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The Collaboratory, Videoconferencing, and Collaboration Technology;

A Report to the Board of Scientific Counselors

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1. Introduction

Efforts investigating videoconferencing and collaboration technologies within the Lister Hill Center are described in this report. It begins with a general overview of the videoconferencing and collaboration technology that we employ at LHC and the Collaboratory setting in which it is used. Research related to the use of videoconferencing and collaboration technology in telemedicine and distance learning is reviewed and the concept of presence is discussed to provide a context for work being done at Lister Hill. Specific videoconferencing and collaboration tools currently utilized in the Collaboratory are described; observations and findings are presented. Our work with collaborative technology within the Center has been itself truly collaborative, involving the Center's Office of High Performance Computing and Communication and the Computer Science and Engineering Branches.

Technologies ranging from telephones, faxes, and computers can be used for collaboration. Computer based tools might include individual email and message board programs, calendar and scheduling programs, polling and consensus generation programs, and applications enabling multiple users to add and edit information in a shared knowledge base. Computer-based tools also can include groupware incorporating the features from several of these programs as well videoconferencing applications. The work reported here focuses on current and emerging off-the-shelf videoconferencing and collaboration technology based on the Internet Protocol (IP) enabling people to communicate via video and audio and, often, share applications on their desktops in real time over the Internet.

Earlier videoconferencing technology, based on television transmission by microwave, satellite, or ISDN lines, did not allow for the transmission of the audio and video communication while simultaneously interacting with computer applications. It usually required special equipment and arrangements with an agent providing service. Consequently, it was used mostly for more formal group meetings and presentations. IP videoconferencing lends itself to both formal and other uses involving individuals or groups. It can be integrated with other IP applications and, since it uses the Internet, has the potential to be more affordable and ubiquitous.

2. Focus and Goals

Given the Office of High Performance Computing and Communication's focus on advanced network applications, it was decided from the start to investigate only videoconferencing and collaboration technologies that were IP based for use on the Internet. While some of these systems have optional hardware and software allowing them to interoperate with some legacy systems, there has been no need to invest in these resources. We do not have a videoconferencing network in place that uses these older technologies and the outside institutions with which we collaborate are only interested in advanced network applications. The venue for most of the work on videoconferencing and collaboration tools is the OHPCC Collaboratory, which occupies the space that formerly housed The Learning Center for Interactive Technology (TLC). The TLC showcased exemplary interactive technology applications in health professions education and disseminated information about their development and use. There was less need for a center to demonstrate such programs as more of them became accessible online. There is continuity between the Collab and TLC because the use of videoconferencing and collaboration tools for education remains an interest. It has and is being used both for educational and other purposes within OHPCC and in many of the external advanced computing projects that the Office has funded.

Experimentation with IP videoconferencing and collaboration tools has been done to:

- Explore alternative technologies that may be of use to NLM in accomplishing agency or project goals.

- Establish a basic communications infrastructure for collaborating with contractors, demonstrating applications, and conducting the work of the OHPCC.

- Develop knowledge and understanding of the technologies being applied in many research contracts funded by OHPCC.

3. Significance

Processor power and network bandwidth have been increasing and technologies are converging. Multimedia is a standard computer feature and DSL and cable systems bring broadband to the home. Moreover, diverse technologies are converging, as photography, telephony and video become digital. The business community has become increasingly interested in the economic opportunities the technology provides, the engineering community has become increasingly interested in network quality of service and end to end performance issues associated with reliably transmitting large multimedia data streams in real-time, and the academic community has become increasingly interested in identifying, developing, and assessing appropriate applications. The Internet2 academic network consortium has an ongoing program to explore transmission of video (both one and two way) over advanced networks. The NLM, as a consortium member and the lead agency for advanced networking in health, has an interest in keeping abreast of the technology generally. The OHPCC, as the organizational unit responsible for conducting and funding projects incorporating interactive video technology for telemedicine and distance learning, has an interest in keeping abreast of collaboration technologies employed in its projects. In addition, it has an interest in using the technology to demonstrate the work it has funded at national meetings and to explore the technology's potential use at the NLM.

4. Videoconferencing and Collaboration via IP

There is a range of IP videoconferencing technologies (Dixon, 2000). Since video consists of a series of individual pictures or frames and they need to be displayed at rates approaching 30 per second to produce full motion, all use some form of compression to digitally encode and decode the video and audio information and accommodate the vast amounts of data that have to be transmitted. Some of these "codecs" perform the task using only software, while others employ additional hardware. The former are very dependent on the inherent capabilities of the computers on which they are installed, while the latter employ standalone equipment, add-in boards, or USB devices for this processing. Some of the technologies are designed to display video directly on the computer and some output video for television display, usually in an NTSC, PAL, or other format. The Internet's user datagram protocol (UDP) is usually employed instead of the transmission control protocol (TCP) to send the video and audio streams. UDP sends packets of data without the error checking and packet resending that is performed with TCP. It is more optimal because of the large data streams being continuously transmitted. Moreover, some degree of packet loss may be tolerable as long as it does not introduce persistent artifacts in streams transmitted. If a computer-based application has built-in features enabling it to be shared at a distance, videoconferencing might be used with it so that users can see and hear each other as they interact. Some videoconferencing technologies provide the capacity to share desktop computer applications that lack this capability inherently.

Conferences can be point to point or multipoint and accomplished via multicast or unicast. Multipoint conferences involve more than two end points. In unicast each video connection is an independent data stream (see Figure 1). A conference between two end points sending and receiving video as unicast at 384 kilobits per second would only consume that much bandwidth, but multipoint conferences in unicast would consume proportionately more bandwidth as other end points are added. Multipoint conferences using unicast typically employ video servers called multipoint control units (MCUs). Three end points on independent networks sending and receiving streams at 384 kbps to the MCU would consume only that bandwidth on their networks, but eventually 1152 kbps (3 x 384) of bandwidth would be consumed at the point in the network where the transmissions converge.

Video servers use either voice activated switching or continuous presence to manage the streams. In voice activated switching, video and audio from the site that is the source of the loudest audio (usually a person speaking) is reflected back to the other end points, although extraneous sounds and cross talk can introduce artifacts. In continuous presence the video and audio from all ends points are mixed and then reflected back. Each end point appears in a separate area of a single window or in smaller, separate windows. There is usually an upper limit to the number of end points that can be displayed. It is possible to include another MCU as one of the end points and use it to extend participation to other sites, when a conference MCU reaches capacity. The Internet2 Commons, a series of MCUs maintained by the Internet2 consortium for use by member institutions, can be deployed this way. Internet2 has demonstrated how these servers can be linked to others around the world to create a single Megaconference of over one hundred end points (Dixon, 2000).

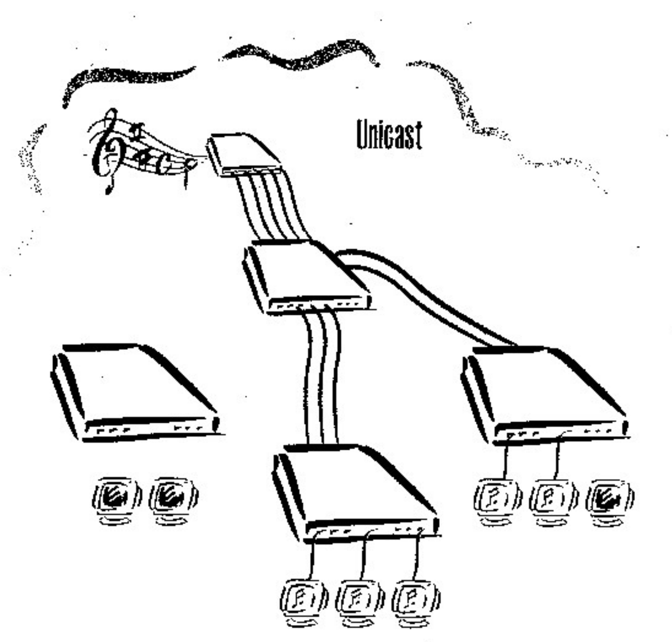

Figure 1: Unicast Transmission

In multicast, packets of data (video or other) are replicated by the routers along the network and passed on to other routers having end points requesting the information. As a result, video can be transmitted as a single stream and the stream only traverses the routers and portions of the network that link to the end points requesting the stream (Figure 2). Multicast is highly efficient, but dependent on the capabilities and settings of routers between end points. Transmission can be blocked if any of the routers between end points either lacks multicast capability or has multicast disabled. Internet2's Abilene network offers multicast capability and most of the institutions connected to it are able to receive multicasts, but the capability might not extend to every router in an institution's local area network. These problems may not be apparent to end users of videoconferencing and collaboration tools and are often beyond their control.

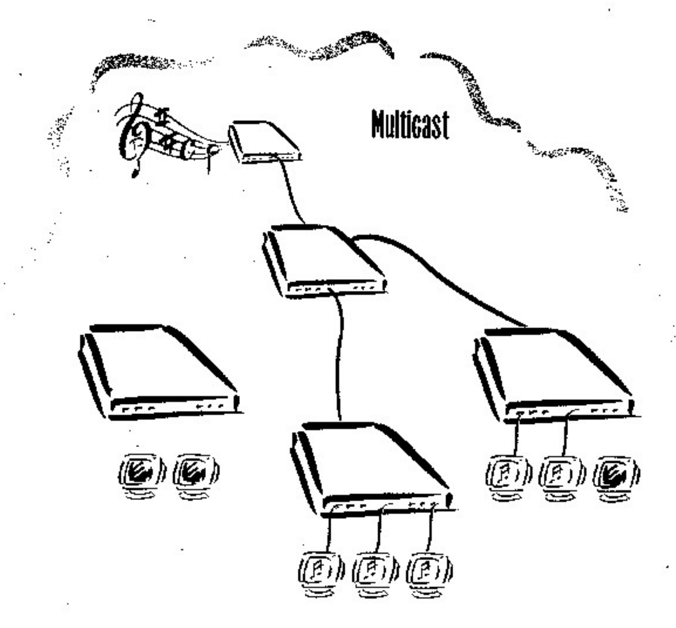

Figure 2: Multicast Transmission

5. Videoconferencing Research

Videoconferencing technology has been applied in many settings, but the areas of most interest to NLM and OHPCC are telemedicine and distance learning. The research needs to be put in perspective, however, because there are inherent problems in trying to assess the effectiveness of communication technology applications.

5.1 The Interpretation Paradox

Most of the literature on videoconferencing and collaboration technology touts its benefits or describes its use in varied settings. Reports explaining the underlying technology are rare. Published research studies of the technology's effectiveness are rarer still. Travel cost savings and the ability to have more frequent and immediate meetings among workers collaborating at distant locations are, perhaps, the most cited benefits. Use of the technology as an alternative when face to face meetings are not possible or difficult also has been mentioned. These benefits appeal intuitively and are congruent with the experiences many have had with the technology, since travel cost savings are relatively easy to estimate and many organizations have relied on the technology, especially in the period immediately after September 11, 2001. (NLM and OHPCC were involved in one major deployment of the technology at that time when Internet2 decided to conduct its Fall 2001 Member Meeting, scheduled for October, entirely online. The Collab became one of the participating sites.)

Documenting the cost and utility of videoconferencing and collaboration technology is easier than assessing its effectiveness in terms of performance and other outcomes. Trying to research the effectiveness of videoconferencing and collaboration technology is akin to trying to assess the effectiveness of the telephone, television, or other communication appliance. It is hard to make broad generalizations because the effectiveness of the technology depends on the uses to which it is put. Separating the features of a communications medium from the messages being conveyed and the way these messages are received and used is an intractable problem because any observed outcomes may be more attributable to the messages and the way technology was applied rather than to the technology itself (Clark, 1994, 1983). But a communication technology's features will drive the ways people choose to use it and shape the kinds of messages conveyed (Kozma, 1994; Ullmer, 1994). Videoconferencing and collaboration technologies are not immune to this paradox.

Research on videoconferencing and collaboration technologies may be even more susceptible to varied interpretation, since the messages transmitted are often more open and from multiple sources. In addition, there often are exogenous factors in the application of any technology affecting interpretation of research outcomes. Administrative, technical, and financial support for implementation, user training and expertise, and user expectations and acceptance are but a few (House, 1974; Surry & Ely, 2002). Consequently, it is not surprising that the overall research on the use of the technology for telemedicine and distance learning is equivocal, although some observations can be made about the technology nonetheless. Even though some confounding of a medium and its messages is inevitable and other factors affect outcomes, it is still legitimate to ask how technology can be most appropriately applied. Research on videoconferencing and collaboration technology in telemedicine and distance learning is reviewed because both application areas have common features and synergistic relationships (Sneiderman, 1998) and because they have been the focus of most OHPCC funded research. Tables 1 and 2 summarize OHPCC funded research projects employing videoconferencing and collaboration technologies for telemedicine and distance learning.

Project	Videoconferencing Focus	Project Report(s)
Beth Israel Deaconess Medical Center	Telemedicine Home Self-Monitoring Pediatrics	Safran, et al. (2001)
Charles R. Drew University of Medicine/University of Southern California	Telemedicine Clinical Interactive Ophthalmology, Emergency Medicine	Flowers & Baker (2001) Stumpf & Zalunardo (2001)
Georgetown University	Telemedicine Clinical Interactive Nephrology	Levine et al. (2001a) Levine et al. (2001b) Turner et al. (2001) Collmann (2001)
University of Iowa	Telemedicine Clinical Interactive Cardiology, Pediatrics, Psychiatry	Harper (2001) Rohland & Flaum (2001) Scholz et al. (2001) Sivitz et al. (2001) Torner et al. (2001) Wakefield et al. (2001)
University of Maryland	Telemedicine Clinical Interactive Emergency Medicine	Cullen et al. (2001)
University of Missouri	Telemedicine Clinical Interactive Cardiology, Dermatology, Internal Medicine	Hicks et al. (2001a, 2001b, 2001c) King, B. (2001) Lobenstein et al. (2001)
University of West Virginia	Telemedicine Clinical Interactive, Home Self Monitoring Multi-Specialty	Reddy et al. (2001a, 2001b)

Table 1: NLM Telemedicine Initiative Projects Using Videoconferencing

Project	Videoconferencing Focus	Project Report(s)
East Carolina University	Telemedicine Cardiology, other	Balch & Simmons (2003)
George Mason University	Education Embryology, Anatomy	Doyle, et al., (2003)
Indiana University	Telemedicine Geriatric Medicine	Weiner, (2003)
Johns Hopkins University	Telemedicine Oncology	Lombardo (2003)
Northrop Grumman	Telemedicine Emergency Medicine	Gagliano (2003

Stanford University	Education Anatomy, Surgery	Dev & Senger (2003)
University of Chicago	Telemedicine Education Anatomy, Surgery	Silverstein (2003)
University of Washington	Telemedicine Education Oncology	Lober & Chou (2003)

Table 2: NLM Next Generation Internet Initiative Projects Using Videoconferencing

5.2 Telemedicine Research

Most telemedicine research reviews fail to illuminate the role of videoconferencing and collaboration technology since they treat telemedicine as a single construct and fail to account for the varied ways telemedicine is practiced and the different types of technologies used (cf., Currell et al., 2000; Hailey & Ohinmaa, 2002; Rione, et al., 2001; Whitten et al., 2002;). Two reviews by Hersh, et al. (2001a; 2001b), however, have distinguished among three approaches to telemedicine where more than just audio is used (e.g., telephone consults) and where telemedicine is employed as a substitute for face to face patient care (e.g., in specialties other than radiology and pathology). Store-and-forward telemedicine services involve asynchronous communication of medical data, primarily among health professionals. Self-monitoring/testing telemedicine services entail health professionals monitoring physiologic measurements and other data that are usually collected in a patient's residence or a nursing facility to augment or reduce visits. Clinician-interactive telemedicine services include real-time clinician-patient interactions that conventionally require face to face encounters. The technologies utilized can include specialized equipment for transmitting certain image data, such as echocardiograms or radiographs (Trippi, et al., 1996; Lee, et al., 1998; Tachakra, et al., 1996) as well as videoconferencing (Baur, et al., 1998; Hayes, et al., 1998; Hubble, et al., 1993; Montani, et al., 1996; Pacht, et al., 1998; Pedersen, et al., 1994).

Videoconferencing mostly has been assessed for clinician-interactive services, but it has been used in conjunction with store and forward services and studied in home monitoring contexts (Hersh, et al., 2001a; Cox & York, 1997; Johnston, et al., 1997; Lindberg, 1997; Mahmud & Lenz, 1995; Nakamura, et al., 1999). The videoconferencing technology used in some studies was over IP, but many employed older modes of transmission (videophones or videoconferencing via ISDN) that share the attribute of being able to simultaneously send and receive audio and video in real-time. Videoconferencing has been documented as being diagnostically useful for otolaryngologic diagnosis (Pedersen, et al., 1994; Sclafani et al., 1999), ophthalmologic screening (Flowers & Baker, 2001; Marcus, et al., 1998), chest pain assessment (Srikanthan, et al., 1997; Trippi et al., 1996), pediatric transport assessment (Belmont, et al., 1995), teleradiology access in emergency departments (Lee, et al., 1998; Tachakra, et al., 1996), Parkinson's disease assessment (Hubble, et al., 1993), pulmonary history and physical assessment (Pacht, et al., 1998), dental evaluation (Baur, et al., 1998), psychometric testing (Elford, et al., 2000; Montani, et al., 1996), and urology assessment (Hayes, et al., 1998). There is also evidence supporting its usefulness for self-monitoring/testing, especially when employed to supplement visits to home bound patients. One study of videophones to augment home visits found patients in the experimental group exceeded the control group in activities of daily living, communication, and social cognition, and had lower health care costs than the control group that more than offset the technology's expense (Nakamura, et al., 1999). A similar study found no differences in outcomes but high patient acceptance and cost savings (Johnston, et al., 2000). Pediatric ventilator patients in homes linked to respiratory specialists by videophone had fewer unscheduled hospital visits than controls (Miyasaka, et al., 1997). Babies of families linked to a neonatal intensive care unit via video over IP required no re-hospitalizations versus twenty per cent for a control group (Gray, et al., 2000). Other less rigorous studies provide additional support for the technology's benefit when used to augment home visits (Mahmud & Lenz, 1995; Cox & York, 1997).

There are, of course, criteria other than outcomes for assessing telemedicine generally and the use of videoconferencing specifically. Better access to care geographically or after hours, quicker service, user satisfaction and acceptance, and cost are a few. There is some evidence supporting each criterion, but results vary (Hersh, et al., 2001a; Hersh, et al., 2001b). Access is often found to improve because in many cases there is no access to the health service prior to a telemedicine intervention. Most patients are satisfied with videoconferencing technology and most clinicians are when it does not interfere with diagnosis (Hersh, et al., 2001a; Hersh, et al., 2001b). Only a few studies compared patient satisfaction when they had encounters with clinicians via videoconferencing and face to face (Allen & Hayes, 1995; Gilmour, et al., 1998; Montani, et al., 1997; Turner, et al., 2003). One (Allen & Hayes, 1995) found patients were more inclined to speak in person and were less inclined to want to use the telemedicine service after in person consultation, while another found it depended on the patient's circumstance (Turner, et al., 2003).

Findings from NLM Telemedicine and Next Generation Internet Projects employing videoconferencing (Tables 1 & 2) are congruent with earlier reviews (Hersh, et al., 2001a; Hersh, et al., 2001b). Most of our Telemedicine and Next Generation Internet Projects using videoconferencing employed additional imaging and data sources and did not examine the effectiveness of the medium itself (e.g., Flowers & Baker, 2001; (Hicks et al., 2001c; Lombardo, 2003; Lober & Chou, 2003). These and other studies that we funded (Hicks, et al., 2001b; Harper, 2001) showed either cost benefits, accessibility benefits, or both. Those studies focusing specifically on videoconferencing found no differences between groups in telemedicine or face to face conditions or no differences in patient or provider satisfaction in the specialties of nephrology (Turner et al., 2001), psychiatry (Rohland & Flaum, 2001), and pediatrics (Harper, 2001). Another study of the technology's use to provide unscheduled after hours care to elderly patients in a nursing home found high levels of physician satisfaction (Weiner et. al., 2003). (The physicians in this study used videoconferencing from either their clinics or their homes.)

One NLM study using videoconferencing for home care was the neonatal intensive care study (Safran, et al., 2001; Gray, et al., 2000) previously reported in the Hersh, et al., (2001a) review and another (Reddy, et al., 2001a) produced no outcomes that could be attributable to videoconferencing.

Several NLM studies identified factors affecting videoconferencing's success. The Turner, et al. (2001) study of dialysis ward patients found that they had more privacy (a head set was used during the videoconferencing sessions), that the clinician was interrupted less than when providing treatment face to face, and that patients were comfortable using the technology for routine care and for emergencies, but that when there was moderate uncertainty about a condition patients prefer face to face. Similar findings were reported in a study using the technology (and other imaging) in dermatology (Hicks, et al., 2001c). Some of our studies showed videoconferencing was not used because of difficulties accommodating physician schedules (Reddy, et al., 2001a; Toner, et al., 2001). A study of its use for care after hours (Weiner, 2003; Weiner, et al., 2003) found incidents often occurred at times physicians were unable to access their videoconferencing stations and that the technology was only needed when dealing with certain types of medical problems. Finally, a study of how different videoconferencing codecs performed under varied network conditions showed that some performed better than others when bandwidth was stressed, that lower quality codecs were often more stress tolerant than higher ones, and that acceptability of video transmitted under varied network performance depended upon the patient's condition (Balch & Simmons, 2003).

Most of the research on videoconferencing and collaboration technology in telemedicine has been to demonstrate its feasibility. Not surprisingly, both Hersh et al. (2001a; 2001b) reviews indicated that the research was spotty and uneven, that telemedicine was used in many specialty areas for which research on its effectiveness was lacking, and that the outcomes of the studies using videoconferencing technology varied depending on specialty area, type of service provided, and patient condition. One study in otolaryngology, for example, comparing real-time video transmission of a complete otolaryngologic examination to the use of still images and a written report found more concurrence in diagnosis between on site and remote otolaryngologists when video was transmitted (Sclafani, et al., 1999). Another study in otolaryngology also determined that image quality between on-site and remote locations was the same (Pedersen, et al., 1994). In contrast, studies show comparable diagnoses by dermatologist seeing patients in person versus seeing 24 bit still images and history data (Krupinski, et al., 1999), but not when they see patients in person or by videoconference (Lesher, et al., 1998). Another study of video in ophthalmology showed high levels of concordance in diagnoses made by on-site and remote ophthalmologists to whom ophthalmoscopic images were transmitted except in cases where patients had cataracts (Marcus, et al., 1998).

Telemedicine studies suggest several factors that affect the quality of service required for varied medical outcomes and, consequently, the appropriateness of videoconferencing technology. Specialty areas where motion plays a more important role in diagnosis and where video is used as a normal diagnostic tool (e.g., otolaryngology) may find the quality of the video data more acceptable than ones that do not (e.g., dermatology). In some specialties (e.g., ophthalmology) the quality of the video may suffice for some patients, but not others (e.g., assessments of patients with cataracts) or be useful for physician-patient interaction when other image data are provided (Flowers & Baker, 2001). Finally, the technology may be intrinsically integral to certain telemedicine services areas, such as clinician/interactive and self monitoring/testing, and consequently contribute more to outcomes, especially if face to face interaction is part of the service requirement. These factors not only apply to the use of videoconferencing generally but to the specific codecs employed in a videoconferencing environment (Balch & Simmons, 2003). Higher resolution is not always better if other, more clinically salient aspects of the data to a particular case (e.g., motion) are compromised by the codec (Balch & Simmons, 2003).

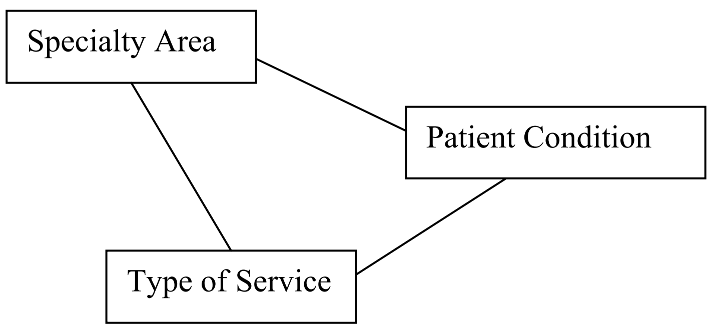

Figure 3: A Three Factor Model for VC QoS Requirements in Telemedicine

5.3 Distance Education Research

Distance learning, like telemedicine, is a multi-dimensional concept that covers everything from independent study to more formal coursework that could be offered by correspondence, asynchronous online communication (e.g., email or the web), or by audio or videoconference (Hanson, et al., 1997). Moreover, there are programs that employ a "blended" learning approach that combine distance education with face to face instruction that are difficult to categorize as either distance or traditional (e.g., Hiltz & Turoff, 1993; Berge, 2002). Most reviews of distance education research, like those of telemedicine, fail to illuminate the effects of videoconferencing because distance learning is treated as a single construct (Berge & Mrozowski, 2001; Hanson, et al., 1997; Simonson, 2002). Moreover, much of the literature focuses on demonstrating feasibility and use.

General research reviews (Berge & Mrozowski, 2001; Hanson, et al., 1997; Simonson, 2002) are still useful in identifying factors potentially affecting distance learning when videoconferencing is employed. One of the foremost findings concerns perseverance and attrition. Drop out rates are often high in distance learning contexts and they are often attributed to: 1) learning occurring at home or in the work place where there are more distractions and pressures on the learner's time; 2) student lack of persistence, self-learning skills, and/or the ability to gauge commitment and manage time; and 3) failure to account for learner isolation and build support from teachers and peers in the design of the learning experience. Another common finding, related to isolation, is that students in distance learning courses appreciate the convenience but, if given a choice, prefer learning in face to face contexts where there is more opportunity to interact with peers before, during, and after class. Finally, most studies comparing distance education classes to traditional ones find no significant differences, regardless of medium, although the outcomes of some studies can be confounded by attrition and other factors. A review study that comes closet to dealing with videoconferencing, a meta-analysis comparing traditional courses with televised courses using video with and without interaction (Machtimes & Asher, 2000), found no significant differences, but a sub-analysis of the televised courses found achievement was better in courses allowing interaction, especially two way audio and video.

One important issue is the synchronous nature of videoconferencing versus asynchronous forms of instruction, such as the use of web sites, message boards and email, which are often incorporated into courses offered on the Internet. It is possible to combine videoconferencing and asynchronous learning resources for distance education, but clearly some of the time, if not place, flexibility dissolves with synchronous communication. Moreover, there are those who have argued learning outcomes are more likely to improve with asynchronous communication because: 1) there is more time to communicate, making it less likely for a few students to dominate discussion; 2) there is more anonymity that increases the likelihood shy and self-conscious students will participate; and 3) the requirement to communicate through written composition encourages more reflection and cognitive processing (Hiltz, 1994; Newman, et al., 1997; Scardamalia, et. al., 1992). While the above benefits of asynchronous communication are possible, they do not accrue automatically and identifying strategies for moderating constructive dialog are active areas of research (Muirhead, 2002; Salmon, 2002). Further, there may be situations where more immediate interaction better accommodates problem solving, where the educational outcomes are to teach teamwork or the performance of time sensitive tasks, or where students must learn to think on their feet (Dobson, et al., 2001; Straus, 1997).

There is some evidence to suggest adopting strategies requiring students to collaborate online has positive effects on completion rates (Cheng, et al., 1991) and that learner satisfaction with distance education is linked to sense of social presence (Moore, 2002). Social presence, the degree that both verbal and non-verbal messages are communicated and the psychological distance the messages convey, has been found to be a strong predictor of satisfaction, even in online courses that are text based (Gunawardena & Zittle, 1997; Tu & McIsaac, 2002). A related concept, sense of community or student perceptions of trust and support from teachers and peers, has been posited to be an indicator of the quality of interaction and the degree of isolation students experience in distance learning contexts (Rovai & Lucking, 2003).

Videoconferencing technology has features that might promote these affective aspects of learning, but the research indicates that the technology does not equate to instruction that is face to face. One study that did not use videoconferencing but did use television with two way audio, found that students in the televised course had less sense of community than those in a traditional class (Rovai & Lucking, 2003). Moreover, it did not make a difference whether students were located remotely or in the studio where the course originated. The instructor may have adopted a more formal, lecture oriented teaching style to accommodate the television medium and students had to step up to a microphone to ask questions rather than speak extemporaneously. Another study using videoconferencing found students at remote videoconferencing end points asked fewer questions than those at course origination site (Kelsey, 2000). The reasons were that: 1) mediated communication lacked the spontaneity of face to face conversation; 2) presenters tended to focus on the originating site audience and ignore remote sites; 3) remote students tended to direct their questions to the on-site facilitator rather than to the originating site; and 4) students were camera shy and content to participate in discussion vicariously. Still, students valued the synchronous communication and having the opportunity to participate. Similar findings have been found with medical residents, especially when conference presenters provide questions in advance, ask for remote site input during seminars, and repeat questions when asked (Mills, et. al., 2001). The dynamics of interaction and its perceived level may affect satisfaction more than personal participation (Comeaux, 1995; Fulford & Zhang, 1993).

The National Library of Medicine's Telemedicine Projects that employed videoconferencing did not address the technology's educational uses, while our Next Generation Internet Projects concentrated more on building infrastructure and testing novel teaching applications where the technology was one component. The University of Washington's Project, for example, involved establishing virtual tumor boards so that board members would not have to travel to a central site. A by product was extended educational access that allowed more residents to observe and participate and that at times attracted standing room only crowds of over ninety (Lober & Chou, 2003). The George Mason University Project, which enabled embryologists to collaboratively demark structures in an image database, also used the technology to offer learning experiences online (Doyle, et al., 2003). Projects at Stanford University (Dev & Senger, 2003) and University of Chicago (Silverstein, 2003) are ongoing and involve combining videoconferencing technology with immersive three-dimensional stereo imaging. The Stanford project also incorporates haptics for distance surgical training. These projects are not at the point where outcomes can be measured. The University of Chicago performed a pilot study, however, involving instruction on the liver and found that knowledge of the liver not only improved on an immediate posttest but continued to advance over time. Follow up interviews revealed that the residents in the study reviewed their textbooks covering the topic because they felt that exposure to the lesson made them better able to comprehend the material. These results, however, may be attributable more to the use of 3D imaging than to videoconferencing.

5.4 Telemedicine, Distance Learning and Presence

Telemedicine and distance learning are two very different contexts for the use of videoconferencing technology. The former typically involve one-to-one encounters that are usually of short duration. The latter usually involve longer encounters over time with many participants. One factor underlying the use of videoconferencing that may have a role in both contexts, however, is sense of presence. In telemedicine sense of presence may be important to the extent it affects diagnosis, treatment, and satisfaction. In distance learning, sense of presence may be important to the degree it addresses the task and social dimensions of learning.

It is probably inappropriate to consider videoconferencing as a complete substitute for face to face meetings (Egido, 1988), whether in the clinic or the classroom, simply because of the technology's inherent limitations. When the technology is used in normal conversation, there are fewer interruptions, more explicit handovers, and a greater sense of psychological distance than when discussion is face to face (O'Conaill & Whittaker, 1993). Moreover, the conversational patterns in videoconferencing and audio conferencing are similar, even though subjects perceive the video as adding benefit (Sellen, 1995). These differences may arise because the view of others is more limited in videoconferencing than when participants are co-located, participants have less control over the point of view, and many of the visual cues affecting interaction (especially those involving peripheral vision) simply are not noticeable within the context of the television screen (Heath & Luff, 1992; Sellen, 1995). In classroom situations, it can be difficult to discern who is talking (Lesniak & Hodes, 2000). Finally, there are circumstances where face to face interaction (and the goal of achieving it via videoconferencing) may be a drawback (Dubrovsky, et al., 1991).

One line of research, followed in most of the studies reviewed, is to identify circumstances where videoconferencing performs satisfactorily and where the technology accommodates more meetings or meetings that would not be possible given the technology's absence (Egido, 1988). The other line of research focuses on developing tools and environments that enhance the current technology, such as eye gaze correction (Jerald & Dailey, 2002) or that augment it. The latter include the development of tools for application sharing and creating shared workspaces as well as telepresence applications involving virtual reality, augmented reality, and three dimensional television. Many of these applications are immersive and entail people at end points interacting in a real, artificial, or partially artificial space. The technologies employed are relatively new and under development, and their feasibility (not to mention their effectiveness) still needs to be demonstrated. In the health sciences, they include projects like TOUCH, an immersive environment where students work interactively in real time to treat a medical emergency (Caudell, et al., 2003), the Stanford Next Generation Internet Test Bed, employing 3D imaging and haptics for surgical training (Dev, et. al., 2002), the Advanced Biomedical Communications Test Bed, employing 3D imaging and real time robotic surgery (Silverstein, 2003), and the 3D Telepresence Project in Medical

Consultation, employing three dimensional real time video for remote consultation and treatment (Welch, et al., in press).

6. Collab Videoconferencing Technologies

Videoconferencing technologies investigated at OHPCC Collab represent a range of commercially available (or almost commercially available) products, some of which date back to 1997. They include:

- iCOSM. (Formerly named Lucent Collaborative Video and Montage.) This was the first codec examined. It was developed at Bell Labs and made available initially through Lucent Technologies and later its spin off corporation Avaya. Add-in boards were used to perform Motion JPEG compression. The product could generate up to thirty two separate streams at frame rates up to thirty per second in 640 x 480, 320 x 240, 160 x 120, and 80 x 56 windows. It could generate bit streams from 128 kbps to 155 mbps. By varying resolution, frame rate and image quality, video could be scaled for varied bandwidth (Gaglianello & Rosenberg, 2000). The product was touted as requiring no multipoint control unit but, in fact, each board functioned as an MCU. The boards were expensive and although they used Motion JPEG for compression, everything else about them was proprietary. Finally, they were difficult to use. Audio artifacts were common, video parameters had to be adjusted to accommodate available bandwidth when initiating calls, and the system usually responded to network congestion by dropping connections. There were few other users, but testing the technology enabled us to establish a relationship with the Goddard Space Flight Center (GSFC) which had both an interest in collaboration technology and the bandwidth to test it.

- H.323. H.323 is an umbrella standard adopted by the International Telecommunications Union for videoconferencing over IP in late 1996. It encompasses several standard codecs for video encoding (notably h.261 and h.263), audio encoding (G711, 728, 729, 722), and application sharing (T.120). The image sizes can range from sub-QCIF to 16CIF, but CIF (one quarter television resolution or 352 x 240) and QCIF (one forth of CIF) are most common. The codec gained popularity when Microsoft announced Netmeeting, its software only h.323 codec, and began to include it with Windows. NLM and GSFC reviewed many of the early products and obtained several for review. Given the computing technology at the time, Netmeeting's performance was sub-optimal and there were audio artifacts. The hardware products tested worked when used at each end point, but did not interoperate. Eventually, NLM and GSFC invested in VCON technology because of its interoperability, built-in echo cancellation capabilities, and capacity to stream data at rates up to 1.5 mbps while also dynamically adjusting video to accommodate fluctuations in bandwidth. Subsequently, we invested in a high end computer and MCU software. The server was the only product at the time having continuous presence and that combined videoconferencing and webcasting. Although the quality is not high, h.323 technology is ubiquitous and cheap.

- MPEG2. We have experimented with codecs using MPEG2 compression, primarily those from Star Valley, but also those from vBrick. The codecs transmit full screen full motion NTSC quality video at bit rates ranging from 1.5 to 15 mbps. Our experiences with the technology are similar to those of East Carolina University (Balch & Simmons, 2003). Bit rates higher than 7.5 mbps produced no improvement in quality while those below 4.5 mbps introduced artifacts. Even though MPEG2 compression was used, other aspects of the technology were proprietary and MPEG2 systems did not always interoperate. The technology appears appropriate for medical applications where television quality is adequate. Additional technology is needed for echo cancellation, however, and costs, bandwidth requirements, and the lack of a user base have limited its application. The technology we acquired was developed by Litton, but the division responsible for the product was sold to another company more interested in its network devices than videoconferencing systems. The status of the technology was uncertain until the videoconferencing technology was spun off to Star Valley.

- Wave3. We also have experimented with a software codec that employs wavelet compression and the session initiation protocol (SIP), a new standard allowing different devices to communicate over IP. The technology was interesting because it produced very good video at bandwidths of less than 1.5 mbps and the programs developed for the Macintosh could interoperate those developed for Windows (at least for certain versions of the operating systems). The software is proprietary with a limited installed base and appears to be available by annual subscription. Full screen full motion video and the capability to interoperate with h.323 systems are recent features.

- Access Grid. The Access Grid (AG) is both an open source and commercially available videoconferencing product that is under development at Argonne National Laboratory and sold by inSORS. Grid technology and multicast are used to transmit and receive multiple streams from multiple sites using common video codecs (h.261 and h.263). A dual processor computer, extra echo-cancellation equipment, and high bandwidth multicast network connectivity are needed. (The rule of thumb for bandwidth is that a three end point stream requires 10 mbps with an additional 2 mbps per additional end point.) The open nature of the technology and the very participatory way that it is being developed, combined with its advanced network requirements has made the technology very popular in the academic research community. Most academic and government research centers have end points or Access Grid nodes, although they are seldom in medical schools. The technology is always on and the metaphor of a venue or virtual meeting room, rather than a phone call, is used to establish communication.

7. Technology Applications

OHPCC applications of the technology have been varied. They have included virtual presentations in the Collab by outside speakers and, mostly, presentations and demonstrations of the technology at national meetings by LHC staff. The latter are summarized in Table 3. Many demonstrations have been much more involved than simply going to a conference and setting up equipment. Our demonstrations at the Radiological Society of North America annual meeting in partnership with Internet2, for example, entailed running a fiber optic line from the NGIX-C "gigipop" (Gigabit Point of Presence for connecting segments of Internet2) in downtown Chicago to McCormick Place, the meeting site. Demonstrations at university sites and at NLM have involved running additional cable or making router upgrades. Even in cases where no network modifications are needed, connectivity, lighting, audio and other factors at an end point affecting conference quality must be tested.

National Meeting	Place/Date	Technologies Demonstrated
Radiological Society of North America	Chicago, IL, 2003	Access Grid, h.323
American Society for Clinical Pathology/College of American Pathologists	Washington, DC, 2002	Wavelet
Radiological Society of North America	Chicago, IL, 2002	MPEG2, h.323
Slice of Life Conference	Toronto, Canada, 2002	Wavelet
Radiological Society of North America	Chicago, IL, 2001	h.323
Internet2 Annual Member Meeting	Arlington, VA, 2001	MPEG2
National Association for Equal Opportunity in Higher Education Workshop on Health Disparities	Washington, DC, 2001	h.323
Radiological Society of North America	Chicago, IL, 2000	h.323
Slice of Life Conference	Salt Lake City, UT, 2000	MPEG2
Internet2 Annual Member Meeting	Arlington, VA, 2000	MPEG2

Table 3: Videoconferencing/Collaboration Presentations and Demonstrations

An experimental multipoint videoconference on Evaluating Health Sciences Resources on the Internet was conducted in June 2001 for simultaneous webcast (Locatis et al., 2003). The effort complemented other work on streaming video (Locatis et al., 2002). It involved four different end points in four different time zones, transcoding the h.323 videoconference stream to a Real Media format, webcasting the conference to 35 sites recruited from the Association of American Medical College's MED-ED listserv, and providing a chat facility for webcast viewers to communicate with each other and the videoconference participants (Figure 4). The approach proved feasible, although certain technical and management problems were identified. Additional follow up programs were planned, but were complicated because new firewall policies at NLM had adverse effects on some videoconferencing codecs, especially h.323.

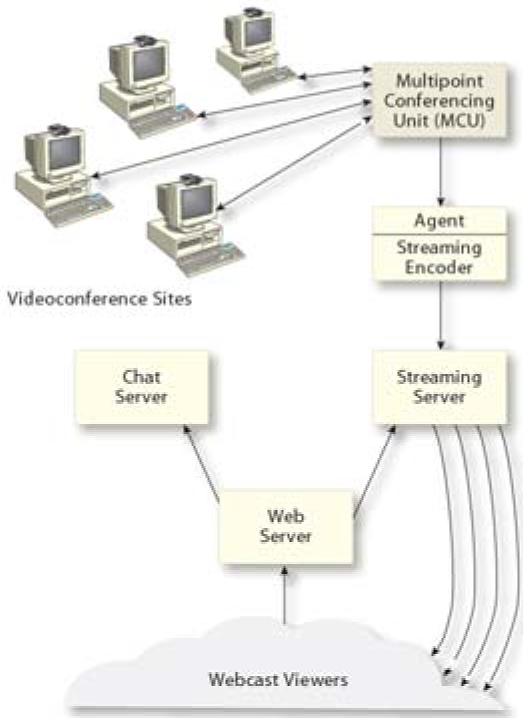

Figure 4: A Multipoint Videoconference/Webcasting Experiment

There have been additional uses of videoconferencing technology in the Collab and OHPCC. H.323 codecs have been used by OHPCC staff to participate in workshops sponsored by NLM and collaborators at GSFC and the monthly videoconferences of the Internet2 Health Sciences Working Group. It was employed in NLM's participation in the Inernet2 2001 Virtual Member Meeting. Recently, a series of feasibility tests were performed and pilot distance education session was done between the NLM and the King Drew Medical Magnet High School affiliated with the Charles R. Drew University of Medicine and Science. (The aim is to offer a series of distance learning seminars as an extension of the NLM Adopt-A-School Program conducted by the Library's Specialized Information Services Division.) The technology also was employed in a virtual site visit involving a review of the Medical Informatics Program NLM has funded at the University of Missouri. Scholars visiting NLM have used the technology to teach distance education classes offered via the Internet2 Commons. The Access Grid node has been used to participate in a series of seminars on advanced networking in medicine that have been coordinated by Project TOUCH and the University of New Mexico Medical School and to participate in a "Kids on the Grid" event on National Bring Your Sons and Daughters to Work Day in 2004. MPEG2 has been employed to demonstrate collaborative use of 3D immersive and haptic technology between NLM and Stanford University to the NLM Board of Regents. These and other collaboration technologies have been used for demonstrations of NLM NGI projects for the BSC and other visitors to the Collab.

8. Observations and Outcomes

Videoconferencing and collaboration tools should be as easy to use as telephones, but they are not. When a conference involves large groups and has a high profile, there can be many hours and days of advanced testing to ensure the network, audio, and video are performing properly. Problems with videoconferencing tools can be classified as those inherent with the technology itself, those related to the technology, and those associated with the policies and predilections of the institutions and people who use it.

Videoconferencing over IP is inherently complicated. Knowledge of the computer platform and its multimedia capabilities is required as well as knowledge of the applications the technology may be capable of sharing. Knowledge of the codec, the network, and the audiovisual equipment being utilized must be added to the mix. When OHPCC first became involved with videoconferencing the inclination was to eschew complicated, expensive room based systems since the technology was evolving to the desktop. One could simply project the desktop to accommodate larger groups. This approach to the technology has been vindicated somewhat. Many room based Access Grid sites, for example, are replacing nodes based on multiple computer systems with Personal Interface to the Grid (PIG) technology employing single computers. Acoustics, lighting, and camera, microphone, and speaker placement, however, still must be taken into account in planning a conferencing environment. Echo cancellation devices, head sets, or management tools directing who speaks are needed to control feedback and other artifacts.

Videoconferencing is further complicated by network incompatibilities that are often outside the user's control. There may be problems with routers along the network between end points. If multicast is used, some routers may not have the feature or it may be disabled. Finally, firewalls can block videoconferencing traffic. Various firewall configurations being implemented at NLM were disruptive for videoconferencing for most of 2003. The h.323 protocol is particularly vulnerable to firewalls. The use of "h.323 aware" firewalls, such as those now at NLM, does not completely solve the problem. H.323 aware firewalls still block incoming calls and attempt to open ports only when outgoing calls are made. Two h.323 end points having "aware" firewalls effectively cancel each other out. Another solution employing tunneling to direct the audio and video packets through commonly open firewall ports can work reliably, but only if one of the end points is outside a firewall. Every NLM NGI project using videoconferencing has reported firewall problems and the Lister Hill Center's network staff has worked hard to develop an architecture putting one segment of the network outside the firewall while insuring the rest is secure.

Technologies using standards that are interoperable or open source tend to be more widely deployed and, consequently, more useful. A collaboration tool with excellent features will be limited if no one is using it. Collaboration at NLM is mostly with outside constituency groups and we do not have the luxury of mandating the use of technology as some corporations may do throughout the enterprise. Standards are still a problem, however, because there are so many from which to choose, and because standard technology may make up one component of the technology but not others. Some standards may be so broad and flexible that interoperability may not be assured. Finally, standards also evolve over time. For example, the h.323 standard allowed for multiple video and audio codecs, but some vendors only implemented a few of them or employed inadequate methods for negotiating which available codecs would be used by the end points. The standard has been updated to include remote camera control and may include a new h.264 higher resolution video codec. New codecs and standards for streaming higher resolution digital video, such as DVTS (Riddle, 2004) and VideoLAN (Cooperstock, 2004), are emerging.

Some of the most formidable problems with videoconferencing and collaboration are exogenous to the technology itself. They include:

- The business plans and corporate strategies of product developers. A company may have a compelling technology, but the network and other overhead requirements for using the technology, lack of interoperability, and pricing and licensing policies may work against it. In addition, while the developers of the technology may be committed to it, upper management may not. The technology may be spun off or no longer supported. Since NLM does not operate a corporate enterprise, but builds working relationships with outside institutions, these external factors affecting technology acceptance and use have to be considered.

- The need for network access. Collaboration requires allowing outsiders access to one’s network. While most videoconferences are planned, some can be ad hoc and when an outside end point uses dynamic addressing or the users at the end point could operate any one of several videoconferencing devices, authenticating the end points to allow access is more difficult. Moreover, many videoconferences are regularly scheduled over long time periods and testing and other requirements often necessitate accessing each end point’s network at additional times. Collaboration tool users are inclined to let outsiders in, but the disposition, indeed mission, of those charged with network security is exactly opposite. The use of the tools poses security threats and adds overhead to firewall management. Firewall mangers may want to know the exact dates, times, IP addresses, ports, protocols and direction of traffic (inbound and/or outbound) for each end point.

- Illusive collaborators. We have identified outside institutions and individuals that have been interested in testing the technology, but finding programmatic uses for the technology is more difficult. Others deploying the technology have reported videoconferencing and collaboration technology has been more easily adopted and more highly utilized among groups that have worked together previously than those that have not. The irony is that the new technology makes possible collaborations that were difficult or impossible to do before. Even testing and troubleshooting technology requires individuals at different end points (often for sustained time periods). Scheduling and availability are problems.

9. Future Work

Future work entails solidifying the current OHPCC infrastructure and doing additional research, development, and formal assessments. There are three levels to future work: 1) a theoretical level; 2) a programmatic level; and 3) a technical level.

9.1 The Theoretical Level

Two theoretical concerns shape future work. Since it is impossible to separate the effectiveness of communication technology apart from its application, one concern is what application areas will be addressed? The other concern is what specific collaboration technologies will be assessed in an application test bed? In the broadest sense, the applications and the technologies *together* constitute what might be considered independent variables of a research effort.

The OHPCC has traditionally been concerned with advanced networking for telemedicine and distance learning. NLM does not directly provide either health care or distance learning, but it does offer information sources that support both of these activities. Consequently, an internal research program focusing on collaboration tools would have maximum payoff if it could contribute to the role of medical informatics in both telemedicine and distance learning generally while also generating outcomes specifically relevant to the Library. The program would investigate the use of collaboration tools to: 1) directly deliver Library services; 2) educate users of Library resources; and 3) improve Library products. The first area would extend access to NLM services, the character of those services, and the "presence" of virtual librarians. The second area would assess the use of the technology to provide distance learning experiences to Library constituency groups. The third area would address the use of the technology as a tool to collect data from users. Each area is described in greater detail in the next section. Research in one area would inform the others and more than one area may be addressed in a single study.

It is clear that collaboration technology is more than videoconferencing and that some features usually associated with videoconferencing, such as sense of presence, can be manifest in asynchronous communication. Moreover, asynchronous communication tools can be used for collaboration. Asynchronous communication technologies, such as web sites and email are already widely deployed and actively researched. (NLM online surveys of its Web resources are examples.) Synchronous communication technologies are newer and less researched (Bannan-Ritland, 2002). The NLM has limited experience in using these tools that include chat and messaging, live webcasts, as well as audio and videoconferences. A range of real time, or near real time technologies would be researched. Comparing the effectiveness of these alternative technologies would be a major goal of the research effort. Applications involving use of synchronous or asynchronous technologies, varied synchronous technologies, and varied combinations of synchronous and asynchronous technologies would be compared.

The dependent variables of the research would include outcome, satisfaction, access, use and cost criteria that are common in assessments of distance learning and telemedicine. Sense of presence, sense of community, and, in some cases, sense of anonymity would be evaluated as factors co-varying with other measures. The precise measures employed will vary somewhat depending on the application area. For example, if the technology was used to provide reference services, outcome measures might focus on the extent to which librarians could respond to search requests. If used for distance learning, outcome measures might focus on how well users could search the resources taught.

9.2 The Programmatic Level

Specific studies would be undertaken in each area: delivery of NLM services, education on the use of NLM resources, and improvement of NLM products. The studies described below address important questions of interest to the Library as well as the telemedicine, distance learning, and collaboration communities. They are not intended to be exhaustive, but examples of the research work that might be done, especially at the start.

<u>Delivery of NLM services.</u> Traditionally, reference services have been synchronous and provided in person. They usually start with a reference interview where the librarian attempts to clarify and refine the user's information request and map it to available resources. The process is often iterative, with the librarian identifying potential resources and modifying initial strategies based on user feedback. There are well documented guidelines for conducting these interviews in person (RASD Ad Hoc Committee, 1996), but their application via chat and messaging is limited (Ronan, 2003). Many failures in answering reference questions can be attributed to poor reference interviews and staff attitudes toward online resources (Sheldrick & Nilsen, 2000). Although videoconferencing generally may not substitute for face to face encounters, does it work well enough in the context of the reference interview? How do users and librarians respond to videoconferencing versus online messaging in providing online services?

In this study, workstations would be installed in a context where medical information is needed and medical librarians are not accessible (school, university, or public libraries). A cadre of medical librarians would be recruited to provide online reference services. Services would be provided by either videoconference or messaging. Ideally, the use of either messaging or videoconferencing technology would be randomly assigned to each setting and participating librarians would be randomly assigned to use each. If this was not feasible, the two treatment conditions would be implemented alternately at each distant end point for periods of time. Reference sessions would be logged and users would be directed to a short online assessment. User assessments would be compared for the two treatments and retrospectively analyzed in relation to type of information request. Librarian judgments of the two technologies would be collected at the conclusion of the study. This study might be replicated with other users (e.g., health professionals) in other contexts (e.g., clinics and hospitals) where professional librarians are lacking. It might even be scaled, depending on the display technology, where users and librarians have full size views of each other.

<u>Distance education on the use of NLM resources.</u> A variety of synchronous technologies can be used for distance learning. The aim of this study is to address the effectiveness of two training modalities, both in single training sessions and in classes that might be offered over time. How do users respond when training by different modalities in different contexts? Do users respond to the training modalities differently when they are employed over time? In the first phase of this study, subjects will be randomly assigned to search training on an NLM database via live webcast or videoconference. In the webcast condition, subjects will be able to use online chat as a backchannel for conversing with the instructor and each other. In the videoconferencing condition, subjects will be able to interact with each other and the instructor via the videoconferencing equipment.

In the first phase of this study, subjects in each treatment will be co-located in a single classroom. Subjects will be able to ask questions anytime in both treatments and there will be a question and answer session at the end. Students will be given searches to perform at the end of the training session and their search performance in terms of accuracy (recall and precision) and efficiency (search time) will be assessed. Satisfaction and sense of presence will be evaluated. The number and type of questions posed in each condition will be documented. In the second phase, the treatment conditions and measures will be the same, but the subjects will be physically dispersed. The results of this condition will be compared to those in phase one. In the third phase, the treatment conditions in phases one and two will be repeated, but subjects will participate in an online class consisting of a series of multiple training sessions conducted over a period of time. Subjects will use webcast/chat or videoconferencing in either co-located or dispersed conditions. The same measures will be made as before, but performance, satisfaction, and sense of presence will be assessed at the end of class, rather than at the end of each session. A sense of community measure will be administered as well. Attendance and attrition rates between those in co-located and dispersed conditions will be compared. Additional studies might expand the assessment context to provide for persistent presence, allowing subjects (students) to access each other before and after class or in virtual lounges or study rooms and, given appropriate display technology, might include the teaching and use of 3D imaging resources.

Improvement of NLM resources and products. This last area involves the use of collaboration technology, not so much as an object of research, but as a research tool. The NLM has used surveys and focus groups to assess its existing products and services. Collaboration tools offer an alternative way to collect user data for formative or summative evaluation. Formative evaluation involves collecting user data in the first stage of product development or early in the process of making revisions. It is useful in developing iterative changes to an interface based on observing and interviewing small groups of persons (often just three or four) using a given version of an interface. It may be possible to use videoconferencing to observe users interacting with a database at a distance, rather than bringing users to NLM or traveling to a distant site. Summative evaluation involves using the tools more formally to collect data about which of two alternatives are best. In this case, the technology may be used with a larger population of users assigned to different interfaces for statistical comparison.

The efficacy of using videoconferencing technology to study users is unknown. In this study, subjects will be randomly assigned to search one of two different interfaces to a database. They will be given selected queries and asked to search until they believe they have satisfied each query. The results of each query will be saved and each search will be timed. In addition, a questionnaire will be administered at the conclusion of the search session and open ended comments will be solicited about the usefulness of the interface. An onsite evaluator will monitor each subject's performance at the same time as a distant evaluator does using videoconferencing technology. A cadre of on and offsite evaluators will be recruited and paired for observing different subjects to insure greater generalizability. The data collected by on and off site evaluators will be compared for consistency both within and between pairs. Half the open ended responses will be collected online and half locally that will later be content analyzed for comparison purposes. A high degree of congruence will indicate videoconferencing's efficacy for data collection and user assessment at a distance. Additional studies might explore use of the technology in Wizard of Oz experiments (e.g., Detmer, et al., 1995) and other human-computer interaction experiments where hidden experimenters monitor users and mimic the behavior of computer programs.

9.3 The Technical Level

Although there have been major accomplishments in establishing an infrastructure for collaboration within the LHC and NLM, some work remains to be done with the technology that is currently in place. Moreover, since the technology itself continues to change, any future work will necessarily involve keeping up with advances and, when possible, contributing to and testing new collaboration tools with others in the Internet2 community.

Tests are nearing completion on the use of tunneling software that should reduce problems communicating with end points having firewall restrictions. The short term plan is to implement the technology on the OHPCC MCU so it can host multipoint (and even point to point) communication in cases where firewalls pose problems. While it has been possible to webcast videoconferences in the past, the streams have been limited to just the video. Any application programs, such as PowerPoint slides, that were being shared in the conference could not be streamed. Tests of alternative ways of capturing at least the audio (and possibly the video) in a videoconference as well as the use of slide, browser, and other application software are nearing conclusion for later webcasting on demand. Tests also are in progress using screen capture software to do live, one directional webcasts demonstrating database search strategies. A related effort is underway to review new chat tools as a way of obtaining audience participation and feedback in webcasts, similar to what was done in our videoconference/webcast experiment.

The OHPCC Access Grid node is an early PIG system that needs some reconfiguration of its peripheral equipment (microphones, speakers, and echo cancellation devices) to make it more suitable for use with larger groups. The near term plan is upgrade the system using commercially available software for routine uses and improve the echo cancellation capabilities and number of microphone and camera inputs for better room use. This work is scheduled to coincide with installation of a wall to wall rear projection screen in the Collab and multi-projector stereo display system that will make the node in the Collaboratory comparable to other room based Access Grid installations. In addition, the plan is to install and test new beta Access Grid software as it is developed by Argonne National Laboratory and, when appropriate, companion software developed in the Access Grid community. One problem with the AG is the paucity of tools for application sharing. Typically, different client programs are developed for locally running selected applications (e.g., a distributed PowerPoint program for displaying PowerPoint slides). To run the applications the slides are downloaded to local machines and then advanced from the presenter's end point. There is limited interaction with the slides (other than advancing them) and no ability to point to a slide's content. NLM could contribute to the community by creating viewers for 3D data and collaborative web browsing and searching that would enable the AG to be used for Visible Human Data or training people to search its information resources. Alternatively, the NLM could develop a general tool enabling those with the same operating system at least to share *any* desktop application (similar to the T.120 functionality in h.323 tools).

Additionally, there will be a need to become familiar with new emerging digital video technologies, if for no other reason than many are likely to be incorporated into technologies presently in use. H.264 is a new industry standard for high definition video codec that is being incorporated into some commercial products using the h.323 standard. The plan is to test these products as they become available and to participate in tests of new video codecs with the Internet2 consortium. The new Internet2 initiative has focused on DVTS, a technology under development by a research consortium in Japan for encapsulating digital video streams on IEEE1394 and transmitting them without further compression via IP, and VideoLAN, open source software to stream video in various MPEG formats. The possible incorporation of these codecs into the Access Grid is currently under consideration at Argonne. Experimentation with new commercial products, such as Microsoft's Conference XP, will have lower priority but will not be ruled out.

10. Conclusion

Continued use and experimentation with videoconferencing and collaboration can be expected to accompany further advances in computing and network technology. In some cases, the technology may be "wrapped" around other advanced applications, such as 3D imaging and visualization tools, so that users can interact with both the tools and each other in real time. In other cases, the communication and collaboration tools and the applications will become more integrated, as it has with some immersive virtual reality environments. Research involving applications of videoconferencing and other collaboration technology will always be confounded to some extent, but that does not erase the legitimacy of asking which applications are most appropriate or in which circumstances these technologies work best. Similarly, there are multiple criteria for judging their success. Effectiveness needs to be judged not only in terms of outcomes, but in terms of user satisfaction, access, and cost. The role of sense of presence and community and their impacts on users need to be assessed when appropriate.

The OHPCC has dealt with significant technical and organizational problems in beginning to build infrastructure within NLM. These efforts need to continue along with participation in tests of emerging technologies that are being done in the Internet2 community. While it is now possible for OHPCC to use the technology in everyday work, identifying applications of the technology within NLM to formally evaluate with different user populations has proved more difficult. Part of the problem is that the technology only lends itself to certain applications and that the end points either need to have the bandwidth and technology in place or be willing to invest in it. In addition, much of the IP technology is new and many investigators in the field are pre-occupied with developing systems and documenting their feasibility more than doing formal assessments. Finally, unlike tests of other computing applications involving data mining and manipulating data sets, tests of collaboration technology mandate the participation of people at distant end points in sufficient numbers to generate meaningful results. These problems are difficult but not insurmountable. They do not diminish the need for NLM to do more in-depth experimentation on the potential contributions of collaboration tools to telemedicine, distance learning, and the Library's programs.

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