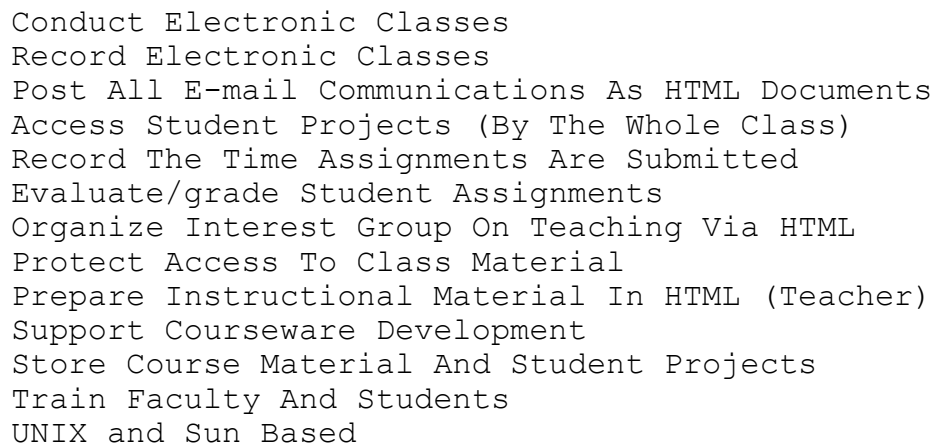
While the MMECR group determined the platform requirements, the functional requirements were issued by Dr. Levin. They are shown in Figure 53.



Participate in Electronic Classes
Prepare Projects In HTML
Record The Time Assignments Are Submitted
Support E-mail Communications As HTML Documents
Train Student

Figure 53. Functional Requirements: Student System

Dr. Levin provided the operational requirements given in Figure 54 for the NSU host and support system. The requirements can be used for any effort that supports text, graphics, or more.



Conduct Electronic Classes
Record Electronic Classes
Post All E-mail Communications As HTML Documents
Access Student Projects (By The Whole Class)
Record The Time Assignments Are Submitted
Evaluate/grade Student Assignments
Organize Interest Group On Teaching Via HTML
Protect Access To Class Material
Prepare Instructional Material In HTML (Teacher)
Support Courseware Development
Store Course Material And Student Projects
Train Faculty And Students
UNIX and Sun Based

Figure 54. Operational System Requirements

Requirements Allocated by System Component

To enable the system design, the requirements were reviewed and consolidated into Tables 4, 5 and 6. The requirements have been grouped into platform requirements, operational requirements, and support requirements. In some cases, the requirements have been interpreted for clarity, and other implicit requirements have been made explicit.

These consolidated tables were used to complete the system design and component selection. The legend "D" reflects a desired capability, and an "R" reflects a requirement. These were subjectively assigned by the researcher.

Summary

In this section, the initial set of system level requirements were defined and allocated. These requirements were used to guide the design of the system components.

Task 4. Consolidate the Data*Introduction*

At this point in the effort, the feasibility of the effort had been shown, the literature search had been completed, and the requirements were collected. This task consolidated the results for reference in the design tasks that followed.

The consolidation was done by interest area--management, courseware, and systems and networks. During the consolidation, unanticipated results were discovered regarding the bandwidth for the four MMECR levels. The area was not under study, however, the results are relevant and are presented.

The material in this section is at the summary level. It is addressed in detail after the design has been presented to the reader.

Major Findings: Management

Management findings were based primarily on the experiences at Purdue University and the University of Hawaii. The findings at both institutions were remarkably similar. The recommendations are summarized in Table 7.

Researchers at both institutions cited the need for separate management of the distance education program. The researchers at both institutions found that traditional educational management did not understand the unique requirements of distance education. Accordingly, traditional management had difficulty in supporting the program and did not provide the priority required for success.

Researchers cited the need to infuse additional skills into the program and the need for funding. They observed that management, educational, technical, and administrative skills were required for distance education.

In that regard, the researcher found that the MMECR group has the skills and structure to contribute to distance education. It was recommended that credit be considered for MMECR project work to encourage more researchers to join the program.

Alliances were considered as a means of increasing knowledge and skills rapidly. North Carolina State University was used as an example for the possible sharing of Sun information. Alliances with corporations specializing in the training of leading edge technology were also mentioned. The multimedia skills and courseware material of these firms could be applied to multimedia distance education.

Leases were recommended on all major procurements. For example, video servers cost well over \$200,000 and could become obsolete quickly.

Platform Requirements	Student	Host	Support
OSI	D	R	R
Windows	R	D	D
UNIX		R	R
Sun Based		R	R
Low Operating and Procurement Cost	R	D	D
Audio only Capability	R		
Video Capable	D	R	
Operation at 14.4 kbps or better	R	R	
HTML Viewer, Editor	R	R	R
Large Screen		D	D
Time Posting	R	R	R
Secure	R	R	D
Help	R	R	R
Self Training	D	D	D

Table 4. Requirements for the Platforms

Operational Requirements	Student	Host	Support
Setup Flexibility	R	R	R
Multiple Whiteboards	R	R	
Application Sharing	R	R	
Display Class Participants	R	R	
Broadcast Question	R	R	
Question Signal and Control	R	R	
Display Control		R	
Control Keys and Icons	R	R	R
Class Recording		R	R
Screen Capture		R	R
Cut and Paste Capability	R	R	R

Table 5. Operational Requirements

Support Requirements	Student	Host	Support
Develop Courseware			R
Review and Preview Course			R
Store Course		R	R
Store Assignments	R		R
Record Grades and Comments			R
File Storage and Retrieval	R	R	R

Table 6. Support Requirements

Management Findings	Remarks
A separate organization is required for distance education	University of Hawaii; Purdue. Separately staff and manage
A distance education laboratory is required	Build a core of expertise
The management college should be involved	CCIS students lack personnel and management expertise
A grant request for funding should be pursued	Use management students; national support exists
Credit is required for the MMECR	Provides project support
A 16 user MMECR System can be built	Provides knowledge base
Lease equipment where possible	Emerging technology
A separate line is necessary for laboratory	Security; operations
NSU must address the cost of multiple ISDN lines	ISDN costs a consideration for multiple students
Conference VTCs are not DeskTop VTCs	Cannot share applications
North Carolina State University is a source of Sun tools	Collection of OSI tools and products for the Sun platform
Students should be photographed (digital) at registration	Use for student ID and MMECR
A CD ROM disk with MMECR software is required	Provide in place of Kermit

Table 7. Management Findings

Courseware Findings	Remarks
Courseware is the key to distance education	Industry will provide the systems and networks
Courseware development is difficult	University of Hawaii, Purdue
Courseware development requires unique skills	University of Hawaii, Purdue
A courseware partnership should be considered	High technology, short courses
Begin a courseware development project	Build expertise
Establish a support system for courseware development	Lease equipment where possible
Leverage courseware	Offer corporate short courses
Establish distance education style guide	An aid to instructors
Distance education is a growth industry	Traditional education is beginning to be restructured

Table 8. Courseware Findings

System Findings	Remarks
Windows multimedia system with V.34 modem adequate for student	Under \$2,000.
DeskTop Video below \$1,000.00	\$100.00 camera available now
Video acceptable at V.34 speeds	Demonstrations to 7.2 kbps
Black and white images adequate	Color not required
Software codec a low cost approach	Until special purpose processors available
Two way sound and one way video required; two way video desired	Use photograph for student image; take at registration
Prioritize voice	Ensures communications
Video performance will improve	Compression and Processing Improvements
POTS/ISDN hubs now available for 16 users	New products in 1996
POTS MMECR for 16 users can be built	Build Expertise
Video servers not yet available for 2000 users	Forecast by 2000
T.120, H.320, H.324 accepted standards	Standards Based Approach
Multimedia ToolKits	Emerging
Courseware Tools	Available

Table 9. System Findings

Network Findings	Remarks
The media is the network limiter of speed and response time	Fiber is the best for interactive networks
POTS, ISDN, SMDS, ATM, cable, and satellite are network alternatives	POTS and ISDN are feasible
ISDN performs better than POTS but is more expensive	Installation delays also a consideration
ISDN does not cover all U.S.	60% coverage
ISDN Adapters are below \$400.00	Approaching V.34 modems
POTS V.34 Modems are below \$200.00	Currently Available
Allow student to chose ISDN or POTS	Pay for POTS only
Satellite delay impairs interactivity	Used with terrestrial link
Upgrade to Internet connection	Await IPv6; timing will not support interactive video.
Internet Protocol Version 6 not available	Forecast in 1997
Gracefully upgrade University LAN	100 MB then Fiber

Table 10. Network Findings

Miscellaneous management considerations were addressed. One consideration was the need for a University position on paying for ISDN. If the University pays for ISDN connections, the costs would multiply rapidly and might prove prohibitive.

Another consideration was the need to photograph students at registration. The digital images could be placed in the University database for use during MMECR classes.

It was found that students needed support software for the distance education program. The software listed in Figure 75 was recommended.

It was found that some managers used a conference room VTC as a distance education model. This model does not provide the location flexibility--or extension to the individual--that denotes distance education. Collaborative computing is a better analog.

Major Findings: Courseware

The findings in courseware are summarized in Table 8. The major finding in this area was that courseware is the key to a successful distance education program.

Throughout the effort, and at many conferences, it became clear that industry would eventually provide the equipment necessary to network groups. The consideration for NSU should be expertise and quality courseware.

Developing courseware for distance education was reported to be difficult and time consuming; it required special teaching skills for delivery. These problems were compounded by the rate of change in technology course material.

In that regard, it was found that firms offering short courses to corporate clients stay current with the technology. They have accomplished this by using specialists who are skilled in the technology, but not necessarily education. The skills of these organizations should be considered in the preparation of course material for high technology topics.

Multimedia specialists could assist in the preparation of selected courseware material. This would provide the ability to leverage the courseware into a profitable corporate training program. This would enhance the potential of distance education program as a separate profit center within the University.

Major Findings: Systems

The systems findings from the previous tasks are shown in Table 9. It was found that the student could procure a multimedia computer with a V.34 modem for under \$2,000. This system was adequate to support the MMECR proposed.

The multimedia system was the current industry offering. Accordingly, the number of students having the system required for the MMECR will naturally increase.

The area of video quality was a major study area in this dissertation. The Proof of Principle Demonstrations showed that systems operating with highly compressed video had adequate quality for distance education. The design proposed ensured that the sixteen user system has performance comparable to the point to point Proof of Principal demonstrations.

The Proof of Principle system demonstrated good audio and useful images down to 7.2 kbps. Improvements were found to immediately improve the performance of the systems. These improvements were V.34 modems and the use of black and white images. In the future, compression and processing power advances will further improve the performance of video systems.

The benchmark numbers on video quality shown in Figure 55 resulted from the demonstrations and the literature search. With today's products and compression, video can be broadcast at 28.8 kbps. ISDN at 128 kbps gives video that has good quality but perceptible gaps in motion, and reasonable video quality begins at 384 kbps.

High Quality Video - 1.5 Mbps (T1) Acceptable Motion - 384 kbps (Fractional T1) TeleConferencing Quality - 128 kbps (ISDN) Portrait Rate Video - 28.8 kbps (POTS)
--

Figure 55. Video Quality and Bandwidth

The host system for the University was designed around emerging products that are defined in Task 6. The products were selected to be consistent with the NSU information architecture, namely Sun and Solaris.

The host system meets University requirements for an Open System and was designed around ITU standards for video teleconferencing and collaborative computing. Toolsets and Courseware development tools are addressed in Task 6.

Major Findings: Networks

The network findings are given in Table 10. It was found that networks used for distance education range from the postal service at the University of South Africa to the intercontinental satellite network of Saskatchewan.

It was found that the network media was the basic limiting factor in performance. Because of its throughput and response time characteristics, fiber was found to be the best technical media for distance education. Unfortunately, it was in the process of being installed nationwide.

Dual channels were used with satellite systems. Video was sent over the satellite link, and voice was sent over a terrestrial link. These systems provided one way video and had perceptible gaps between the channels.

VSAT technology was found to be an exciting emerging technology. It may form the basis for a future distance education network, however, the equipment was not yet widely available.

Because of availability, the only realistic alternatives for distance education were found to be POTS and ISDN. POTS and ISDN also had utility as international distance education networks. SMDS and ATM were in their early stages of deployment, and ATM was not widely available.

Although POTS was substantially cheaper, ISDN was accommodated in the system because of its performance. Some students will want ISDN despite its cost. "ISDN provides the best proven connection (for video) today" (Glancy, 1994, p. 43). Switched 56 kbps service was also included in the design.

POTS effectively covers the United States. It was found that 85% of the homes can use 28.8 kbps modems. ISDN offers about 60% coverage due to the lack of switching equipment.

It was recommended that the student be allowed to select either POTS or ISDN based on their cost and performance preference. Because of its limited availability, a system based entirely on ISDN was not recommended.

The Internet offered ideal coverage for a distance education program. Unfortunately, it was found that the Internet would not support the timing requirements for interactive video.

Developments were underway that were expected to improve the performance of the network, however, the degree of improvement was debated by noteworthy Internet researchers. It was recommended that Internet connections be deferred until the improvements are demonstrated.

Bandwidth Findings for MMECR Levels

Although it was not a specific goal of the effort, the research established the minimum communications bandwidth required for each level of the MMECR. The findings are shown in Figure 56.

Level 1: Text	2.4 kbps
Level 2: Graphics	2.4 kbps
Level 3: Audio	4.8 kbps
Level 4: Multimedia	9.6 kbps

Figure 56. Minimum Data Rates Required by ECR Levels

From the current ECR, it was known that students operating at 2.4 kbps can participate in text based ECRs, the Level 1 system. This rate was also adequate for the graphics capability required for the Level 2 system with Lynx.

During the Proof of Principle demonstrations, 4.8 kbps provided adequate voice. Accordingly, audio can be achieved on the system at 4.8 kbps rate, achieving the Level 3 audio capability.

From the demonstrations, Level 4 or multimedia capability began at 7.2 kbps. This level provided audio, application sharing, and low frame rate video.

The 7.2 kbps rate was unique to the Creative Laboratories system. Since the faculty requirements include Open System, the rate of 9.6 kbps is used for the multimedia Level 4 system.

The 9.6 kbps rate was widely available in the communications programs. The rates of 2.4 and 4.8 kbps and 9.6 are supported by widely available communications programs including Kermit, ProComm, Terminal for Windows, and Twinsock.

Summary

In this section the results from the previous tasks have been consolidated. In management, a separate organization has been recommended by those working in distance education. The recommendation was based on the specialized nature of distance education and the different skills required.

It was found that the distance education requires unique and diverse skills. It was doubted that one organization or individual can grasp more than a fraction of the knowledge domain. Extension of the MMECR to the management school was recommended, and University and corporate alliances were addressed.

Courseware was found to be the key element in distance education. It was projected that industry will deliver the hardware necessary to implement the system. The long term success or failure of a distance education program therefore rests on the courseware.

In systems, it was found that a Windows based system with a V.34 POTS modem will support the MMECR requirements for the student. A sixteen user host system has been designed based upon equipment that will support both ISDN and POTS users. The designs are presented in the later tasks.

In networks, POTS was the cheapest acceptable network. It had adequate bandwidth at 28.8 kbps and it was the most readily available network to the student. ISDN would provide better performance, but at a significant increase in cost. POTS systems are expected to improve in performance.

Task 5: Define a Systems Concept

Introduction

The system was designed in a three step process. First, a system concept was developed; second, components were selected; and third, the operational software was defined. In this section, the system concept is presented. Task 6 addresses the component selection, and task 7 details software design.

The Initial Screen and Operational Concept

In the design process, Whitten et al. (1994), recommended that the existing system be analyzed. In this case, the existing system--the original ECR--was analyzed to determine its functional capabilities.

It was found that the user screen for the text based ECR was divided into two areas. The instructor used the upper portion of the display, and the students used the lower half. Text was displayed in these areas, and a command area was used to allow user actions and show a student list.

An implicit capability was the teacher's ability to control the conference by selecting a student to ask a question. The results of the ECR analysis are listed in Figure 57.

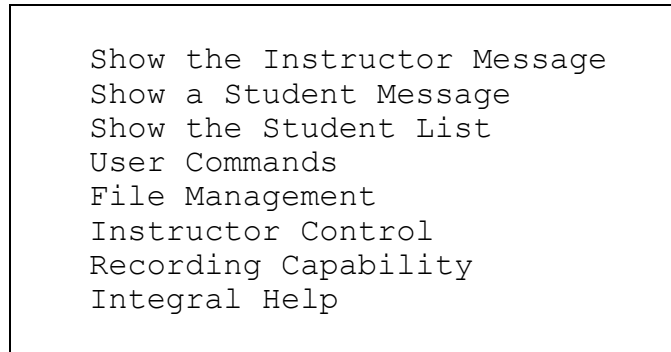


Figure 57. Capabilities of the ECR

As the second step in the design process, video and audio functions were added to the ECR functionality. This resulted in an initial MMECR concept. For the initial video concept, the screen was allocated as shown in Figure 58 and described below.

The screen concept was based on the commonly available fourteen inch diagonal video display (8"h x 10w"). For the instructor, a 17" (minimum) diagonal screen was used. The underlying concept was that all participants would see the same screen at the same time. This common screen design required less processing to store and distribute than multiple screens (one for the students and one for the professor).

In operation, the video of up to fifteen students (S1 . . . S15) would be displayed. Fifteen was selected as a reasonable tradeoff with the available screen size, and the projected availability of components. The image size of 1.5" x 1.5" was chosen for the starting concept. This was the approximate size of a passport picture.

Teacher (3 x 3)		Whiteboard (3 x 6)			
I C O N S	S1	S2	S3	S4	S5
	S6	S7	S8	S9	S10
	S11	S12	S13	S14	S15

Figure 58. The Initial Screen Layout (8"h x 10"w)

In the initial concept, the Instructor was displayed in a 3" x 3" frame that could also be used as a backup white board. A 3" x 6" area was allocated to the white board area. The 1.5" x 4.5" was used to display ICONS for system control.

A scenario for the class was postulated. The fifteen students and the instructor would view the common screen at their separate locations. The video and audio of all participants would be available to everyone.

The instructor could present the material in three or more ways. First, the instructor could simply speak and lecture. Second, the instructor could use the whiteboard. All participants would see the material simultaneously, and the professor would talk to the material. Third, the instructor could display viewgraphs in the Whiteboard area, or overlay them on the instructor's picture--if the instructor wanted to use the white board as well as viewgraphs. The system would have the necessary ICONS to enable these actions.

A "token" approach was adopted as the initial concept for control of the class. This approach was used in the Creative Laboratories system and other groupware packages.

The instructor would be initialized with the token. The students would be given an ICON to indicate a desire to be recognized, however, release of the token would be controlled by the professor.

If a student were selected, the image would be highlighted in some fashion. A border around the image or transposing it to the instructor area were possible approaches.

Audio for the class was not addressed in great detail. It was assumed that the all users would hear one another simultaneously; similar to a conference call.

The Final Screen and Operational Concept

As the third step in the design process, the initial concept was presented to the NSU faculty at the Summer Institute. Their comments were used to modify the concept and arrive at the design proposed for the system. Further, the audio concept was defined to control processing power and bandwidth.

From the faculty comments, it was clear that the system concept needed more instructor control over the video portion of the class. To meet this requirement, the Screen Concept depicted in Figure 59 was developed.

The concept envisioned multiple screens (1 - 4). In the figure, the four screens are listed across the top, and the possible display choices are listed down the side. The setup screen was to be used by the instructor prior to the class. An "X" would be used to tell the system which material to present on which screens. This is described by example using Figure 59.

Information	Screen 1	Screen 2	Screen 3	Screen 4
Control Icons	X	X	X	X
Whiteboard 1	X			
Whiteboard 2		X		
Whiteboard 3				X
Instructor			X	
Student Images			X	
Student Question	X	X	X	X

Figure 59. The Setup Screen

In the example, the Instructor had decided to use all four screens for the class. On the first screen, the instructor wanted the control icons and a whiteboard. The professor had defined the screen by setting the "X" under screen 1 in these two rows.

The student question could not be selected or deselected. The bar is displayed on all screens and was used to control the class. The student question was envisioned as a sixteen position vertical bar that was used by the student to signal the instructor.

On the second screen, the Instructor wanted the control icons and a second whiteboard. On the third screen, the control icons, the instructor's image, and the students' images were to be presented. In this example, the fourth screen was to be used for a shared application, such as a viewgraph presentation program.

In operation, the instructor would select a screen using the system control icons (or control keys). The instructor would go to the screen and enter data on that screen. The selected screen and the teacher's voice would be broadcast to all the students. If a student signals a question--and the instructor enabled the question--the student's voice would be broadcast to the other students and the instructor.

Under the concept, audio and video were transmitted only from the position selected by the instructor. This was the MMECR equivalent of the ECR instructor control.

Students who did not have a video capability would be identified with the picture taken at registration. Their name would be displayed if the picture was not available. Control keys would be provided for faculty who did not like the point and click interface.

As a second example, Figure 60 shows the settings to initialize the Initial Concept Screen shown in Figure 58. In this example, there is only one screen, one whiteboard, and all the images.

Information	Screen 1	Screen 2	Screen 3	Screen 4
Control Icons	X			
Whiteboard 1	X			
Whiteboard 2				
Whiteboard 3				
Instructor	X			
Student Images	X			
Student Question	X			

Figure 60. Setup Screen Reflecting the Initial Concept

The MMECR operational concept described above reflected the results of the three phased design process. The design was completed in view of the functional requirements and the available bandwidth and processing constraints.

The use of the speaker question feature was a significant development. Conventional VTCs had a system control requirement, but no user control requirement. Conventional VTCs enabled any speaker to speak at any time, similar to an audio conference. Accordingly, multipoint systems required the processing power to decode the audio and video from all sources simultaneously.

The ECR had system control features, but also a user control feature. Not everyone "speaks" at once. The instructor picks who speaks in the ECR, as in a structured classroom. This user control was adopted and used for the MMECR design.

The user control feature limits both processing and bandwidth. Since the instructor controls who speaks, the network can carry one transmission at a time. That is, it is a half-duplex broadcast signal. Even though fifteen users are receiving a signal, it is the same signal. Accordingly, a single codec can be used.

The codec in the NSU host can ignore the student's incoming line until the instructor selects a student, or until a polling period was exceeded. It was recognized that this would result in "frozen" images on the part of the student, however, the requirements that were identified did not include quality student images. Nor did they include simultaneous voice among all the users.

Designing the MMECR using the ECR control concept as the model for audio control was a significant development in the design. The concept significantly reduced the processing and network loads. If the standard VTC concept, or audio concept had been used, the cost of the system would have risen dramatically, and the design may not have been feasible. This approach was a result of studying both ECR operation and conventional VTCs operation.

The Student System Concept

To guide the component design, a system level concept was necessary for each of the three system components. For the student system the concept was simply a Windows based multimedia PC. The PC acts as a single node in the network over a POTS or ISDN line. Recommended components, including audio and video, are listed in Task 7.

NSU Host Concept

The NSU host system was more complex than the other systems because it needed to interface with sixteen user systems over the network. A block diagram for the NSU host is shown in Figure 61. The figure shows the components of the NSU host system at the top level.

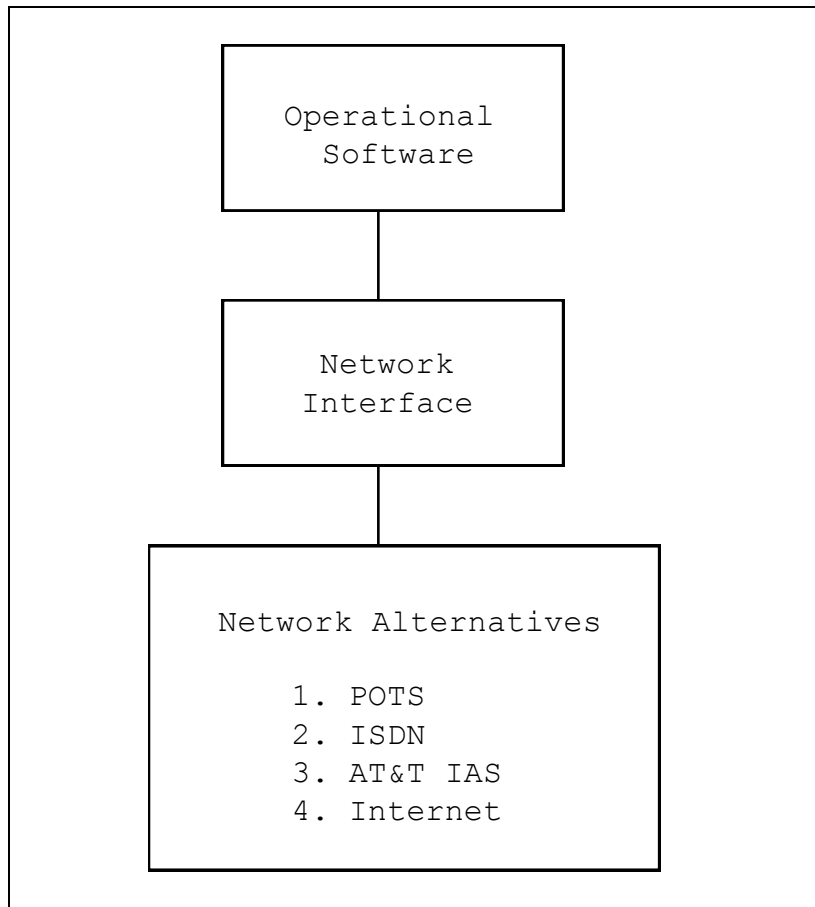


Figure 61. System Block Diagram for NSU Host

In the Figure, the top block is the Sun with the software that implements the operational concept. Based upon the MMECR guidance, the Sun with Solaris was used as the system platform. Solaris is the Sun version of UNIX. The operational software is described in task 7.

The middle block is the network interface. This is the equipment that connects the Sun to the network. Selected components for this crucial equipment are given in task 6.

The lowest block shows the Network alternates. Based on the study of the available networks, the decision was made to support POTS, ISDN, and switched 56 kbps in the initial design.

The real-time performance of POTS and ISDN was known. Further, VTC systems had been satisfactorily operated over these networks. The Internet was known to have timing problems with the current protocols, and IAS had unknown timing. Because of these considerations, the decision was made to implement the system on the higher performance networks and extend the design to IAS and the Internet after the system was operational.

To avoid security problems and conflict with ongoing operations, it was decided to use a separate line for the system until the design can be proven. It was found that a single T1 line would provide adequate service for all users. The T1 line will directly connect to the recommended network hub. The hubs recommended in task 6 will perform the inverse multiplexing function for the system.

If POTS and ISDN were used simultaneously, a ISDN-PRI line would be required; this is a T1 connection with a format to handle ISDN. With a single hub, no more than four ISDN users with twelve POTS connections would be used. This would be within the bandwidth of the available ISDN-PRI channels.

The Support System Concept

The concept for the support system was a single system running in an off-line mode. The Sun SPARC 20 running Solaris would be used as the platform on a non-interfering basis with its NSU host functions.

If this did not prove satisfactory, a second Sun or Power PC would be procured. Components for the support system are described in Task 7.

Summary

In this section the operational concept and the top level block diagram were presented. The operational concept reflects requirements from the Proof of Principle demonstration and the faculty interviews. The concept provides flexibility and control for the instructor. The concept provides the full functionality of the original ECR and adds audio and video capability.

At the system level, the student system was a PC running Windows. The NSU host was the Sun SPARC 20 running Solaris; the same system was used for the support system.

The NSU host would accommodate 16 users using a separate telephone network connection. It would be kept separate from the existing NSU communications structure until the system is proven.

The recommended connection was a T1 line for the POTS only alternative, or a ISDN-PRI line for the simultaneous ISDN and POTS alternative. Connections to IAS and the Internet would be deferred until the system is operational.

In this section, a system concept was postulated. Components are selected in task 6, and the design of the operational software is given in task 7.

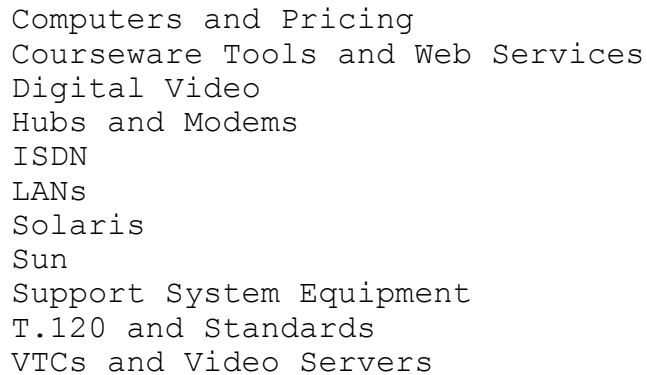
Task 6: Survey and Select the Components

Introduction

The system concept was presented above. In this section, the system concept is taken to the component level.

To complete the this task, the requirements were reviewed and a product survey was conducted for suitable components. To conduct the survey, equipment catalogs were reviewed and multiple technical conferences were attended. Over fifteen inches of product data sheets were gathered in the areas shown in Figure 62.

The technical conferences attended were listed in Figure 39. At the 1995 DeskTop Video Conference sixty vendors displayed the latest in video teleconferencing products. At the 1996 COMDEX show, over two thousand vendors displayed information systems and products. These show were used to subjectively compare and select products.



Computers and Pricing
Courseware Tools and Web Services
Digital Video
Hubs and Modems
ISDN
LANs
Solaris
Sun
Support System Equipment
T.120 and Standards
VTCs and Video Servers

Figure 62. Product Areas Investigated

To comply with the NSU information architecture, some components have already been specified, for example Sun and Solaris. These components were augmented where necessary to complete the design to the component and module level.

It should be noted that the researcher had no financial interest in any of the products recommended. All products discussed are on an "or equivalent" basis. The researcher does not endorse any of the products discussed.

There is tremendous discounting available within the industry, and products should be carefully evaluated prior to purchase. The purpose of identifying specific products was to detail the design.

The components required for the system are summarized in Figure 63. This figure is at a functional level. Each element of the system is subsequently identified by manufacturer and model number in the material that follows. All of the components necessary to build the system are available today for less than \$100,000.00.

Note that three alternatives are identified for the network interface. Products for each of these alternatives are specifically addressed.

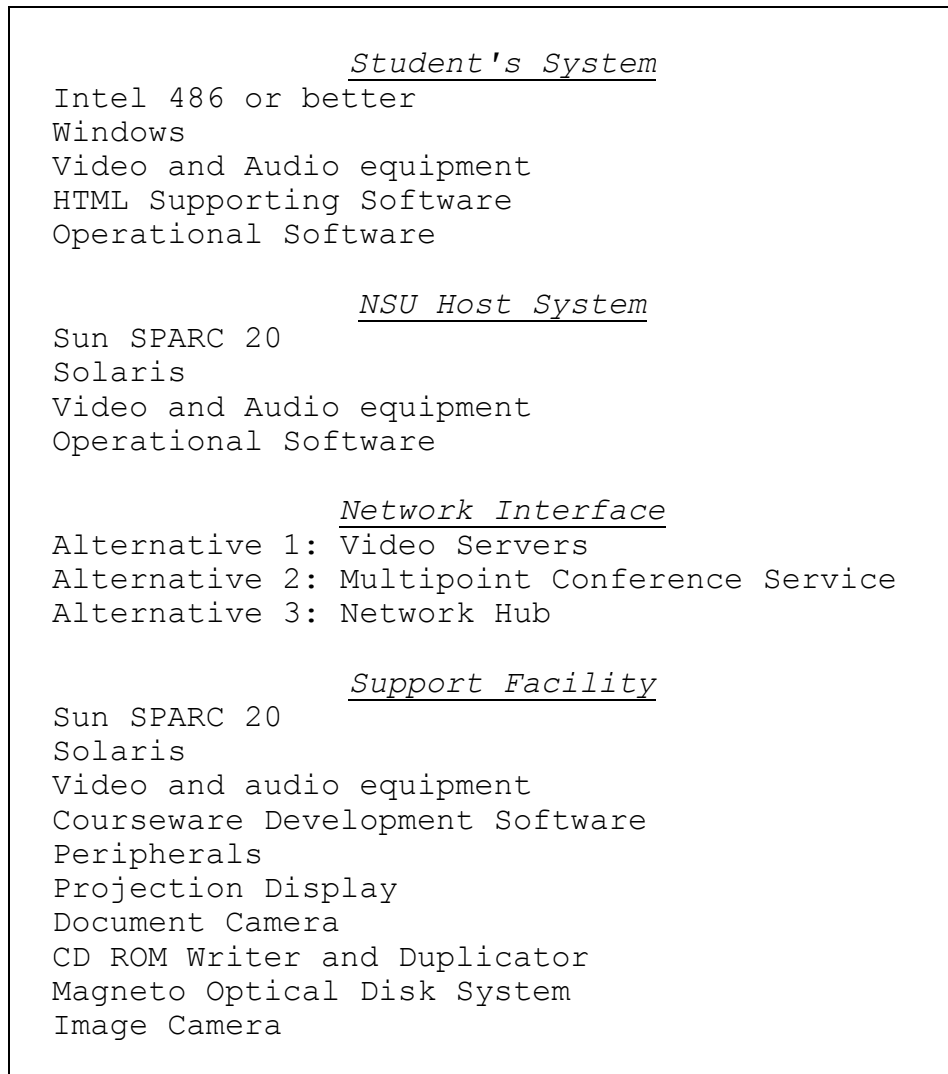


Figure 63. System Components (Functional Level)

Components for the Student System

The basic platform for the student system is an Intel 486 running Windows. The system is detailed in Figure 64. Based upon the MMECR requirements, Windows 3.1, Windows for Workgroups, Windows 95, or Windows NT can be used. A Intel 486DX33 or better is assumed.

<u>Student To Procure</u>	
Intel 486DX33 or better	
Windows 3.1 or equivalent	
Creative Sound Blaster or equivalent	
CD ROM with audio card	
Speakers and Microphone	
Camera (Connectix)	
V.34 Modem (US Robotics Sportster)	
<u>NSU To Provide</u>	
HTML Software	
MMECR Operational Software	

Figure 64. The Student System Components

To this basic configuration, a CD ROM with audio card must be added to support multimedia, audio, and software loading requirements. A microphone and set of speakers is required for audio. The Creative Sound Blaster is recognized as a leader within the industry, and is recommended. Any sixteen bit sound card with 2X or better CD ROM can be used however.

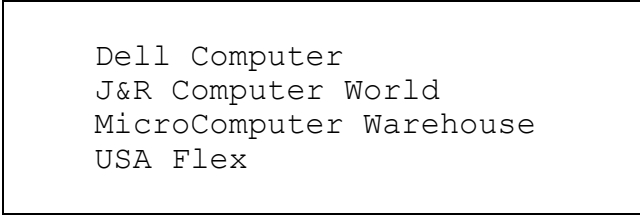
A video camera is not required for the student. The student's camera is needed only to send the image to the University. Using the software codec approach, the student will be able to see the image broadcast from the NSU host without a VTC camera or video board.

To provide an image for those students without a camera, the NSU host will insert the still picture taken at registration. In this way, all participants will have a visual image of who is in the class. If the picture is not available, the student's name will be displayed.

The HTML software for the student system will be provided by NSU and is detailed in Figure 75. It will be provided on CD ROM. The MMECR operational software with the codec will also be on the CD ROM.

The operational software implements the design presented in task 7. This software will include the codec and will support the functionality of the MMECR.

The student system is typically marketed as a "multimedia" package. The systems are available for under \$2,000 from multiple sources including the discount vendors in Figure 65. Telephone numbers are given in Appendix A.



Dell Computer
J&R Computer World
MicroComputer Warehouse
USA Flex

Figure 65. Selected Discount Vendors

If the student desires a camera, the black and white Connectix is available for \$99.00. It does not require a video card and connects to the RS-232 port on the PC. The researcher procured the Connectix camera and VTC software for \$99.00 at the November, 1995 "COMDEX" industry show.

In informal trials the performance was impressive. The system delivered crisp quarter frame black and white images. At \$99.00, the Connectix was the lowest cost system found. Recent reports support this finding (Poor, 1996).

Since the need for student images in the system was questioned by the NSU faculty, the use of black and white images provides a reasonable tradeoff in the system. Further, the black and white 4 bit per pixel image requires on one-sixth the bandwidth of a twenty-four bit color image.

A more complete list of VTCs and video equipment than the list provided above can be found on the Internet. The address is in Appendix A. Almost one-hundred products are fully described.

Components for NSU Host

As a part of the design process, Whitten et al., 1994, noted that it is important to determine the information architecture of the organization. In the case of NSU, the architecture is Open System Architecture with UNIX and Sun as the software and hardware platforms. The workstations run Solaris, Sun's version of UNIX.

The Sun workstations are very powerful and state of the art equipment. The Sun systems can be upgraded through the addition of a multiprocessor card. Sun also has announced a Sun "Ultra" series of workstations. These sixty-four bit systems are even more powerful and offer dedicated multimedia processors in their design.

Figure 66 gives performance capabilities of selected Sun and other processors. The data were compiled from Rowell (1995), Crothers (1995), Wingfield (1995), and Sun (1995). Note that these results should only be used to gage relative power of the machines. Their performance and relative ranking can vary with the application.

Because of its performance and upgrade capabilities, the Sun is an excellent processor for the MMECR. As shown, newer processors are demonstrating higher speeds, however, this is to the MMECR's advantage.

Model	Clock Speed (MHz)	SPECint92
SPARC 20 (M50)	50	77
Intel P5	100	112
SPARC 20 (M71)	75	126
SPARC 20 (M151)	150	169
Intel P6	133	200
SPARC Ultra	143	206
SPARC Ultra	167	240
Power PC	133 (2 CPU)	300

Figure 66. The Performance of Various Processors

The instructor may use the NSU host or may be remote on a PC. Both locations require the same additional equipment as the student, namely, a camera, video card, audio board, speakers and microphone. For the instructor locations, the ear set and microphone combination of the Creative system should be upgraded.

Since the operational software will always run on the NSU host, a PC similar to the student's will be adequate for the remote instructor. The Sun system comes with a 17" or larger display that is adequate, however, a 17" display is also recommended for the remote.

Network Interface Alternatives

During the effort, it was found that the network interface can be accomplished in one of the three ways. First, an existing video server could be procured. Second, a video service--such as AT&T's WorldWorx--could be used. Third, NSU could procure a network hub to build the MMECR using components discovered during this product search.

Since this is a crucial area in the design, a detailed review of the network interface options was undertaken. The results on all three options are treated separately below.

Network Alternative 1: Video Servers

Video servers were a featured item at the September 1995 DeskTop Video Conference. VideoServer, Teleos, AT&T, PictureTel, Quadraplex, and C-Phone demonstrated products. These vendors represent the known video server suppliers and are listed in Figure 67.

No information could be found on the remaining products mentioned in the literature, Figure 29. The reasons for this are not known, but it is speculated that some vendors have not progressed to the product stage. Further, the market is market by significant reselling. The PictureTel and AT&T hardware were supplied by VideoServer who only sells through resellers.

Sun, the supplier of the NSU Alpha computers, has not demonstrated a video server at the conferences. InSoft features a LAN based DeskTop video teleconferencing system for Sun platforms, however, they have not offered a video server.

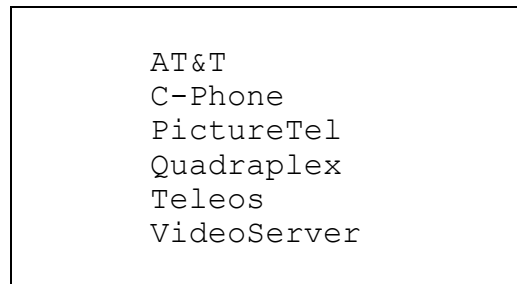


Figure 67. Vendors Offering Video Servers

Writing a featured article for the Wall Street Journal, Bulkeley reported that VideoServer has ". . . locked up the video conferencing companies and the carriers for now . . ." (Bulkeley, 1995, p. c1). This researcher found that VideoServer does have an industry leading product, however, the researcher feels that the qualifier "for now" is a very important part of Bulkeley's statement.

Three observations made by Bulkeley aid in understanding the market: (i) VideoServer holds no patents on the technology; (ii) AT&T and VideoServer will have very similar products; and (iii), AT&T can sell bridges cheaply because it gets revenue from increased line usage (Bulkeley, 1995).

Based upon observations at the conference displays, it was found that the available products are very similar. Further, the systems are based on common components, making the lack of a patent position by any of the vendors important.

No controlled comparisons or test results were found to support any conclusions on video server performance. To gain insight into the products and their claimed capabilities, however, a first order comparison was conducted based on high level design requirements for the MMECR.

In the material that follows, design requirements for a MMECR video server are addressed and the video servers are compared to the requirements. Where indicated, the marketing information was confirmed through discussions with the vendors. The vendor information came from a mix of technical and marketing sources.

To assist in determining a video server approach for NSU, design requirements for a MMECR video server were postulated. The requirements are stated in Figure 68. They are intended to represent a basic set of design requirements for the MMECR.

Regarding the design requirements, the system must first be standards compliant to meet NSU's open system requirement. In the case of video teleconferencing, this means T.120 compliance. All known vendors are supporting the emerging T.120 standard, and intend to offer T.120 compliant products.

Support T.120, H.320, H.323, and H.324
Sixteen or More Conference End Points
Simultaneous Video Display on All Channels

Figure 68. Basic Requirements for the Video Server

Second, the baseline design calls for sixteen inputs that may be POTS, ISDN, or LAN. The input rates may vary. For example, the POTS connections may be anywhere from 9.6 kbps to 28.8 kbps, and the high speed connections should support ISDN (64 kbps or 128 kbps) and switched 56 kbps channels. Switched 56 kbps channels provide full United States coverage. Accordingly, the video server must be capable of supporting multipoint connections at heterogeneous transfer rates.

Third, the design calls for all subscribers to simultaneously view the same screen, and for audio to be available simultaneously. The simultaneous audio is important as a means of connecting the conference participants when the instructor is using the full screen for a selected image.

No video servers currently meet all the requirements listed in Figure 68. The key requirements that cannot be met are T.120 standards compliance--including the H.324 POTS capability--and simultaneous display of sixteen images.

The vendors have announced they will begin offering T.120 compliant products when the standard is ratified. T.120 is very important because the standard will enable vendor independent hardware and application sharing over heterogeneous communications media. Accordingly, the ratification of T.120 standard is a key milestone in the definition of the MMECR.

Interestingly, major vendors--including PictureTel and Creative Laboratories--will offer T.120 compliant products in addition to proprietary products. They claim that the proprietary products have better performance.

Regarding the number of conference end points, all the vendors except Quadraplex can handle sixteen or more conference participants. Regarding the ability to simultaneously display participants, all the systems except Quadraplex can simultaneously display four sites.

In its marketing brochure, C-Phone claims the ability to display all sixteen sites by cascading its units. The C-Phone display format is sixteen equally sized images on the screen. The ability to display four sites was witnessed at the 1995 DeskTop Video Conference. The sixteen site display was not demonstrated.

The vendor claimed number of direct connection ports and simultaneous display capabilities are shown in Figure 69. Three video servers can network at least sixteen ISDN end sites and display four sites simultaneously: C-Phone, Teleos, and VideoServer. To determine possible industry direction regarding the display of multiple sites, discussions were held with the Project Manager of the PictureTel "Montage" product (Semanite, Personal Communication, October 10, 1995).

Vendor	Ports	Screens
C-Phone	16	4
Quadrplex	4	2
Teleos	72	4
VideoServer	48	4
- PictureTel	48	4
- AT&T	48	4

Figure 69. Vendor Claimed Ports and Display Screens

Semanite indicated that PictureTel will not go beyond the display of four sites for Montage for three reasons: (i) the cost of the required codecs is high; (ii) the processing is very complex; and (iii) the usability is questionable. PictureTel has found wide variations in user opinions on the way multiple images should be displayed. Semanite's experience on user preference on image presentation confirmed the researcher's experience. Each individual has their own preference on the "best display".

Regarding the company itself, PictureTel has established itself as a leader in Video TeleConferencing for conference room type applications. The company is a market leader in terms of sales for teleconferencing. The company has recently introduced DeskTop video equipment and has a collaborative computing product called "LiveShare Plus". PictureTel is clearly committed to a standards based approach, and has been vocal at conferences in expressing the role of standards in the survival of the teleconferencing industry.

The company offers a family of video servers in its Model 8000 series. The chassis start at \$49,500 and go as high as \$250,000. The company claims the system can support up to 2,000 sites in a single meeting by cascading servers, and up to eight independent conferences. As the sites are cascaded, however, time delays develop in the display.

The researcher's office has a \$250,000 PictureTel Model 8816, their most capable product. It supports up to sixteen end points and eight separate conferences. The system has been effective, although its utilization factor is far less than 100%. The system requires highly skilled, dedicated support, and has proved difficult for untrained operators to use. The company has provided excellent on-call support.

The office is considering adding the Montage line to get the T.120 capability. Unfortunately, the Model 8816 is not upgradable and would have to be salvaged. This is an indication of the risks involved in dealing in an emerging technology.

Video Server Corporation is a new company aiming specifically at the multipoint teleconferencing market. The company is working with Intel, and has been identified as the market leader by the Wall Street Journal (Bulkeley, 1995). The company has been actively courting business agreements with major telecommunications firms including Sprint, MCI, and Bell South.

VideoServer has installed its equipment in a distance education system at Washington State University. The company claims that the system is used to offer 77 classes to over 2,300 students located at branch campuses.

VideoServer offers four basic models that interface up to 48 ports. The Model 2020 used in Figure 69 is their top model. The company supports standards, and has provided for standards variability in its designs.

Teleos has just entered the marketplace. The company has a comprehensive list of servers designed to span the market. Their VideoRouter was released in June of this year and has performed well in Beta testing (Messmer, 1995). The product line can handle 20 to 72 ports. The top of the line product is designed for corporate communications centers.

The Teleos products are of interest because their Model 40 and higher "Multi" systems support up to 76 RS-422 ports. These ports could be used to add V.34 or V.Fast modems to the server. Modems are supplied with an RS-232 interface that is convertible to RS-422 with an adapter plug.

Creative Laboratories is not developing any products to support POTS multi-point conferencing and does not see themselves as a supplier of multipoint equipment. They are, however, supporting the AT&T VERSIT alliance approach to multipoint conferencing described below. Creative Laboratories believes a multipoint conferencing approach based on VERSIT will best meet the needs of its customers (Crilley, Personal Communication, September 29, 1995).

Since PictureTel and Creative Laboratories are leading suppliers of VTC systems, the outsourcing of video servers by these two companies may have market significance. The size of the market may be the deciding factor, or it may be concern over the communications carriers in the market.

The significance of the communications carriers can be seen by considering AT&T. As a communications carrier, AT&T can integrate the video server into their data services. AT&T has in fact done so using video servers supplied by VideoServer. VTC users can opt to use the AT&T video servers for multipoint conferences instead of owning and maintaining their own server. This addressed in the section below.

Today, the effort has found three companies that offer a video server capable of networking sixteen sites and displaying four sites: VideoServer, C-Phone, and Teleos (AT&T and PictureTel use VideoServer). No inherent technical or patent advantages have been found in the available video servers, and the devices appear to be based upon the same technology. Of the available servers, VideoServer appears to have the strongest position as reported by Bulkeley. As a supplier to PictureTel and AT&T, their technical product has been proven in the industry.

If the University procures a video server now, the products can support sixteen ISDN sites and eight simultaneous conferences at a cost of about \$250,000 (PictureTel Model 8816). The available systems enable users to hear all sites and see one site at a time. No video server is available to handle POTS inputs.

Near term, the video server vendors are adopting T.120 as a standard, and will offer products based upon the standard. The standard will support heterogeneous communications inputs--including POTS--and application sharing. The ratification of T.120 with the related H.320, H.323, and H.324 standards will enable vendors to provide products that meet the MMECR requirements, including application sharing.

In the future, product developments are proceeding rapidly, and special purpose video chips have been announced by major vendors. The emergence of these low cost processors will enable the development of significantly lower cost, more capable video servers. Using a product development and implementation time of five years, this places the future at 2000. The hardware developments may proceed rapidly, but the T.120 application sharing is expected to be difficult.

Regarding the technology and its evolution, Table 11 is offered. The Table projects video server technology based upon the developments previously discussed.

Network Alternative 2: Multipoint Conferencing Service

A carrier provided multipoint conferencing capability is an attractive alternative for applications requiring occasional video teleconferences. In the case of NSU for example, the existence of a cost-effective, carrier integrated video server could eliminate the need for a stand-alone video server at the University. Further, if the carrier server provides T.120 service for sixteen subscribers, the use of such a service could be highly attractive.

<u>Today</u>
48 ISDN Inputs
8 Conferences
Hear All, See One
Some Application Sharing
Shared Codecs
Dedicated Support
\$250,000
<u>Near Term (1998)</u>
72 Heterogeneous Inputs
More than 8 Conferences
Hear All, See Four
Some T.120 Application Sharing
Special Purpose Codecs
Dedicated Support
Less than \$250,000
<u>Future (2000)</u>
2000 Heterogeneous Inputs
No Conference Limits
User Controlled Display
Full T.120 Application Sharing
Codec per channel
No Dedicated Support
Less than \$100,000

Table 11. Projections of Video Server Technology

Labriola evaluated AT&T's WorldWorx service and concludes "Multipoint Conferencing is real" (Labriola, 1995, p. NE18). The author stated that Sprint and MCI have similar capabilities, although AT&T was selected for Labriola's test. The findings are summarized in Figure 70.

Up to Twenty-three Users
Average cost - \$1 per minute per user
Accepts heterogeneous systems
Accepts ISDN or Switched 56 kbps
No document sharing

Figure 70. WorldWorx Multipoint Service

There are limitations in using a carrier provided video server, however. These limitations involve the format of the composite display, LAN connectivity, and the current lack of a POTS capability.

The display limitation involves the composite frame. Since the carrier video server would receive all the inputs, it would necessarily control the format of the composite frame. The subscriber--such as NSU--would be limited to the composite frame offered by the server. For example in a sixteen input case, the carrier's server might determine that two alternating screens of eight inputs is best. The subscriber would have limited, if any, capability of affecting the display. If NSU has its own video server, the University can manipulate the inputs as it desires.

The LAN limitation exists because the carrier based server would have no direct connection to the University LAN. A LAN connection for NSU is important for the MMECR because the LAN provides high speed access to NSU's information system and database.

Despite these limitations, the use of a T.120 carrier based service such as AT&T is a viable alternative. NSU has management experience with AT&T, and is using the company to meet current telecommunication requirements. Moreover, video multipoint conferencing through a service would enable the University to avoid the procurement and operation of video servers that are expensive and evolving.

Using a conferencing service would enable the University to concentrate its expertise on the MMECR software and courseware. The University's existing video server equipment could be used for MMECR research, including the development of courseware.

The researcher believes that AT&T is a strong competitor in the future video server market. The reasons are as follows: because AT&T is a carrier, the video server can be shared in terms of procurement cost and maintenance; they are the leader of a major industry standardization alliance, VERSIT; and, they are developing a special purpose chip to lower the cost and increase the performance of video servers.

The AT&T VERSIT alliance includes AT&T, Apple, IBM, and Siemens-Rolm. The alliance is based on an agreement to use a version of T.120 that is more restricted than the full standard. By specifying critical variables within the T.120 standard, the alliance believes that it can improve interoperability while maintaining compliance with the full standard (Warrick, 1995). As a spin-off company from Apple, it is not surprising that Creative Laboratories is backing the VERSIT alliance.

The VERSIT hardware suppliers will build their VTC equipment to the VERSIT version of T.120. The VERSIT equipment will be interoperable with non-VERSIT equipment that meets the full T.120 standard.

While the AT&T alliance does not offer a product, AT&T did demonstrate VideoServer as a part of their WorldWorx communications network at the Desk Top Video Conference. In addition to VERSIT and WorldWorx, AT&T Microelectronics presented their special purpose Audio Video Processor designated "AVP III" to support their video efforts as indicated earlier.

Another alternative for the University is to use a network conferencing facility such as Galacticom. Galacticom offers a multipoint conference service that has been used by the MMECR for a multipoint conference. Like AT&T, Galacticom represents an alternate approach to video servers should the University decide to out-source its VTC video server requirement. Galacticom does not support real-time video at this time.

Network Alternative 3: Network Hub

A video server provides both the network adapter to the telephone line and the codec(s) in an integral package. It was noted in Chapter II that these connectivity and codec functions can be separated.

In surveying the components and designing the system, a device known as a network hub was found. A network hub possesses the necessary features to interface the Sun workstation to the telephone line--using ISDN, POTS, or Switched 56 kbps.

Until recently, such devices were not available in a single package. However, at the 1995 COMDEX show, the researcher found network hubs that will enable the MMECR to be built.

One system is made by US Robotics (Total Control Enterprise Network Hub/16). The system will interface sixteen V.34 channels directly to a T1 connection and the LAN. This US Robotics system only accepts POTS inputs. Motorola and Hayes offer similar products.

The US Robotics Total Control NETServer/16 and the Motorola "BitRUNR" hubs accept up to sixteen POTS, ISDN, or Switched 56 kbps inputs and connects them directly to a T1 line.

The systems were so new that pricing was not final. A marking estimate of \$50,000 for a fully populated Motorola system was given, however. The US Robotics POTS system is \$10,000. Manufacturer information on these products is included in Appendix C.

Connection to the Sun is accomplished over the Ethernet or RS-232. All use V.34 for POTS, and the US Robotics has V.34 "SVD" modems that "Share Voice and Data" over the network--a desirable feature.

The Motorola specification sheet claims that its BitRUNR product is the "first high performance, multiprotocol dial-up internetworking solution for enterprise networks." The results of this product search support that claim.

Two functions were required for the MMECR: network connectivity, and the codec function. The hubs identified provide the requisite connectivity. The codec function is accomplished using software residing in the Sun. This software approach is detailed to the module level in Task 7.

The network hub approach will enable an MMECR to be developed now that meets NSU requirements and supports heterogeneous multipoint conferences over POTS and ISDN. It further achieves a major goal of this dissertation by enabling the design of the target low cost MMECR.

Network Alternatives: Advantages and Disadvantages

The network alternatives are listed for consideration in Table 12. Advantages and disadvantages are included.

The network hub alternative is preferred. This alternative supports a POTS and ISDN system now at minimum cost. Since the system is software based, technology upgrades can be easily accomplished.

Components for the Support System

Based upon MMECR guidance and the NSU commitment to the Sun architecture, the NSU host Sun SPARC 20 with its video equipment will be used as the support system. If system sharing is a problem, a second machine can be procured.

Network Alternatives	Advantages	Disadvantages
Procure Video Server	Controllable Asset Supports Application Sharing Builds Knowledge Base	No POTS Capability Investment Cost Support Cost Technical Obsolescence Proprietary Rights
Carrier Provided Service (AT&T, MCI, or Sprint)	No investment cost No support burden Technical upgrades	No POTS Capability Operating cost No application sharing No asset control
Network Hub & Software Codec	Controllable Asset Supports Application Sharing POTS, ISDN, Switched 56 kbps Low investment cost Low operating cost Builds knowledge base Software Upgradeable Unlimited Rights	Technical risk
Internet Solution	Connectivity	Performance

Table 12: Network Alternatives

Solaris, or UNIX, is the operating system for the support system. UNIX is a major part of the University's information architecture. Windows is the architecture used by the student and by many of industry software developers.

The disparate information architectures is well known, however, it would be ideal if the MMECR group took steps to "Bridge the Gap" between the University UNIX environment and the Student Windows environment. The ability to run both UNIX or Windows on the support system will enable student projects beneficial to the MMECR effort and the University.

In that regard, two products were found that enable both UNIX and Windows to be run. One was a software solution, and the other was a hardware solution.

The software solution is a Sun Software product, "Wabi". Wabi is a software emulator that runs Microsoft Office and Lotus SmartSuite on Solaris. With Wabi the user can cut and paste and drag information between Solaris and Microsoft Windows. Using Wabi in the support system would enable researchers to use either UNIX or Windows based applications.

The hardware solution is the IBM Power PC. The Power PC is a joint venture involving IBM, Apple, and Motorola. The RISC based Power PC will run Solaris, Windows NT, Mac OS, and OS/2.

At COMDEX 1995, IBM claimed that the Power PC will run Solaris applications faster than the Sun SPARC 20 systems. This claim was researched, and the independent results supporting the claim were found. Comparisons show that the top of the line Power PC will run three times as fast as a Pentium 90 MHz (Rowell, 1995). By comparing Sun results against the same standard, the Power PC is faster than the Sun SPARC 20.

Procurement of a Power PC as an option for research would provide the MMECR with an alternate hardware platform. The system can run Solaris and Windows, and could be used for projects addressing the gap between the student and the University architectures.

Completing the basic hardware for the support system, a projection display, document camera, a CD ROM writer and duplicator, Magneto Optical disk system, and a digital photo camera are recommended. The projection display is used to show the live or recorded class to a large audience.

The projector could be replaced by a more compact LCD Panel for overhead projectors, however, the researcher prefers the projector because of brightness and built-in sound. The document camera is used to show the class hard copy material, and the photo camera is used to take pictures of the students at registration as previously discussed.

The CD ROM writer and duplicator will be used to distribute software and training material to the students. The magneto-optical disk with jukebox would be used to store and retrieve classes.

Class recording would be accomplished by furnishing the magneto-optical disk with a copy of the instructor's data stream. At 28.8 kbps, a 230 Mbyte disk will hold over 20 hours of recordings. Using the 35 platter jukebox recommended below, access to over seven hundred hours of material can be provided.

In the review, the products shown in Figure 71 were surveyed. All these peripherals are compatible with the Sun system. The product review indicates that the peripherals are all state of the art.

The selections indicated by an asterisk were made by the reviewer. The selections were subjective, and pricing should be the major consideration for procurement. Pricing is given as a rough order of magnitude.

<p><u>Projection Display (\$7,500.00)</u></p> <p>Apollo QX575C</p> <p>*InFocus LitePro 570</p> <p>Sanyo PLC-510M</p> <p>Panasonic PT-L390U</p>
<p><u>Document Camera (\$3,600)</u></p> <p>Altec Lansing AVC1000</p> <p>PictureTel FlipCam</p> <p>*Cannon RE-650</p> <p>CD ROM Writer and Reader (\$10,000)</p> <p>*Genis CD Standalone Duplicator</p> <p>Genis CD-Maker/CD-Blaster</p> <p>Meridian Personal 500P</p>
<p><u>M-O System (\$4,000)</u></p> <p>*Fujitsu M2531 (\$4,000)</p> <p>Hewlett-Packard SureStore</p> <p>Philips Infinity 6000</p> <p>Sony OSL-6000</p>
<p><u>Digital Photo Camera (\$1,000)</u></p> <p>*Casio QV-10 (96 Images)</p> <p>Kodak DC40 (48 Images)</p> <p>Epson Photo PC (32-160 Images)</p>

Figure 71. Peripherals for the Support System

Software for the support facility consists primarily of courseware preparation tools. The courseware area is being studied separately under the MMECR. In this effort, it was found that courseware preparation was instructor dependent. Accordingly, it is recommended that NSU provide a standardized set of tools and develop a style guide for each tool. The style guide would be used to standardize selected user options such as font type and size, logos, and chart preferences.

Regarding the tools themselves, the inclusion of the Wabi software or the Power PC will enable Windows based (and UNIX based) tools to be used. A basic set of tools is shown in Figure 72.

PowerPoint and Authorware will support multimedia material. Authorware is a highly recommended product for creating interactive educational courseware. The IEEE has also chosen Authorware for their use on Software Engineering Multimedia courses (Marshman, Darnell, & Spikins, 1992, p. 272). Greenberg of Digital Video rated it a 9.4 of ten and states that ". . . it is clearly up to the state of the art . . ." (Greenberg, p.18, 1995). It was selected as PC Computing Magazine editor's choice and it was also selected as the top product in its class by Multimedia World magazine.

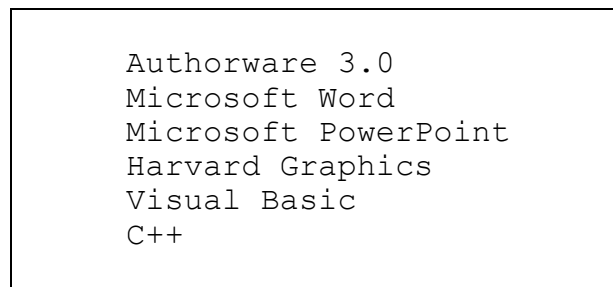


Figure 72. Basic Support System Software

In addition to courseware preparation, it is anticipated that the support facility will be used for studies in distance education and supporting technology. As these studies are defined, the need for additional equipment should be specified.

In addition to the readily available C++ and Visual Basic, a developers ToolKit should be considered. These development environments enable customers to tailor the screen to their particular application. PictureTel offers such a ToolKit as does Intel. The toolkits that have been announced or are in development are shown in Figure 73. They have not been evaluated.



Figure 73. Firms Pursuing Developer's Tool Kits

Support Software Components

To support the MMECR group Level 2 efforts, a review of Netscape with PPP was undertaken. During the review, difficulties were encountered with the PPP link. Ensuing efforts to resolve the problem resulted in a complete review of support software for the MMECR.

For a viewer, Netscape was evaluated as was Mosaic 1.0 and 2.0. (Mosaic requires the freeware package Win32 to operate). These were evaluated in conjunction with a communications package called TwinSock.

The later version of Mosaic is far superior to the former in speed of presentation and quality of display. Mosaic and TwinSock are public domain products that are less powerful than Netscape with PPP, but accomplish the same MMECR functions. PPP is a full TCP/IP product that allows a connection to the Internet through the Nova host. PPP allows for individual Internet addresses for each of the clients. TwinSock must be run on the client machine under the control of a Nova resident server, "tshost". The "tshost" program is provided with the TwinSock package. TwinSock uses the NSU Internet address. TwinSock supports both the Mosaic and Netscape viewers.

While Mosaic 2.0 and TwinSock are public domain programs, the rights to Netscape are unclear. The program was originally made available as freeware, however, it is understood that the later versions of the product are restricted rights. The most widely used Internet viewer, Netscape is available in New York for under \$30.00. Netscape with the Beame and Whiteside PPP reportedly retails for about \$100.00.

The commercial Internet service provided by Prodigy was also used as a viewer. It was found to be very suitable as a viewer. For \$8.00 a month for five hours of use, it provided a low cost means of accessing NSU and the MMECR when NSU AT&T service was unavailable. Other MMECR researchers have reported similar results with American OnLine and CompuServe.

In evaluating the viewers, it was found that Netscape is vastly superior to Mosaic 1.0 in presentation quality. However, little difference was found with Mosaic 2.0. Netscape was ranked first because it was found to be more forgiving in presenting text that does not exactly conform to HTML syntax. In speed of execution, very little difference was found between Netscape and Mosaic 2.0 when used over TwinSock. Mosaic 1.0 is noticeably slower.

Setup ease, was not an issue with the viewers. Mosaic 2.0, Mosaic 1.0 and Netscape setup easily. TwinSock is more involved but straightforward. PPP was found to be troublesome because it modifies the autoexec.bat and config.sys files and uses more lower memory--a performance consideration in PCs.

A feature that was found useful is a standalone mode. Mosaic 2.0 operates in a standalone mode, and this enables the user to write a page in HTML and view it without having to be connected to a network. This feature is a very useful feature for the student.

Regarding the communications packages, the results were biased by difficulties with the PPP software. Overall, the researcher preferred TwinSock for the reasons shown in Figure 74.

<p>Easy to use. Installation Straightforward. Supports both Netscape and Mosaic (1 and 2). Execution speed adequate. Operates over IAS at 14.4 kbps</p>

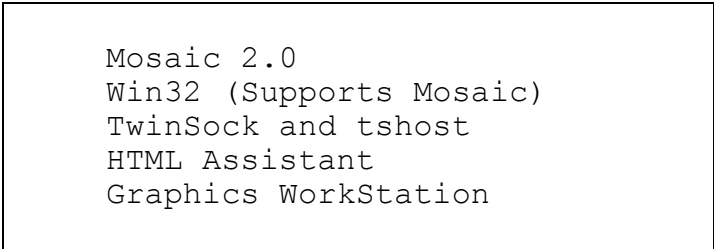
Figure 74. Observations on TwinSock

Regarding the other products, the researcher preferred the HTML Assistant over the Word package. It was found to be much easier to use. The researcher found it faster to write in HTML Assistant and view in Word Internet Assistant (or Mosaic 2.0) even though Word has a built in viewer.

For photo and graphics files, the researcher found the freeware Graphics WorkStation package. The program converts over twenty different picture formats including gif or jpeg. The program is easy to install and use.

In summary, the researcher found that the products listed in Figure 75 provide a very capable HTML support software capability for the student. Because the products are public domain programs, the University could freely distribute the programs to the students.

The programs in Figure 75 will easily fit in a single CD loaded in uncompressed format. The CD would save numerous hours for new MMECR members and would enable students to prepare and view HTML documents quickly. This CD ROM would then represent all the software required for the MMECR project. It would represent a zero cost (initial and operating) support software system for the student.



Mosaic 2.0
Win32 (Supports Mosaic)
TwinSock and tshost
HTML Assistant
Graphics WorkStation

Figure 75. No Cost Support Software for the MMECR

The researcher now uses HTML Assistant and Mosaic 2.0 (standalone) exclusively for the preparation of HTML documents. For those who require the best quality viewer, Netscape is outstanding and is reasonable in cost. It has earned its position as the most commonly used viewer.

Regarding the Beame and Whiteside PPP communications package, however, the issue is the need for a long distance call. It was found that TwinSock was a cheaper and more effective alternative for the researcher. Also Prodigy with its local telephone number and viewer was a cost effective connection into the Internet and MMECR.

Summary

The objective of this task was to define the system design to the component level. The task has been accomplished and the results are shown in Table 13.

The components specified in Table 13 provide NSU with a baseline MMECR design that can be assembled today. This achieves a major goal of this dissertation.

The system proposed is low cost. A student can procure the equipment required for the MMECR for less than \$2,000.00. The University can buy the MMECR components in Table 13 for under \$100,000.00.

<u>Student's System</u>	
Multimedia Intel 486 (\$2,000)	
Windows (N/C)	
V.34 Modem (\$200)	
Connectix Video (\$100)	
HTML Supporting Software (Figure 75)	
Operational Software (Table 14)	
<u>NSU Host System</u>	
Sun SPARC 20 (N/C)	
Solaris (N/C)	
Wabi (N/C)	
Connectix Video (\$100)	
Sound Blaster Audio (\$400)	
Operational Software (Table 14)	
Motorola BitRUNR Network Hub (\$50,000)	
<u>Support Facility</u>	
(Adds to NSU Host System)	
InFocus LitePro 570 Display (\$7,500)	
Cannon RE-650 Document Camera (\$3,600)	
Genis Standalone CD ROM Duplicator (\$10,000)	
Fujitsu M2531 M-O Disk System (\$4,000)	
Casio QV-10 Image Camera (\$1,000)	
Support System Software (\$10,000: Figure 72)	

Table 13. MMECR Component Level Design

The figure for NSU includes a recording and CD ROM duplication capability, expensive features that can be deferred until the operational system is proven.

The two key components in the system are the Network Hub and the operational software. The researcher has studied the available products for the last two years and the hub was not available until recently--a statement supported by the Motorola product announcement.

The components in Table 13 with the operational software addressed in the next task will provide NSU with a MMECR that will support up to sixteen POTS or ISDN users. Alternatives for lowering the cost and risk are also addressed.

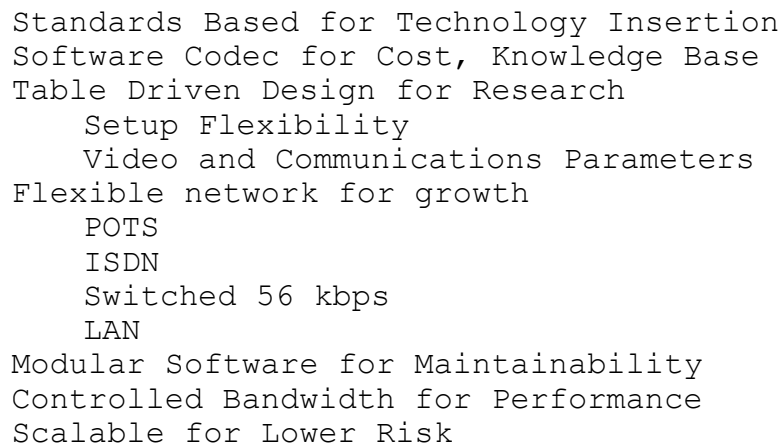
Task 7. Design the Operational Software

Introduction

At this point in the design process, feasibility has been demonstrated, a system concept based on the requirements has been presented, and a component level design has been completed. The hardware components were listed in Table 13, and the support software components were identified in Figure 72 and 75.

To complete the design process, a module level design for the operational software is now presented. Two separate software programs packages are addressed: one for the student system; and, one for The NSU host.

The designs are based upon the considerations shown in Figure 76. These considerations are discussed first and then the designs are addressed.



Standards Based for Technology Insertion
Software Codec for Cost, Knowledge Base
Table Driven Design for Research
Setup Flexibility
Video and Communications Parameters
Flexible network for growth
POTS
ISDN
Switched 56 kbps
LAN
Modular Software for Maintainability
Controlled Bandwidth for Performance
Scalable for Lower Risk

Figure 76. Design Considerations

Standards Based

First and foremost, the system should be standards based. This means the system should be built around T.120 for application sharing, H.320, H.323, and H.324 for video, and the G.711, G.722, G.723, and G.728 for audio. The industry has adopted these standards, and even previous holdouts--Intel and Creative--have adopted these standards.

Adopting a "standards first" design provides NSU with two benefits. First, it will ensure the ability to procure components cost-effectively. Second, it will enhance knowledge in this important technology area.

Based upon expressed corporate positions, it is projected that the VTC industry will upgrade the technology in view of standards. Adopting a standards based approach will keep the University well-positioned for technology insertion. Compatible components and products will be competitively available.

Adopting a standards first approach will provide a learning and research environment for NSU students and the MMECR. By building to the standards and using the products in a working system, the University will enhance its knowledge base and expertise in the mainstream of the technology.

Software Codec

Compression and decompression is required on both the audio signal and the video signal. The design could be implemented with either a hardware or a software approach, however, the researcher recommends the software approach. The advantages and disadvantages considered for each approach are shown in Figure 77.

Codec Approach	Advantages	Disadvantages
Software	Cost Flexibility Design Control Learning Base Easily upgraded Standards Compliant Interface Control	Performance Schedule Technical Risk
Hardware	Performance Technical Risk	Cost Rights

		Lack of Application Interfaces
--	--	--------------------------------------

Figure 77. Hardware or Software Codec

The primary considerations favoring the software codecs are cost, flexibility, and the ability to control the application interfaces. If the system is to be built using existing hardware (or software) codecs, the application interfaces for these component must be well known. In practice, these interfaces are proprietary and difficult to obtain.

The primary consideration favoring the hardware approach is processing power. With a software codec approach, the processor has to run the codec, a job that can be accomplished easily by a hardware codec. In this case, however, processing power is not an issue.

When this study was begun, the Intel 386 was the basis for systems being sold. Today, it is difficult to find a Intel 386 based machine. Many NSU students entering in 1996 or later will have a Pentium or better system.

Since the processor speed is expected to continue to improve, the researcher believes that processing power will not be a limiting factor in the system. Wilson presents results using the InVision conferencing package running on a Pentium 90 with the National Semiconductor software based codec. The author claims the CPU load varied from 10%-15% (Wilson, 1995).

Wilson noted that the current family of processors has the power to support real-time compression for two way video at a cost below hardware based systems (Wilson, 1995). Working at National Semiconductor, the author supports a design approach based upon a software codec and POTS based delivery over V.34. One of the significant points that the author makes is that the lower bit rate of POTS based systems as opposed to ISDN prevents the overload of the codec (Wilson, 1995)."

Wilson claims: "A Pentium class PCs can run a QCIF H.320/ISDN software codec while the P6 should perform even better thus enabling an explosion of software based video conferencing products (Wilson, 1995)." Intel has already begun shipping the P6 (Wilson, 1995; Davey, 1995).

The driver behind Wilson's approach was price. Wilson uses a H.320 based hardware approach of \$2500. Wilson contrasts that with a software codec approach of \$200-\$700 including the camera and the V.34 modem.

Rubery also supports the software codec approach. The author finds that they are the cheapest solution and downloadable (Rubery, 1995)."

This researcher has reached the same conclusion. The processing power is available for a software codec approach. Further, the nature of the MMECR as a research project makes research and project work in the codec area attractive.

When the special purpose processors, such as the AVP III of AT&T are readily available and standards compliant, the researcher would revisit the decision. However, in the near term, the software codec approach has been selected for the system design.

Table Driven Design and Prioritized Bandwidth

The approach to system setup was described in the discussions surrounding Figure 59. The design described there gives the instructor full control over the screen format and execution.

Internally, the MMECR design is table driven; that is, user selectable parameters are provided. This enhances the utility of the design for operational flexibility and experimentation. The list of variables that need to be included in the tables are shown in Figure 78.

Frame Size (Pixels)
Frame Rate (FPS)
Color Bits (4-24)
Audio Bandwidth (2.4 kbps-28.8 kbps)
Audio Priority (1-3)
Video Bandwidth (2.4 kbps-28.8 kbps)
Video Priority (1-3)
Data Bandwidth (2.4 kbps-28.8 kbps)
Data Priority (1-3)
Minimum Poll Rate (Tenths of a Second)

Figure 78. System Tables

For experimentation the operator can modify the values controlling selected video and communications parameters. The parameters selected are shown in Figure 78; system implementers may add others. For full flexibility, separate parameters are recommended for the instructor and the students.

Flexible Networks

The original concept for the system was based on homogeneous POTS networks. Based upon network coverage and the Proof of Principle demonstration, the researcher believes that the most effective distance education systems will be POTS based. However, ISDN does provide better performance, and the cost of the equipment has decreased significantly since the study has begun.

In the final concept, it was found that there is no need to distinguish between the networks. The Motorola and US Robotics Hubs can accommodate POTS, ISDN, or LAN connections, and the software modules proposed include codecs for all media. Accordingly, students can select the network for which they are willing to pay.

The system presented here has the flexibility to accept ISDN (H.320) or POTS (H.324) connections. Additionally, the system components can accept LAN (H.323) connections from faculty and students connected to the LAN. Since the selected network hub has the required connectivity, this can be simply accomplished by adding the required software codecs. Accordingly, network flexibility has been included in the design.

Modular Operational Software

The operational software is defined to the module level in Table 14. Two programs are envisioned comprised of common modules. One program tailored for the student and one for The NSU host. The modules included in both are shown in the Table as are significant tables and buffers.

Modules and Data	Student	Instructor
Initialization	X	X
System Setup		X
System Tables	X	X
Transmission Control Table		X
H.32X Codecs	X	X
G.7xx Codecs	X	X
Student Buffers (15)		X
Instructor Buffer (1)		X
Record/Retrieve		X
T.120 Interface	X	X

Table 14. Operational Software Modules

The initialization module contains the code that is necessary to initialize the student's system and the teacher's system. Remote login by the instructor will be accommodated. The System Setup module allows the instructor to controls the screen format as described in Figure 59. This module will also control the System Tables specified in Figure 78.

The Transmission Control Table is explained in the section below. After this Table are the codecs modules. These are the software routines that implement the coding and decoding of the audio and video signals in the system. As stated previously, the function of these modules can be replaced by applicable special purpose cards. The codecs will operate on the sixteen user buffers--fifteen students and one instructor.

The student and instructor buffers are used to contain the inputs from the sixteen users. The incoming coded V.34 streams from the modems will be stored in these buffers. They will be decoded and assembled into a composite screen that is then broadcast to all sixteen users.

The Record and Retrieve module is used to control the recording and playback of the class. The T.120 module will control the application sharing.

It is recommended that the modules be built in C++ or Visual Basic. The choice should be left to the builder.

Controlled Bandwidth for Performance

The Transmission Control Table is a key element of the design. The Transmission Control Table contains one flag for each user. It is displayed to the instructor on all the MMECR screens. It is referred to as the "question bar" in the Screen Concept.

When the instructor is presenting, the instructor's flag in the Control Table is set, telling the system that the processing power of the system should be dedicated to coding the instructor buffer.

While the instructor flag is set, the system will only poll the students for a question. Student images will be retrieved as needed, and only when requested by the NSU host system. If a question message is received during the poll, the question flag will be posted on the instructor's screen. When appropriate, the instructor will select the student. This selection tells the system to allocate the processor to the selected student's input buffer, and to broadcast the student's image and voice to the other users (including the instructor). When the student is done, the instructor deselects the student, and selects another student or resumes broadcasting.

To implement this concept, the system must contain a question message in addition to the audio and video coded data. For speed in processing, the question message should not be coded. Sending it as an unencoded byte saves the system from having to decode the incoming buffer.

This control scheme will result in an apparent half-duplex operation to the users (only one speaker and moving image at a time). However, the scheme reflects the ECR scheme of instructor control that has proven to be effective for classes. Additionally, it reduces background noise from the student's homes and prioritizes the bandwidth of the system to the active user's voice and image.

The control scheme reduces the processing requirements on the NSU host to no more than a simple point-to-point link. The NSU host only has to code the instructor and broadcast one audio input and one composite screen when the instructor is in control. When the student is in control, the system only has to decode that student's input and broadcast the audio and composite screen.

The Sun SPARC is significantly more powerful than the 486DX33 systems used in the Proof of Principle demonstrations. The V.34 modems should give bandwidth four times greater than the 7.2 kbps achieved with the Creative modems in the demonstrations. The Connectix camera is a black and white camera requiring one sixth the bandwidth as the Creative system. Accordingly, it is believed that these improvements and the control scheme will provide performance on the sixteen user system that is significantly better than the point-to-point Proof of Principle demonstrations.

Scalable for Lower Risk

The components for the system listed in Table 13 are estimated to cost \$86,600. To reduce technical risk, NSU may desire to take a lower cost approach to the system.

The design proposed supports such a course of action, that is, the design is scalable. Alternative design approaches are listed in Figure 79. The "System Cost" column represents the cost of the resulting system.

Alternative	System Cost
Baseline (Table 13)	\$86,600
Defer Support System	\$50,500
Use US Robotics Hub	\$10,500
Use Three V.34 Modems	\$ 1,100

Figure 79. Risk Reduction Alternatives

The first alternative design simply defers the procurement of the Support System components. There is no impact on the operational system.

The second alternative defers the support system and replaces the POTS or ISDN Hub with a POTS only Hub. This results in a sixteen channel system that supports V.34, but not ISDN. That is, the system is now a homogeneous V.34 system instead of the heterogeneous V.34, ISDN, Switched 56, and LAN system proposed. The Motorola Hub costs \$50,000. The V.34 US Robotics POTS Hub cost \$10,000.

The last alternative is the "no frills" option. Under this concept, NSU buys three V.34 modems at \$200 each, the video equipment, and the sound card and proves out the software. This can be accomplished for \$1,100.

Regarding the software, it also is scalable. Modules for a core implementation are shown in Figure 80. The MMECR could develop only these modules and prove them on the \$1,100 "No Frills" system in Figure 79.

Of the three options, the "no frills" option at \$1,100 is very attractive. If this proves out, the University would then need to decide on the V.34 POTS solution or the fully communications solution.

Building the "no frills" system will assist in making the decision. If the V.34 used in the "no frills" system proves out as an acceptable media, NSU can adopt POTS as its network of choice over ISDN.

Modules and Data	Use in Core Implementation
Initialization	Yes
System Setup	Yes
System Tables	Yes
Transmission Control Table	Yes
H.32X Codecs	H.324 Only
G.7XX Codecs	G.723 Only
Student Buffers (15)	Yes
Instructor Buffer (1)	Yes
Record/Retrieve	No
T.120 Interface	No

Figure 80. Risk Reduction Software

The POTS only alternative is also attractive. It has schedule advantages and is a medium risk approach. A recommended approach with rationale is offered in Chapter V.

Summary

The design of the operational software was presented in this section. The modules, major tables, and buffers have been delineated and described. The features of the system have been addressed.

This material completes the design. The hardware components were identified in Table 13. The software components were identified in Figure 72, 75 and Table 14. The operational concept was described under Task 5, and revisited in this section.

The system will be based on industry accepted standards for teleconferencing. The design recommends a software codec for cost and flexibility, although hardware components could be substituted. It is pointed out that the software codec approach will provide multiple opportunities for research. Further, the system uses a table based design that is ideal for experimentation.

The system and its components will support heterogeneous inputs from POTS, ISDN, and LAN sources. The system utilizes a transmission control scheme for the sixteen user system. The control scheme, with improved V.34 modems and black and white student images, promises performance that is equal to or better than the point-to-point Proof of Principle system.

The NSU system can be implemented for less than \$100,000. Risk reduction alternatives have been presented that lower the cost to \$1,100. For NSU students with a multimedia Windows based PC and V.34 modem, the cost of the system is zero. For those with a 486DX33 or better, three additions may be required. A V.34 modem (\$200.00), sound package and CD ROM (\$400), and an optional VTC camera (\$100).

In summary, the design presented here possesses the characteristics listed in Figure 81. It is believed that the design will result in a significant upgrade to the ECR. Further, it will provide multiple opportunities for research that will increase the prominence of NSU in distance education technology.

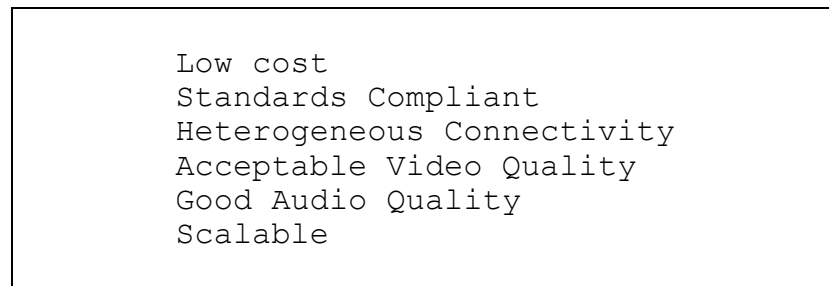


Figure 81. Characteristics of the Resulting Design

Task 8: Issues and Recommendations

Introduction

During the conduct of the effort, issues were encountered that the researcher feels should be highlighted for discussion at NSU. They are summarized in Table 15.

<u>Management</u>	
Organization Structure	Separate
Staffing	Compensate
Courseware Preparation	Collaborate
Establish a Laboratory	Build knowledge base
MMECR Program	Expand
<u>Courseware</u>	
Standardized Tools	Delay
Style Guide	Investigate now
Courseware Library	Rapid Development
High Technology	Leverage Courses
Architectures	Close the Gap
Student Equipment	Publish a Standard
<u>System and Networks</u>	
Network Bandwidth	Cost over Quality
ISDN versus POTS	Student decision
Video Server	Lease or WorldWorx
Internet Connection	Delay until IPv6
Metropolitan Network	100 Mbps LAN

Table 15. Issues and Recommendations

A recommendation is included for each issue, however, these are only the researcher's observations. They are offered in support of discussion on the distance education program at NSU.

Management

Regarding management, the developments in computers and communications are leading to a major restructuring and downsizing of the workplace. After reviewing the material on education and educational technology, the author believes that this restructuring will eventually extend to education. While the number of distance education projects is currently limited, the same forces that are fueling downsizing in industry and government will come into play in education.

In the area of Management, issues were highlighted that should be considered by Nova Southeastern University. The first deals with organization and staffing, and the second deals with courseware and a third deals with a research facility.

As shown in Figure 7, the faculty at Purdue strongly favors separate management of the distance education program. As reported, the educators at Purdue could not attract and hold the staff they needed to pursue distance education. The results at the University of Hawaii were similar, Figure 8.

The considerations reported from Purdue and Hawaii should be reviewed in detail at Nova Southeastern University. Based on the reports, the researcher recommends that the distance education program be separately managed and staffed. Because of the high technology involvement, it is also recommended that salary premiums or other compensation be offered for instructors in distance education.

Courseware development and market position in distance education emerge as issues that need to be addressed. If the educational marketplace experiences a major downsizing and restructuring, it is believed that the institutions with the strongest courseware will be the most likely to survive.

In the development of courseware, Nova Southeastern University may want to consider a consortium approach. This was utilized on the Saskatchewan program.

There are numerous small high technology educational firms offering credible corporate training. The researcher recommends that a collaborative assistance agreement be considered with such a firm. If these specialists were used as consultants, it would augment the NSU courseware capability while maintaining its educational integrity. Collaboration with an interested University is also a consideration.

The University should consider the establishment of a laboratory for distance education. In addition to providing a facility for the study and generation of interactive video concepts, this facility could serve as a research setting to study distance education developments.

Issues such as video quality versus bandwidth, compression technique versus processing power, and courseware effectiveness could be evaluated. The laboratory could be used to export the technology and courseware developed to the University. The design of the support system presented here should be considered as a start for such a facility.

The distance education laboratory could be used to build a base of expertise. Barriers in the area of distance education include the lack of expertise in addition to the lack of the technology. The technology necessary to support the MMECR is emerging, but the supporting knowledge base represents a more severe barrier.

Regarding the lack of expertise, it is recommended that the MMECR project be continued. It has been found that the MMECR group is working directly on areas involved with distance education. Participating members should be granted credit for their project work, and participation in the group widened to include business and education students.

Courseware

Emerging technology will enable telecommuting at a cost unimaginable five years ago. The cost of this technology coupled with the cost of travel and continuing education will change the economics of education products.

Employers will be looking for low cost ways of keeping their staff technical proficient. New products and courses will be required in the resulting marketplace. The maturing of the population may also impact this marketplace. In short, the educational market and product will change.

Given this environment, the long term viability of NSU's program rests in its ability to deliver quality courseware. It was reported that quality multimedia instruction requires different skills and techniques than traditional teaching. Further, the multimedia courseware is more labor intensive than traditional course material to develop.

To assist in the courseware development process, NSU should adopt a development program built around standardized tools, a style guide, and a courseware library. Initially, the University should allow the instructors to determine the optimum tools for the development of courseware. Once tools are defined, a style guide should be published, the tools mandated, and a library of the resulting courseware maintained. The library can then be used for rapid "cut and paste" short courses that could be used offering as industry short courses.

In conducting this effort, it was observed that the Student information architecture and the University information architecture were different. One uses Windows or Lotus and the other uses UNIX. This situation is certainly not unique to NSU, however, UNIX represents a problem for students working in a the non-UNIX environment.

The first difficulty is in using UNIX. There is little argument that the Windows interface is easier for a novice to use than UNIX. Secondly, students have difficulty in executing projects using UNIX because they do not have easy access to machines running UNIX.

If students are viewed as a resource that can be used for projects, it would be ideal if the architecture gap were eliminated or at least closed. Closing the gap cannot be accomplished in the near term, however, the recommendations on the purchase of Wabi or a Power PC were made to begin the process. Wabi is a software bridge for Solaris, and the Power PC is a hardware alternative. Either will enable Windows based courseware development products to be run. The use of LINUX is also a possible solution.

Lastly in the courseware area, it is recommended that NSU publish a "recommended" minimum computer capability for students. This recommended configuration can then be used as a floor in the development of distance education products. The student equipment recommendations listed in Table 13 should be considered.

Systems and Networks

The systems and network issues involve bandwidth, quality, coverage, and cost. ISDN has more bandwidth and provides better quality than POTS. ISDN comes with heavy cost and installation penalties, however. The use of POTS offers a reasonable balance of cost, quality, and network coverage.

The best network solution would be the Internet. Unfortunately, all the trials indicate it is marginal for real-time applications. In this regard, it is recommended that NSU let others take the lead on the Internet for video use and wait for IPv6 results.

The researcher is not optimistic on Internet use for audio or video until it becomes ATM based. George Heider from Intel (ProShare) shares similar views. "Video over the Internet is not satisfactory (Heider, 1995)."

Regarding cost, ISDN video servers are expensive to buy and maintain. They can be purchased, leased, or a service (WorldWorx) utilized. The researcher favors the later two options until the technology stabilizes and the costs come down. Further, the researcher recommends that existing ISDN video servers be used for conference room type applications, not distance education with collaborative computing. Michael Black, the Vice President of DataPoint would agree. ". . . what is good for the conference room is not necessarily good for the PC (Black, 1995)". So does Heider: "ISDN is satisfactory for the office, but not the home (Heider, 1995)."

Regarding the NSU MAN, fiber should be used wherever practical and cost-effective. Unfortunately, this does not include connection to the NSUs PCs and workstations. For these connections, the 100 Mbps twisted pair is the cost effective media of choice at this time.

The investment in a fiber optic link to connect the University hub facilities is recommended. Further, if a link could be made to the Hotels that serve the Institute, high quality interactive video would be assured.

Summary

Eight tasks have been accomplished for this effort. The tasks have resulted in the successful design of a distance education system for NSU. A "no frills" prototype of the system can be built by the University for less than \$2,000. A fully capable sixteen user system can be built for less than \$100,000.

The most pervasive task in the effort was the literature and product searches. They resulted in an understanding of the trends involved in this rapidly emerging technology.

The design tasks have included the demonstration of feasibility, the gathering of requirements, and the consolidation of the data. Once this was accomplished, a systems concept was developed, hardware and software components were selected, and the operational software was designed. All designs were presented to the component and module level.

Issues were identified throughout the effort. These have been included with the researcher's recommendations. They are intended to support discussion at NSU.

Chapter V Conclusions

Introduction

The objective of this effort was the design of a low cost distance education system for Nova Southeastern University. The objective has been met.

NSU can build the complete system proposed for under \$100,000. The system will accommodate students using heterogeneous POTS, ISDN, switched 56 kbps, or LAN connections. The system integrates with existing Sun and Solaris architectures at NSU.

Lower cost alternatives have been identified. A sixteen channel system that operates over POTS can be implemented for less than \$11,000; a three channel pilot system can be built for under \$2,000.

Students with an Intel 486 multimedia PC can participate in the MMECR at no additional cost. Students without the requisite capability (sound card, microphone, speakers, and CD ROM) can add the capability for under \$400. Modem upgrades to V.34 are recommended, but not necessary. V.34 modems are available for under \$200.

The design has been presented to the component and module level. The concept of operation has been presented, and design details on the operational software have been given. Cost estimates have been provided.

The design is supported by Proof of Principle demonstrations and extensive literature and product searches. The Proof of Principle demonstrations showed that multimedia information, including video, could be transmitted at rates down to 7.2 kbps. At that rate, images were recognizable and the audio was acceptable.

The design proposed is based on ITU standards and uses a software codec. Polling has been used to ensure that the system is equivalent in quality to the Proof of Principle system. Black and white student images are used to reduce the transmission requirements below that required by the Proof of Principle system.

An extensive product search enabled all necessary components of the system to be identified. The product search resulted in over fifteen inches of product information sheets. Model name or numbers are provided for all components, and the equipment can be procured today.

In Chapter I, the effort was introduced and the significance was explained. A Glossary was presented to help explain some of the terms of reference in the paper.

In Chapter II, the literature search was presented, and the technology was introduced with a discussion of a simplified VTC. The literature search resulted in the compilation of over 190 references.

In Chapter III, the methodology for the eight tasks was described. Chapter IV contained the findings and results.

In this Chapter, the effort is concluded with a brief review of the findings and results. These are first addressed by study area, and then by goal. A program to build the MMECR and recommendations on future research complete the Chapter.

The Research Areas

Three areas were the focus of this effort. They were management, systems and networks, and courseware. Table 16 shows selected findings in these areas; detailed findings were presented in Table 7 through Table 10.

Management

Separate organization for distance education
 Separate staffing for distance education
 Distance Education Laboratory for Research
 Let the student pay for ISDN
 Network progress is paced by fiber installation

Courseware

Courseware is key
 Build courseware expertise
 Instruction is situational
 Quality student images not essential

Systems and Networks

Standards based design recommended
 Software codec for low cost design
 Black and white student images for bandwidth
 V.34 modems superior to predecessors
 Internet questionable for real-time use

Table 16. Selected Findings

Management

The major finding in this area is that distance education should be separately managed and staffed. This conclusion is based on the results reported at Purdue University and the University of Hawaii. Researchers at those institutions found that distance education required unique management and teaching skills. They recommend separate staffing with increased compensation.

This finding should be considered in conjunction with the recommendation to establish a support system and laboratory for courseware development and research. To resource the separate organization, it is recommended that a grant be pursued. Further, it is recommended that the MMECR group be used as the initial research core for the organization. A proposed plan of work and schedule for the MMECR to develop the system proposed here is included below in conjunction with this recommendation.

There are management issues regarding the networks used for distance education. First, ISDN has received a tremendous amount of attention. There is no doubt that ISDN provides better bandwidth than POTS, however, it has serious drawbacks as a network for the student. The drawbacks include its operating cost, coverage shortfalls, and installation delays approaching a year. If NSU desires to maintain an affordable education package, the sole use of ISDN will place a financial burden on the student that has to be considered against the lower performance, lower cost, POTS alternative.

Regarding network progress throughout the United States, it was found that the pacing item was the deployment of fiber-optic cable to support ATM. Areas of capability will emerge as the fiber optics are deployed, but the progress will be paced by two items: the RBOC's desire and ability to finance the improvements, and the ability of the line crews to physically lay the cable.

Courseware

In the area of courseware for distance education, it was found that quality courseware is the key to a successful distance education program. In that regard, it is recommended that the courseware development be separately staffed and compensated. This is in line with findings at Purdue, where it was found that the existing faculty could not support distance education. The use of a consortium, or consultants, should be considered. It would be ideal if the courseware developed could be leveraged to compete in the corporate short course training market.

To lower the cost of the courseware and ease the development process, it is recommended that NSU establish a courseware library in the support facility. A set of courseware tools and a style guide should be developed to standardized the material developed.

Lastly, some instructors at NSU did not find it necessary to see the student in the distance education system. This finding was consistent with results that indicate an audio only system is as effective as a voice and video system. From these findings it was determined that quality student images were not essential to the system.

Systems and Networks

The Proof of Principle demonstrations and the results reported have shown that POTS can be used for the MMECR. The system will improve as the processors become more powerful and better compression techniques are implemented.

The combination of standards, software codec, student polling, and black and white images have enabled a system to be designed that is remarkably low in cost. The tradeoffs incorporated into the design will enable comparable or better performance than the Proof of Principle system.

To design the system, the study focused on recent and emerging technology. It was found that analog based V.34 modems have emerged that provide reliable communications at 28.8 kbps. Further, network hubs that support heterogeneous V.34 and ISDN channels now enable the MMECR to be built.

The Internet offers ideal student coverage for the MMECR. Unfortunately, the protocol used--TCP/IP--was designed for text based messages, and the protocol does not provide speed of service. Accordingly, it is recommended that NSU refrain from major Internet investments until Internet Protocol version 6 is tested. Similarly, connection to IAS should be deferred until the system is developed and proven.

The Four Goals

Developments in Distance Education Technology

The first goal was to forecast developments in distance education technology. To accomplish this goal, it was necessary to understand video and processor trends, compression, networks, and courseware.

In researching the status of video technology, it was found that low cost systems were available that enabled video teleconferencing using POTS. These systems were used for experimentation and demonstrated for the NSU faculty. They demonstrated recognizable images and acceptable audio with a compression ratio of 350:1.

Advances in processing power and compression algorithms will enable much higher compression ratios (10,000:1). Accordingly, the system designed here will offer improving audio and video quality over time.

ATM is the direction of future networks. When this fiber optic based network is in place, the throughput and real-time restrictions of the current networks will be eliminated.

Regarding the Internet, there are differing opinions among leading researchers about its future ability to handle real-time data. Until the new Internet Protocol is developed and proven, this researcher is skeptical about its use for interactive real-time applications.

Regarding courseware developments, progress will be slow. The development of courseware for distance education is very difficult. Progress will be based on greater reuse and standardized tools, and multimedia specialists will see increasing use in the development of the courseware.

Determine the Requirements at NSU

The second goal was to determine the requirements at Nova Southeastern University. This has been accomplished and presented. The requirements included the inputs of the NSU faculty, and MMECR group.

Surprisingly, the finding with the greatest impact involved the requirement for the student image. The faculty did not see the need for high quality student images. Some members of the faculty did not believe they were required at all.

Operating from this observation, the researcher was able to lower the cost and bandwidth of the system by using black and white student images. Additionally, this observation enabled the polling algorithm to be used to control bandwidth. This allocates the maximum bandwidth to the instructor. The design provides an update of the student image only when they ask a question or the system is idle.

Identify Designs for NSU

Three alternate designs have been proposed. They range in price from under \$2,000 for a pilot system to \$100,000 for the full system. The cost driver is the network hub. It ranges in price from \$600 to \$50,000 depending on the number of channels and the types of networks supported.

The lowest risk design uses three V.34 modems. Using this design, NSU can build the software and test the system before making any major investments.

If NSU desires a more aggressive alternative, it can purchase the US Robotics sixteen port V.34 enterprise hub. Hayes offers a similar product. This is an \$11,000 alternative. This alternative only supports POTS channels, however, it provides a platform that can be used to demonstrate the operational software for the full sixteen user system.

The third alternative is to purchase the hub with full POTS, ISDN, LAN capability. Pricing on this device has not been finally set, but the marketing indications are that it will be \$50,000. It may be possible to obtain the system as a loan, or it may be possible to interest Motorola or US Robotics in a collaboration. This results in a \$50,500 solution for the host system.

The balance of the system cost is in the support system, and these costs should be deferred until the system is proven. These alternatives are listed in Table 17.

Alternative	Cost	Advantages	Disadvantages
POTS (3 channel)	\$1,100	Lowest Cost	Schedule
POTS (16 channel)	\$10,500	Low cost All 16 channels	POTS only
POTS or ISDN 16 channel	\$50,500	Full network capability	Expensive Risk

Table 17. MMECR Alternative Designs

Recommend a Design

Table 17 lists the advantages and disadvantages of the three approaches proposed. The POTS 16 channel alternative is recommended.

The 16 channel POTS alternative gives system researchers a reasonable research platform and design goal. If they are successful, the equipment will provide an operating capability for NSU. The cost is reasonable, and it will enable student researchers to gain expertise in all areas of the system except the ISDN networking.

In that regard, ISDN has proven to be technically and financially challenging, even for industry. By concentrating efforts on the codecs, control software, and network interface for the POTS system, NSU can build its expertise in these areas.

The effort to build the software components and network the 16 channel POTS system appear to represent excellent, achievable student projects. Recommendations in this regard are included below.

The MMECR Group

For over a year, the researcher has participated in the MMECR group. It has proved a stimulating forum for research.

It is recommended that the MMECR be expanded, and that Master's degree students be awarded credit for their project work. If this can be accomplished, the MMECR represents an excellent source of talent for project work, including building the software components of the proposed MMECR system.

A task breakdown for the project is proposed in Figure 82. Tasks are grouped by timeframe so an initial program of effort could be structured.

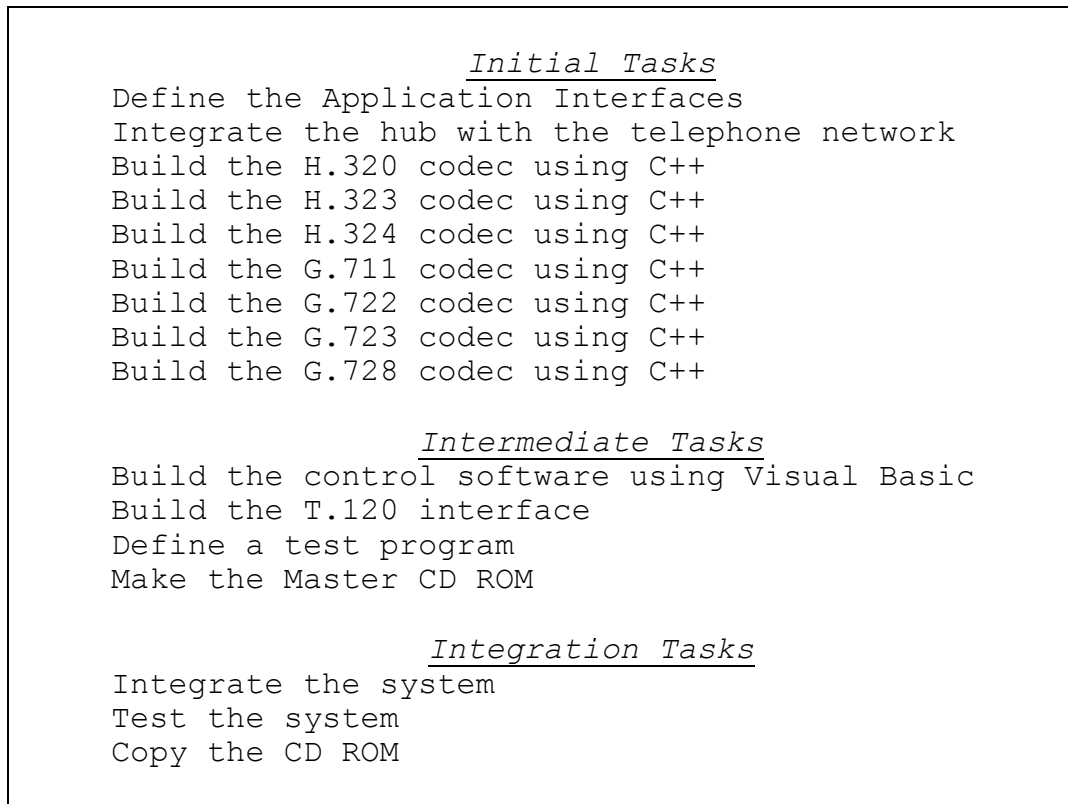


Figure 82. Possible Research Tasks

The MMECR has created multiple opportunities for publication. As an example, the requirements defined here as well as requirements gathering by ECR and HTML, would seem to merit interest at a suitable forum.

If the system proposed is implemented, papers are anticipated on the implementation of the system, its use in courseware design, video quality and human factors studies for distance education, product evaluation, and system effectiveness vis a vis other educational techniques.

Future Research Areas

The literature search for this effort revealed numerous areas that might be of interest for future researchers. A number of barrier areas were encountered that were outside the scope of this effort. The areas are listed in Figure 83.

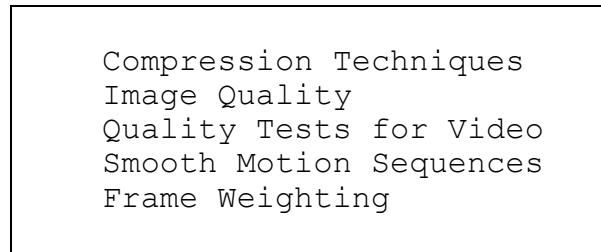


Figure 83. Future Research Areas

The advances in processing power have enabled new methods of compression to be developed. Compression and compression techniques is an area of research for those with a mathematical interest. Application specific compression techniques may also be of interest.

A valuable research area involves the objective evaluation of video quality. There is no known quantified information available in this area. Variables in this area include frame size, frame rate, and color density (number of color bits) versus application effectiveness.

An area related to video quality is frame weighting. In normal video broadcasts, all frames are weighted equally. In a sporting event certain frames are of more importance. An intelligent codec could prioritize the frames. Timing would be maintained by reducing the content of low priority frames. Similarly, portions of frames could be weighted. The action part of the screen could be transmitted more frequently than the stationary parts.

The support facility proposed will give NSU a system for distance education research. The support facility will also enable research to be conducted in courseware preparation, tools, and material distribution.

Summary

Today's rapid paced technical environment provides a wonderful opportunity for NSU. Capabilities that were previously forecasts are now becoming reality.

The MMECR project has enabled the University to monitor the pace of developments in technology and distance education. Accordingly, Nova Southeastern University is well positioned to enhance their position as a leader in distance education.

The knowledge gained from the effort can be used to improve the current NSU distance education electronic classroom and assist in the investment decisions that the University faces in upgrading its distance education system.

The Chief Technology Officer of Sun Microsystems, Eric Schmidt, speaks to the need for rapid action on the part of NSU: " . . . in my experience, by the time I have figured out there is a problem, between six and twenty companies have already been founded to solve it (Adam, 1995)." The pace of developments in distance education is no less. It is hoped that the University will capitalize on this effort and move forward quickly.

In closing, the objective of this dissertation was to develop a low cost video system for distance education. A design has been presented that can be implemented at no cost to many students--a "no cost" system. A sixteen user system for the University has been recommended that costs less than \$11,000.

In short, the objective has been met. The effort is complete.

Appendix A Information Sources

Monmouth College Library.

Monmouth College On-line Catalog. Technical Topic
or Subject.

Guide to Periodicals

ACM Guide: QA76, first floor reference section.

ACM: Stack 1 and Stack 10, basement

IEEE: Stack 23

Proceedings of the IEEE: Stack 47

Ft Monmouth Technical Library - Interloan Library

CD-ROM

Proquest - IEEE Publications on Disk

INSPEC, the IEEE on Disk; becoming available

Science Citation Index

Dialog on Disk

Journals ACM, IEEE

Information Sources
(Continued)

Nova Southeastern University

Computer Select CD-ROM at Einstein Library
Dissertation Abstracts
First Search; Internet database access
 INSPEC, the IEEE on Disk - restricted
 World Catalog of Books (Worldcat)
 Contents 1st (Journal Database)
 Microcomputer Abstracts
ERIC - Database at Syracuse University
Hytelnet - Internet Libraries
 Fla. State
 Smithsonian
 Einstein at Harvard

Drexel University

Dialog on Disk - restricted

University of Pennsylvania

Science Citation Index
Dialog on Disk

Information Sources
(Continued)
World Wide Web Sites

Connectix--www.connectix.com
Hayes--www.hayes.com
ISDN Rates--listproc@tap.org
ISDN Information--alumni.caltech.edu/~dank/isdn
ITU--www.imtc.org/imtc
ITU Specifications--iii.net.imtc
Levin, J. C.--www.nova.edu/~jclewin
Microsoft--www.microsoft.com
Motorola--www.motorola.com
North Carolina State University--
www2.ncsu.edu/eos/service/ece/project/succeed_info
Nova Southeastern University--www.nova.edu
PictureTel--<http://www.pictel.com>
Simpson, Michael J.--www.nova.edu/~simpsonm
Sun Corporation--www.sun.com
US Robotics--www.usr.com
Video Equipment Survey--[www2.ncsu.edu/eos/service/ece/
project/succeed_info/dvvc_survey](http://www2.ncsu.edu/eos/service/ece/project/succeed_info/dvvc_survey)

Information Sources
(Continued)
Selected Telephone Numbers

Dell Computer: 800-449-3355

ISDN Information (AT&T): 800-992-ISDN

ISDN Information (Intel): 800-538-3373 x208

J&R Computer World: 800-221-8180

MicroComputer Warehouse: 800-696-1727

USA Flex: 800-759-0334

Appendix B
Multimedia ECR Pages

Appendix C
Selected Product Information

Connectix Camera
QuickCam

Motorola BitRUNR Hub

Hayes Century Rack

US Robotics Enterprise Hub

Appendix D
Biography: Michael J. Simpson

Education

Nova Southeastern University: 1992 - Present
Fairleigh Dickenson University: MBA, 1981
University of Pennsylvania: MSE, 1970
Drexel University: BS, 1966

Experience

Thirty years in the design, development and production of large DOD information systems. Multiple assignments including software and system designer, Deputy Project Manager, Project Manager, and Deputy Executive Program Manager. Project Manager for automated test systems; Deputy Project Manager for command and control systems; Technical Manager for spread spectrum communications systems, and Deputy Executive Program Officer for command and control.

Recent Publications

Two recent papers were presented (see references). A Metrics paper was presented at a DOD Conference in 1995, and a paper on International Interoperability was presented at an IEEE Conference in 1994. Other papers have been given to national and international groups as large as six hundred attendees.

Appendix D
(Continued)

Awards

Awarded the Distinguished Civil Service Medal on two occasions. Numerous performance awards and DOD commendations.

Affiliations

Board of Directors, Armed Forces Communications and
Electronic Association
Senior Member, IEEE
Member Delta Mu Delta, National Honor Society in
Business Administration

Personal

Married: Maureen
Two Adult Children: Scott and Neal.

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Glossary

Asymmetric. In an information exchange between two points on a network, the quantity of information passed by the two points can be equal or unequal. If the quantity of information is equal, the exchange is symmetric. If the information exchange is unequal, the exchange is asymmetric.

Asynchronous Transfer Mode (ATM). "The method of data transmission used by Broadband ISDN. Specified as 53-octet fixed length packets transmitted over a packet switched network" (Schnaidt, 1992, p. 439).

Audio Card. The audio card provides the PC interface to a microphone, speakers, and the CD ROM. It also performs the analog to digital conversions that are necessary to convert analog audio signals to digital.

Bandwidth. The rate at which information can pass over a media or network (Portway & Lane, 1994).

Basic Rate ISDN. "Two bearer channels of 64 kbps for bulk data transfer plus a data link 16 kbps channel for control and signaling information" (Schnaidt, 1992, p. 439).

Broadcast. "Transmission of the same data to all destinations" (McDaniel, 1994, p. 74).

CCITT (Consultative Committee for International Telegraphy and Telephony). Now the ITU (International Telecommunications Union). A standards setting body.

Codec. Used to refer to a coder, decoder, or both. To compress (or code) data and decompress (decode) it back to its original form, the coder and decoder must be matched. The algorithm used in one must be based on the algorithm used in the other. Accordingly, coders and decoders are typically found together, and can reside on the same processor chip. See Lossy and Lossless.

Coder. A coder is an algorithm that takes data, such as an image, and transforms it into an alternate form. The alternate form in this case is a reduced size representation of the original. See Codec.

Collaborative Computing. A form of computing that has been enabled by the emergence of networks and software designed to support groups. In collaborative computing, a group of individuals work on a common problem or item of interest. This can involve a common application or database on which all of the individuals are simultaneously collaborating. The computer records the collaborative results.

Common Intermediate Format (CIF). ITU image display format using 352 x 288 pixels.

Compression. Transforming information to reduce space or bandwidth requirements. See Lossy and Lossless.

Copper Loop. The set of all twisted pair wire connections from the telephone subscriber's residence to the first interface point of the telephone company's equipment. Includes over 140 million lines.

Decoder. A decoder is an algorithm that takes data, such as a compressed image, and transforms it into a representation of its original form. In this case a representation of the original image. See Codec.

DeskTop Video Teleconferencing (DVTC). Video teleconferencing using a desk top computer augmented with additional equipment. Typical additional equipment include a camera, video board, audio board, and a high speed communications link. (See Figure 15).

Digital Cosine Transform. A form of lossy compression. Transforms time domain information to frequency domain information or reverses the process. The basis for ITU H.261.

Downsizing. Reducing, simplifying, or restructuring an organization, computer system, or area of interest.

Electronic Class Room (ECR). A multipoint network that allows users to share information on a same time, different place basis. In practice, a user connects to the ECR using a PC and modem and shares information with the other users in the classroom. Messages and data are exchanged. As used in this report, ECR is differentiated from MMECR. ECR refers to the original text based NSU system created by Dr. John Scigliano, Dr. Jacques Levin, and Donald Joslyn. MMECR refers to the on-going project and proposed system for multimedia information exchange including video, audio, and data.

Fiber-optic cable. "Thin, flexible strands of clear glass or plastic that can serve as a transmission media capable of carrying several gigabytes of data over short or long distance" (Ralston & Reilly, 1993, p. 549).

Fractal Compression. A form of lossy compression yielding very high compression ratios.

Full-duplex. A network media, such as a set of telephone wires, may be full-duplex or half duplex. In a full-duplex system, both end points of the media may transmit simultaneously. In a half-duplex system, only one end point may transmit at a time.

Graphics Card. The graphics card converts the data from the computer memory into a format suitable for the display. Typical formats are VGA and SVGA.

Groupware. "Computer software specifically designed to support the collective work of teams" (Sprague & Watson, 1993, p. 437).

Half-duplex. A network media, such as a set of telephone wires may be full-duplex or half duplex. In a full-duplex system, both end points of the media may transmit simultaneously. In a half-duplex system, only one end point may transmit at a time.

Heterogeneous Network. A network consisting of nodes that have dissimilar communications or information systems architecture.

Homogeneous Network. A network consisting of nodes that have similar communications or information systems architecture.

HyperText Markup Language (HTML). The computer language used to achieve interoperability on the Internet. A standardized language interpreted by computer programs called "Browsers" (For example, Lynx, Mosaic, and Netscape).

Institute of Electronics and Electrical Engineers (IEEE). A standards setting organization.

Integrated Services Digital Network (ISDN). A network standard for telecommunications. The basic capability utilizes two 64 kbps data channels and a 16 kbps control channel.

Interface. "A mechanical or electrical link connecting two or more pieces of equipment. A shared boundary. A physical point of demarcation between two devices at which the electrical signals, connectors, timing and handshaking are defined. The procedures, codes, and protocols that enable two entities to interact for a meaningful exchange of information" (Guengerich, 1992, p. 350).

International Standards Organization (ISO). A standards setting organization.

International Telecommunications Union (ITU). A standards setting organization. Formerly the CCITT.

Internet Protocol (IP). See TCP/IP.

Internet. "A collection of more than 2,000 packet switched networks located principally in the United States, but also in other parts of the world, all linked using the TCP/IP protocol" (Schnaidt, 1992, p. 445).

Interoperability. "The ability of one manufacturer's computer equipment to operate alongside, communicate with, and exchange information with another vendor's computer equipment" (Schnaidt, 1992, p. 445).

JPEG Joint Photographic Experts Group. A standards setting organization. Also, a standard for compression of images.

Local Area Network (LAN). "A computer network located on a user's premises within a limited geographical area" (McDaniel, 1994, p. 392).

Lossless. A characteristic of the compression and decompression process. If data is compressed and subsequently decompressed such that the data is exactly the same, the process is lossless.

Lossy. A characteristic of the data involved in the compression and decompression process. At high rates of compression, some data can be lost. If the lost data does not impact the application, the data is referred to as lossy.

Metropolitan Area Network (MAN). A high speed network connecting computers in a regional area.

Modem. A device to transform digital information to analog information or the reverse process. Used to connect a computer to a transmission media such as a telephone line.

Motion Picture Experts Group. A Standards setting group. Also refers to a series of compression standards.

Multicast Backbone (MBone). A broadcast protocol for the Internet. The Internet uses the point to point Internet Protocol (IP). MBone adds broadcast addressing to the Internet. This means that a single address can be used in the packet to contact a group.

MultiMedia Electronic Class Room (MMECR). A multipoint network that allows users to share multimedia information on a same time, different place basis. The information includes simultaneous video, audio, and data. See also Electronic Classroom.

Multimedia. "The communicating of information in more than one form including text, audio, graphics, animated graphics and full motion (Freedman, 1991, p. 396).

Multipoint. A type of network that connects multiple nodes (points), or users.

Network Hub. A device that connects the multiple communications lines comprising the network.

Network. "The communication or connection system that enables computers to talk to another computer or another device" (Williams, 1993, p.362).

Open System Interconnection (OSI). The seven layer protocol stack developed by ISO for data communications. The layers are as follows: physical, data-link, network, transport, session, application, and presentation (Ralston & Reilly, 1993).

Open Systems. An approach to building information processing systems using hardware, software, and network components that comply with industry accepted standards such as OSI (Guengerich, 1992).

Packet Switching. Data is segmented into packets and sent across a circuit shared by multiple subscribers. As the packet travels over the network, devices such as switches read the addresses and route the packet to its proper destination (Schnaidt, 1992).

Packet. A collection of bits comprising data and control information sent from one node to another (Schnaidt, 1992).

Personal Computer (PC). A stand alone computer equipped with all the system, utility, and application software and the input and output devices and peripherals that an individual needs to perform one or more tasks (Guengerich, 1992).

Platform. Hardware architecture and systems software of a particular model or family of computers. The standard to which software developers write programs. Sometimes refers to the hardware and its operating system (Guengerich, 1992).

Point to Point. A type of network that connects only two nodes (points), or users.

Polling. A control scheme for multipoint networks. In a common network with multiple users, a scheme is required to control the flow of information. In a classroom, for example, students may speak when they want (on demand), speak when recognized (one at a time), or all speak sequentially (polling). In polling, all users on the network are periodically asked if they want to transmit. The network controller (the teacher) controls the timing and frequency of the polls.

POTS. An abbreviation for Plain Old Telephone Service. Refers to the capability of connecting to another network node using a dial tone and telephone number. Also referred to as the Public Switched Network (PSN) and Public Switched Telephone Network (PSTN).

Primary Rate ISDN. A T1 line that is segmented into twenty-three 64 kbps channels plus a control channel (Schnaidt, 1992).

Protocol. A standardized set of rules that specify how a conversation is to take place, including the format, timing, sequencing, and error checking (Schnaidt, 1992).

Quarter Common Intermediate Format (QCIF). An ITU image display format using 176 x 144 pixels.

Routing. "The process of determining the path to be used for transmission" (McDaniel, 1994, p. 589).

Scalable. The ability to be increased or decreased in size (Guengerich, 1992).

Sub-Quarter Common Intermediate Format (SQCIF). ITU image display format using 128 x 96 pixels.

Super VGA. A display format of 800 x 600 pixels per screen.

T1. A telephone line with a bandwidth of 1.544 Mbps.

TCP/IP. The protocol suite developed by the Advanced Research Projects Activity of DOD. "A set of communications protocols developed to internetwork dissimilar systems" (Freedman, 1991, p.589).

Transmission Control Protocol (TCP). See TCP/IP.

Twisted Pair. The wiring used in the Copper Loop. Patented by A. G. Bell in 1881.

UNIX. A multitasking, multi-user operating system. Developed by Bell Labs and widely implemented in Universities and corporations.

Very Large Scale Integration (VSLI). A technique for manufacturing computer chips that places very large numbers of components on a small chip. The benefits of VSLI are lower cost and better performance.

Video Card. A video card provides the PC interface to a camera. It can also be used to mount the codec components (See Chapter II, Figure 15). The video card performs the analog to digital conversions that are necessary to convert analog video signals to digital.

Video Graphics Array (VGA). A display format based on 640 x 480 pixels per screen.

Video Server. A network device for multipoint video connections. A video server provides interfaces and connectivity for multiple communications lines carrying video and other information. Differentiated from a hub because it contains one or more codecs.

Video Teleconference. A conference between two locations using video and audio equipment to connect the participants.

Wavelet Compression. A form of lossy compression yielding very high compression ratios.

Whiteboard. A workspace area on a computer display. Used to display, manipulate, or communicate information.

Wide Area Network (WAN). "A network that provides communications services to a geographical area larger than that served by a LAN or MAN" (McDaniel, 1994, p. 744).

List of Abbreviations

ATM	Asynchronous Transfer Mode
B-ISDN	Basic Rate ISDN
CAI	Computer Aided Instruction
CCIR	Consultative Committee for International Radio Communications
CCITT	Consultative Committee for International Telegraphy and Telephony
CD ROM	Compact Disk - Read Only Memory
CIF	Common Intermediate Format
CODEC	Coder/Decoder
DCT	Discrete Cosine Transform
DOD	Department Of Defense
DRAM	Dynamic Random Access Memory
DVTC	DeskTop Video Teleconferencing
E-mail	Electronic Mail
ECR	Electronic Class Room
FPS	Frames Per Second
Gbps	Giga Bits per Second
G.711	ITU Standard for Audio compression (64 kbps)
G.722	ITU Standard for Audio compression (64 kbps)
G.723	ITU Standard for Audio compression (5.6 kbps)
G.728	ITU Standard for Audio compression (16 kbps)
H.221	ITU Standard for Multiplexing (ISDN)
H.223	ITU Standard for Multiplexing (POTS)
H.261	ITU Standard for Video compression (ISDN)
H.263	ITU Standard for Video compression (POTS)
H.320	ITU Standard for ISDN Video
H.323	ITU Standard for LAN Video
H.324	ITU Standard for POTS Video
T.120	ITU Standard for Collaborative Computing
HDTV	High Definition TeleVision
HTML	HyperText Markup Language
ISDN	Integrated Service Digital Network
ISDN-PRI	Primary Rate ISDN
ITU	International Telecommunications Union (Formerly CCITT)
JPEG	Joint Photographic Experts Group
k-12	Kindergarten through twelfth grade
kbps	Kilo Bits Per Second
kB	Kilo Bytes
LAN	Local Area Network
LBRV	Low Bit Rate Voice

MB	Million Bytes
MBone	Multicast Backbone
Mbps	Million Bits Per Second
MMECR	MultiMedia Electronic Class Room
MO	Magneto-Optical (Disk)
MPEG	Moving Pictures Experts Group
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
NCSU	North Carolina State University
NSU	Nova Southeastern University
NTSC	National Television System Committee
PAL	Phase Alternation Line
PC	Personal Computer
POTS	Plain Old Telephone Service
QCIF	Quarter Common Intermediate Format
RGB	Red Green Blue
SMDS	Switched Megabit Data Service
SQCIF	Sub-Quarter Common Intermediate Format
SVGA	Super Video Graphics Array
V.34	Standard for 28.8 kbps Modems
V.Fast	Standard for 28.8 kbps Modems
VCR	Video Cassette Recorder
VGA	Video Graphics Array
VLSI	Very Large Scale Integration
VSAT	Very Small Aperture Satellite
VTC	Video Teleconferencing