Usage of Web Conferencing for Manufacturing Engineering and Technology Education – The PRIME Experience

Scott Daugherty – Robert Morris University
Winston F. Erevelles – Robert Morris University
Pearley Cunningham – Community College of Allegheny County
Sunday Faseyitan – Butler County Community College
Robert Myers – Westmoreland County Community College

I. The Genesis of Video Web Conferencing

Video web conferencing is an effective way for two or more people to visually and verbally communicate over large distances. It is widely used in distance education, industry, and government sectors. The technology capitalizes on the use of the World Wide Web and its availability in government, industry (87% of U.S. workers have broadband access[1]), academe, and most homes. The "Internet" was developed by scientists and researchers at DARPA in 1962, long before most people had any concept of what a computer was or could do[2]. Primarily used for research, this resource saw no real change for 30 years. In 1990's the "World Wide Web" was developed by a group of people who worked on different components of this new technology to make the WWW a reality[2]. In the mid 1990's, businesses saw potential profit from this network of people, and the Internet boom started with online companies and also traditional companies making profits online. The World Wide Web has revolutionized the way people do business and communicate in a global society.

II. Components and Infrastructure needed for a Web Conferencing System

A generic video web conferencing system consists of at least two users communicating via the World Wide Web. These users would be working at personal computers that have enabling software for web conferencing and are equipped with peripherals such a camera and a headset with a microphone. The computers are networked to a server that controls/moderates the flow of information. The hardware and software described above may be either proprietary or generic in nature and may or may not be bundled with existing operating systems. Systems typically offer users the capability to transmit and receive video and audio images and files, share screens or even software, conduct public and private conversations, and access a common electronic whiteboard.

The costs to implement an effective web conferencing system appear in Table I. Many costs in a video web conferencing system are predictable in nature. Not all the costs involved are static, so a budget must be carefully planned.

Table I. Costs for a Video Web Conferencing System

Static Costs	**Approximate Range**
One time purchase	
Server Setup fee	$250 – 500
Camera (x5)	$50 – 100
Headset (x5)	$8 – 30
Video Server	$4,000 - 30,000
Misc. Hardware, cables, router, etc	$25 – 50
Reoccurring static fees	
Co-Location Set-up fee	$0 – 500
Server Maintenance Fee / Month	$150 – 500
Bandwidth / Gigabyte / Month	$300 – 500
ISP Fee / Month	$250 – 800
ISP Rack Space	$200 – 300
Variable Costs	
Bandwidth Overcharge / Month / Gigabyte (pro-rated)	$300 - $500 / Gig / Month
Individual PC maintenance / Hour / Person	1 - 2 hours / $15 - 20 an hour
Set-up new member / Hour / Person	1 - 2 hours / $15 - 20 an hour
ISP server power usage / Month	$10-25

Display of Static and Variable costs involved. Prices were obtained from several vendors and ISP's.

Examination of Table 1 will reveal that costs are concentrated in network access fees. While web conferencing systems may be operated using dialup services, the lack of bandwidth will adversely impact the quality of the conference. While this may not be a factor in personal communication or chat systems, higher bandwidths are necessary to attain the desired system performance in a group setting or for commercial and academic environments.

III. Video quality in web conferencing

Video web conferencing has come a long way from jerky screen images and crackling audio[3] as it started off with single images traveling over modems and phone lines refreshing every couple of seconds - sometimes once every few minutes. Today, only a few short years later, the capabilities have changed with advances in technology although the goal still remains the same - to communicate. A standard DSL or cable modem connection can transfer roughly 12 frames per second of video with little or no trouble. This is the minimum transmission rate that must be achieved for the human eye to detect smooth movement[4]. Internet traffic can sometimes interrupt this rate, and cause the occasional freezing of frames even with today's high bandwidth connections.

Web-based video conferencing differs from other methods that are used for communications and distance learning. For example, a movie theater projector operates at 24 frames per second (fps) using a filmstrip and displaying an entire image at once[2]. Most American televisions interlace their refresh rates – this means that they refresh every other line of the image[4]. However, a computer screen renders the entire frame in one "refresh" pass - this calls for higher transmission rates to simulate smooth movement[4]. While this paper will not address the workings of the

human eye relative to computer screens, televisions or movie theatres, the experience of current users and the information presented above suggests a great need of improvement for web-based systems to compete with, and operate at the same quality levels as film and television while being cost competitive. "Hollywood quality" or 24 fps is possible with current computing equipment and a high bandwidth connection –in fact, with the right equipment one can obtain close to 30 fps. However, the costs can be prohibitive. Most digital video cameras can currently record 30 fps. Trying to obtain bandwidth on the web for 60 fps, the fastest the average human eye can detect, is pointless due to the camera's limitations. Developers will continue to push video compression technology in the future and make 30 fps and eventually 60 fps available on the web. Video on the web has come a long way in its first 10 years of existence, but it has room for improvement. As distance learning expands its scope, in PRIME's case this means tapping into experiential learning resources at remote locations, this issue will continue to be of great interest.

IV. Advantages and Challenge of Web Conferencing

Advantages

Time compression technologies have been increasingly used in various engineering fields in order to make organizations lean and compete on a global playing field. This philosophy also extends to inter- and intra-organizational communications. The ability of web conferencing systems to create virtual teams and enable virtual meetings will facilitate the reduction or even elimination of travel costs. These overall costs include transportation and transit, cost for food and lodging, and lost or reduced employee productivity due to his/her absence from the work place. This is especially the case in lean economic times when travel budgets are the first to fall prey to cost cutting measures. In comparison, a video conferencing system could pay for itself in very short order depending on the size of company and amount of travel needed especially for repetitive meetings involving several people. The transition is eased by the fact that most web conferencing systems have a fairly "user-friendly" interface that makes it easy to learn. This reduces training time, minimizes mistakes made in meetings, and enables users to become productive in a short time.

Challenges

Video conferencing has not achieved what some would call "critical mass" because it has always been more attractive to hop on a plane or drive to a meeting location[3]. Real-time face-to-face meetings are costly, but business has been conducted that way for centuries[3]. Some organizations will be slow to change, and that can impede web conferencing throughout their supply chains. Hardware such as cameras, earphone headsets, and servers (either purchased or rented) can raise the initial fixed costs quickly. Video web conferencing requires high-speed Internet connections that can also be costly. Depending on system usage and changing bandwidth needs, variable costs can be difficult to project over extended periods of time.

A challenge in video web conferencing is keeping up with new technology or upgrades in existing systems. In addition, video conferencing systems are susceptible to human error. These can occur at a number of locations throughout any video conferencing system and most commonly will be experienced at the user's end. Leaving hardware components unplugged, clicking on the wrong area on a user screen, and the failure to follow directions accurately can all

lead to system malfunctions. Issues of connection speeds and hardware compatibility can also cause major problems. The software itself in many systems may have its own shortcomings – one common example is the fact that most video conferencing software allows a user to see only one person at a time.

Organizational and human issues may also snare or delay the implementation of web conferencing within a given system. Typically IT departments are in charge of much more than a video conferencing server, and have multiple accounts, servers, computers and other network devices to administer, maintain, and operate. When a port needs to be opened on a firewall for instance, one may have to wait a few hours or a few days depending on schedules and also existing policies and procedures for gaining both permission and access. For example, PRIME currently deals with five separate IT departments, all running very different networks of varying magnitudes, and with differences in the size of each department and their scope of work. Repeated testing of all systems prior to a scheduled web conference along with advance notification is necessary to solve a majority of problems. The importance of understanding these dynamics and obtaining the buy-in from these departments and organizations at all levels cannot be emphasized enough.

PRIME had to address each of the challenge and potential pitfalls very carefully. Technology has disadvantages and risks that must be considered. Many can be avoided doing a simple cost analysis before one gets started and running performance checks frequently throughout the life of a system. Continuous research and following updates through publications and Internet forums will help organizations keep up with the latest changes. Video web conferencing can be expensive if not used frequently enough, or if overused. For example, if an employee is using this technology to talk to someone in the building about matters unrelated to work, e.g. lunch later that day, this employee is using valuable bandwidth and costing the organization money. This is because at the time of this writing, charges for bandwidth access, is set-up like cellular phone calling plans. When one exceeds the allotted minutes in a calling plan, or in this case bandwidth, there is an overcharge fee. This is of course depending on your organization's set-up and is assuming the organization pays and rents space and hardware. If an organization is not using the video conferencing system as intended, it can be an expensive yet non-value added utility.

V. Web Conferencing at PRIME

PRIME developed several concepts and investigated several systems in search of a suitable solution for its web conferencing needs. A list of several desired features was compiled and the top three prospects investigated by PRIME were compared using the framework that appears in Table II.

VCON's strength appeared to be in high quality video and audio, along with the standard components that made for an impressive solution. Microsoft's NetMeeting software had all the options there were needed from a standards perspective and appeared to be relatively flexible. Lotus' Sametime software was another flexible system that was extensively investigated.

Table II. Comparison of Web Conferencing Systems Investigated by PRIME

	NetMeeting	VCON	Sametime
HQ Video Communication	3	1	2
HQ Audio Communication	3	1	2
Screen Sharing	3	2	1
Software Sharing	3	2	1
Whiteboard	3	2	1
Group Chat room	3	2	1
Personal Messaging	2	3	1
File Transfer	3	2	1
Bandwidth Needs	2	3	1
Network Flexibility	2	3	1
Overall User Friendliness	3	2	1
Overall Costs	2	3	1
Overall Total	3	2	1

Note: 1 is the best score.

With all three systems catering to the overall needs of the coalition, the focus shifted to flexibility of the solution. PRIME is spread across multiple universities, colleges, and industrial sites that all have different networking capabilities. While VCON is an established distance education tool, it was eliminated at this point because it was the least flexible due to the bandwidth requirements and overall cost of the system.

Microsoft's NetMeeting and Lotus' Sametime appeared to be relatively equal. Both systems were compatible with already purchased Logitech cameras and all versions of windows operating systems. However, PRIME felt that Lotus's Sametime was more user-friendly, and offered more customer support than the NetMeeting system. NetMeeting can require complicated installs and updates that a potential user may have to do themselves. While relatively simple for the average user, this was something out of PRIME's control. On the other hand, Sametime installs and updates itself when connecting to the server and the updates to the video conferencing server are done on administrative side with no effort from the potential user. Sametime also offers excellent network flexibility compared to VCON and NetMeeting. With these advantages in mind, PRIME decided to adopt the Lotus Sametime web conferencing solution.

Some of the features supported by Sametime have proven to be very useful. One of the more prominent features is the screen sharing and software sharing combination. With these tools, one can allow a remote user to take control of a particular software application running on a local machine. This allows users that may not have that software resident on their machine to work with the program. An example of such collaboration may be found with students preparing for a technical project presentation. Student "A" may be in a Westmoreland County Community College, Youngwood, PA computer lab with Microsoft's PowerPoint running. Student "B" may be at any of the other campuses or even at home on their personal computer. They can meet on PRIME's Sametime server to discuss their presentation. Student "B" may want to make editorial or content changes but may not have local access to either the application or that particular presentation. Student "A" would then share PowerPoint with student "B". Student "B" would then have full control over PowerPoint, but no other software or utilities. Now the two students work together creating their presentation and sharing an equal workload. This approach has

several extensions that would enable distributed teams to work very effectively despite being separated geographically. A sample screen appears below in Figure 1.

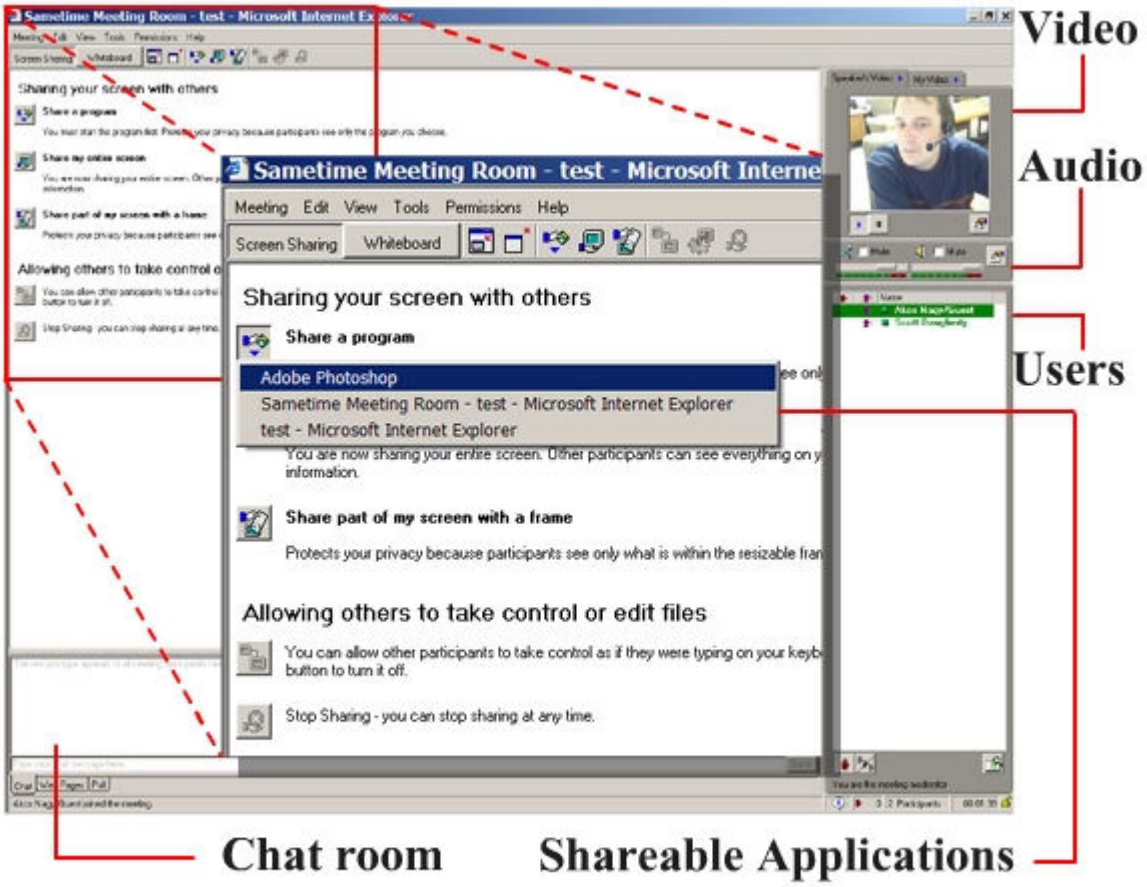

Figure 1. The Lotus Sametime Web Conferencing Environment

Some of the other tools include an electronic Whiteboard, which is basically a color marker board, where the chat room can openly share ideas on the board much like an instructor using a traditional blackboard. The different chat capabilities are valuable to the program, because it allows for multiple forms and levels of communication between users. The users can use the public chat room which is would be used to convey a message to the entire audience. Another way to communicate is through personal messages. This allows communication between users without disrupting the direction of the meeting.

Given the system's video and audio capabilities users may not need the chat functions at all. The video image that appears in the corner of the screen for all participants is that of the individual transmitting an audio signal at a given point in time - i.e. the system is set up so that individual who is talking at a given point in time automatically causes his/her video image to be projected onto the computer screens of all conference participants. This would allow for various users to

remotely access and participate in laboratory demonstration or sessions at a remote site. Human nature dictates that the audience in a room tends to look at whoever is talking - so this is a logical feature. However, this feature does not allow for multiple people talking at the same time, as would be the case in an animated discussion or disagreement! This is where the chat function would prove especially useful. In addition, web conferences may be moderated, thus enabling the moderator to maintain order and control of the room at a given time.

VI. Commissioning the PRIME Web Conferencing System

PRIME purchased a dedicated video conferencing server from IBM for approximately $5,000 and located it at Robert Morris University (RMU) facilities. Several issues were encountered when this server was kept behind the campus firewall. RMU, like many universities, has a tight security system. In order to attain and maintain this level of security, many schools completely shut off ports that are not used by everyday Internet browsing and file transfer applications. This approach allows for easier control over what enters and leaves the campus network. Almost all video conferencing systems use these "unused" ports to increase the speed of the system. This allows the video to be transmitted with a smaller chance of interruption. PRIME personnel, led by the Technical Programmer worked closely with RMU network staff and decided that allowing certain static IP addresses (Internet Protocol Address), which are unique addresses assigned to certain computers, through the firewalls as an acceptable solution that would maintain the security of the system while providing for video acceleration.

This solution encountered some bandwidth trouble, as remotely located members of PRIME had to compete with students on campus for system resources. This was most apparent during the day when the system was sometimes heavily congested, but the system ran as desired during the evening hours. This was not an acceptable constraint.

Another challenge that PRIME anticipated dealt with the issue of static IP addresses. It was felt that partners or new users would not be able to guarantee obtaining a static IP address to penetrate the firewall. For example, when adding a new member at this stage, the static IP had to be obtained, communicated to the IT department at RMU, and then manually added to the approved list – a time consuming process. This set the stage for a move to a system or process that would allow PRIME and its constituents to automate some of the steps involved with its system and eliminate others completely.

PRIME researched local Internet Service Providers (ISP) and one ISP located near the Sametime facilities in California. The research led to the placement of the video conferencing server and PRIME's new web/file server (used for file storage and back-up) at Nauticom (a Pittsburgh ISP) for a relatively low cost. More importantly locating the server there centralized the servers geographically for PRIME, and now the servers may be accessed from anywhere in the world at throughputs of up to 5 megabytes per second. The PRIME web conferencing network architecture appears below in Figure 2.

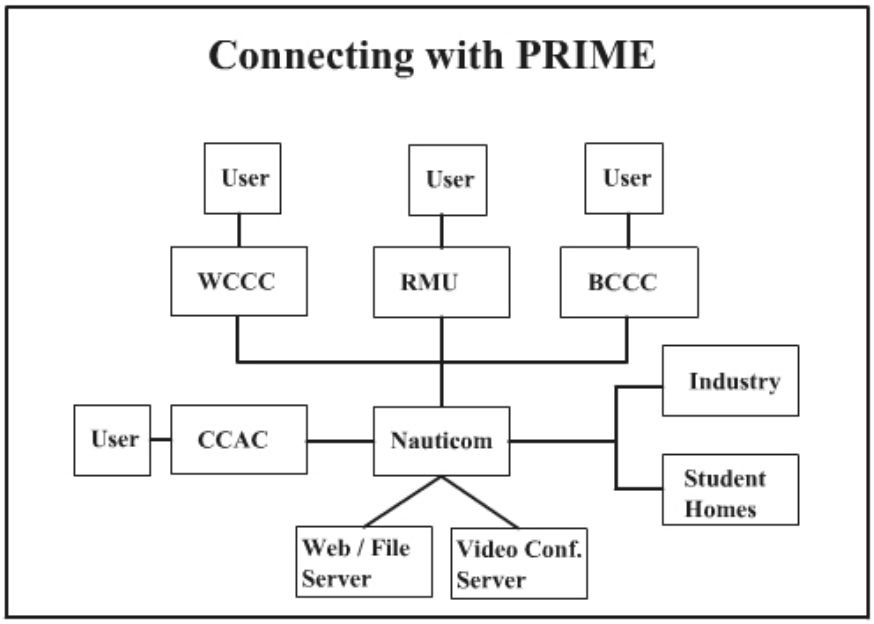

Figure 2. The PRIME Web Conferencing Network.

VII. Growth of Video Web Conferencing and PRIME

Currently the PRIME system connects members in the Western Pennsylvania area – the geographic reach of this system however may extend to reach users at any location. This system will be heavily used in the implementation of PRIME's Manufacturing Learning Model for manufacturing engineering and technology students and facilitate collaborative learning. This collaboration is currently focused on remote access to facilities at each campus. PRIME is experimenting with access to the RMU Learning Factory and the programming, monitoring, and control of an automated machining and assembly cell within the Learning Factory. This cell features Haas VF-1 and SL-20 CNC machines; Fanuc M16-iL, A520i, and LRMate200iB robots for material handling and assembly; Montronix force, power, and vibration sensors for process monitoring; a Bosch conveyor system; a Balogh RF Auto ID system for part tracking; and an Allen Bradley SLC 5/05 programmable logic controller for process monitoring and control. The vision is for a remotely located student is able to access this facility and actively participate in experimental learning within this environment. Tasks requiring manual intervention and safety procedures and standards will require local personnel.

As PRIME grows to stretch its boundaries beyond southwestern Pennsylvania, the video web conferencing will grow with the coalition and become a vital part of its operations. Because of the versatility of the system and the usage of the web, PRIME can connect and communicate with anyone in the world. An ongoing challenge for PRIME in the future will be keeping up with new technology and implementing it. The continued development of the World Wide Web is expected to result in lowered costs for increased bandwidth. This in turn is expected to reduce overall costs of conferencing systems and while improving their quality. PRIME will seek stay on the cutting edge of technology with video web conferencing in manufacturing engineering and technology education.

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SCOTT DAUGHERTY
Scott Daugherty is the Technical Programmer for PRIME. He attended Purdue University where he earned a B.S. in Computer Graphics Technology and specialized in Manufacturing Engineering. He also has knowledge of website design, CAD, and digital multimedia.

WINSTON F. EREVELLES
Winston Erevelles is a Professor of Engineering at Robert Morris University and Director of the PRIME coalition. His teaching, research, service, and publishing interests are in the areas of Manufacturing Processes, Automation, Robotics, Rapid Prototyping, Programmable Logic Controllers, and Computer Integrated Manufacturing. He has worked as a Manufacturing Engineer and Plant Manager at Mykron Engineers, India. Dr. Erevelles earned his B.S. in Electrical Engineering from Bangalore University, India and his M.S. and Ph.D. in Engineering Management (Manufacturing Engineering emphasis) from the University of Missouri-Rolla.

PEARLEY CUNNINGHAM
Pearley Cunningham is a Department Head and Professor of Engineering Technology and Physics at the Community College of Allegheny County. He also serves as a co-PI for PRIME. He has 28 years of teaching experience in engineering technology, controls, and automation. Dr. Cunningham earned a B.S. degree in Education from Ball State University, an M.S. in Physics from Ohio University, and his Ed.D. from Nova Southeastern University.

SUNDAY FASEYITAN
Sunday Faseyitan is a Professor of Engineering Technology & Assistant Dean at Butler County Community College. He also serves as a co-PI for PRIME. He has 22 years of teaching experience in various areas of design and manufacturing and has also worked in industry for 7 years. Dr. Faseyitan earned a B.S. in Mechanical Engineering from the University of Akron, an M.S. in Industrial Engineering from the University of Pittsburgh, and an Ed.D. in Higher Education Administration from the University of Akron.

ROBERT MYERS
Robert Myers is a Professor and Division Chair for Science and Technology at Westmoreland County Community College. He also serves as a co-PI for PRIME. He has 3 years of military experience and has spent the last 30 years in electronics and related areas. Dr. Myers earned a B.S. in Industrial Arts from the California University of Pennsylvania. He earned a Masters of Education, a Vocational Certificate, and his Doctor of Education from the University of Pittsburgh.