Transatlantic Course on 24/7 Collaborative Engineering and Product Data Management

Jan Helge Bøhn[1] and Reiner Anderl[2]

Abstract – This paper describes a new course on 24/7 collaborative engineering and product data management. A key element of this course is to use state-of-the-art hardware and software technologies to deliver live, transatlantic, team-taught joint lectures, and to facilitate synchronous and asynchronous student design collaboration with colleagues overseas: Unigraphics is used for CAD/CAM/CAE; Teamcenter Engineering is used for PDM; Teamcenter Community is used for synchronous and asynchronous collaboration; and Centra and high-end video conferencing equipment is used for delivering live lectures and for team meetings. The students work in four-person teams, with each team consisting of two US and two German students, that, as a class, model and redesign parts of a production vehicle using data that has been provided by an industry partner.

Keywords: Automotive, CAD, Design, Global, PDM

INTRODUCTION

The past ten years has seen an unparalleled, explosive growth in global engineering activities. Computers, networking, and software now enable engineering activities to be managed and distributed globally. Global multinational corporations have pioneered this evolution, and smaller, national, and regional corporations and local government organizations are now increasingly following in their footsteps. The National Science Foundation has recognized the need to respond to these changes by recently increasing its emphasis on the education of globally engaged engineers and scientists that can function successfully in a global economy. Still less than 1% of US engineering students get to experience global engineering by studying abroad or otherwise collaborating with students in other countries. Similarly, though many engineering education programs emphasize team-based capstone design projects, hardly any engineering students are exposed to product data management (PDM). Instead, students typically manage their design project data haphazardly and in a manner that can hardly be characterized as orderly and professional, though they are increasingly expected to do so when they enter the global workforce.

This paper describes a new course on 24/7 collaborative engineering and product data management that begins to address these deficiencies in current engineering education. A key element of this course is to use state-of-the-art hardware and software technologies to deliver live, transatlantic, team-taught joint lectures, and to facilitate synchronous and asynchronous student design collaboration with colleagues overseas. The premise is the belief that these technologies can now finally deliver an acceptable performance that does not hamper the natural modes of interactions, even at a distance.

Indeed, prior efforts in this area have been hampered by the limitations of available communication technologies [1,2]. Typical synchronous communication tools have included regular telephone conferences, high-end H.320 video conferencing (ISDN), and low-cost computer-based video conferencing (e.g., Microsoft NetMeeting). The ongoing costs of regular telephone conferences and H.320 video conferencing tend to make such communication events an infrequent occurrence. Likewise, the poor quality of NetMeeting and its likes tend to discourage their regular use: Users must make minimal physical movement during the conference or the image disintegrates; there is

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typically an awkward 1-2 second delay in the transmissions; and with increasing frequency, their use is inhibited by networking firewalls and network address translators. Hence, students in these environments have gravitated towards relying near-exclusively on asynchronous communication methods and technologies, such as travel (once or twice), e-mail, and FTP. Furthermore, any multi-site collaboration activities have been occasional at best, and then primarily focused on sub-dividing and integrating the tasks between the different sites. While such an environment might suffice for a senior design project, or for an online asynchronous course, it is clearly not suitable for a conventional classroom environment with live lectures and interactions with the instructor.

The past few years have seen two important developments. The first is the reduction of travel in support of multi-site projects. This reduction has been driven by the fear of terrorism and by the need to reduce the costs of doing business. The remaining business travel is increasingly restricted to coach-class, and telecommunication technologies are increasingly being sought to replace travel. The second development is that networking and computing technologies have advanced significantly to provide viable alternatives to travel. It is now practical to integrate and synchronize product data management systems on a global scale, and telephone services (VOIP) and video conferencing (H.323) can be delivered and included in the fixed costs of computer networking. Indeed, because of the vastly increased quality and bandwidth of the global computer network, VOIP telephone service generally has less noise than conventional analog telephone service, and H.323 video conferencing (IP based) is more reliable between countries than H.320 video conferencing (ISDN). In addition, specialized video conferencing hardware can now provide high-resolution video (1024x784) and clear audio with no significant delay at a onetime upfront cost that is comparable to a single transatlantic one-week exchange of 5-6 students.

These technological advances beg the following questions: First, has the time arrived when we can effectively deliver a university course on a transatlantic basis, complete with true, multi-site-mixed student teams, very much the same way we deliver courses locally? And, second, in attempting to do just this, what can we learn from observing the collaborative habits developed by our students, so as to give us a better insight into how today's technologies can facilitate overseas collaborations? This paper will attempt to answer these two questions.

COURSE STRUCTURE

The Technische Universität Darmstadt (TUD) and Virginia Tech (VT) are both members of the Partnership for the Advancement of Collaborative Engineering Education (PACE), a global industry/university partnership [3,4]. It was in this context that the need for a course on 24/7 collaborative engineering and on product data management was identified, and that such a course could be team-taught between TUD and VT. The premise was to use state-of-the-art hardware and software technologies available through PACE and elsewhere to deliver live, transatlantic, team-taught joint lectures, and to facilitate synchronous and asynchronous student design collaboration with colleagues overseas: Unigraphics for CAD/CAM/CAE; Teamcenter Engineering for PDM; Teamcenter Community for synchronous and asynchronous collaboration; and Centra and high-end H.323 video conferencing equipment for delivering live lectures and for team meetings. Furthermore, the students would work in four-person teams, with each team consisting of two US and two German students, that, as a class, would then model and redesign a sub-system of a production vehicle using data that would be provided by a PACE industry partner.

Semester Timing Coordination and Academic Level

The first challenge we faced was to overcome the differences in semester scheduling between TUD and VT. At TUD the Winter semester runs from mid-October through mid-February, whereas at VT the Fall semester run from late-August through mid-December and the Spring semester runs from mid-January through early-May. Furthermore, the number of credits awarded would need to fit into the curricula at the two universities. The solution was to offer a six semester-hour credit, Fall-Spring semester sequence at VT that overlapped a four semester-hour credit Winter semester course at TUD. That is, four semester-hour credits (eight credit points) would be in common between TUD and VT; and one Fall semester-hour credit (two credit points) prior to the joint credits, and one Spring semester-hour credit (two credit points) following the joint credits, would be offered exclusively at VT (Figure 1).

The second issue to be decided on was the academic level of the course. We decided to target the course at seniors and first-year graduate students, and to make English the course language. At this level the students have basic CAD skills, a fundamental understanding of the engineering design process, and the ability to perform general engineering analysis. Furthermore, and quite importantly, the students at this level at both universities have available slots in their curricula for technical electives. Finally, this particular level was selected because it is acceptable to offer courses at TUD in English at this level: Their international students often know English better

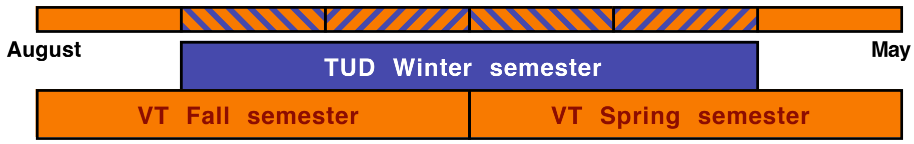

Figure 1 Managing the timing difference in semester schedules.

than German, and the German students often request to have their upper-level courses taught in English to increase their expose to technical English.

Additional VT-only Course Credits

For the 2004-2005 academic year, Unigraphics NX 2.0.4.2 was selected as the CAD/CAM/CAE software system for the course. This is a comprehensive software system that offers a broad range of modeling tools and analysis tools. Though the students in this course are required to have had prior CAD experience, it is unlikely that they will be competent across this software's broad array of capabilities, many of which can be applied to the design project in this course. The first semester-hour credit during the VT Fall semester, which is offered exclusively at Virginia Tech, is therefore structured as a self-paced study in which each student develops an individual study plan to further their capabilities with Unigraphics, and in particular with its advanced modeling and analysis capabilities (e.g., structural, thermal, kinematics). The students base their study plan on the comprehensive portfolio of integrated online tutorials (CAST) that come with Unigraphics. Then, at the end of this first segment of the course, the students must generate a report reviewing the modules they studied and describe the self-generated sample exercises they completed. Likewise, during the last semester-hour credit during the VT Spring semester, which is also offered exclusively at Virginia Tech, the students explore the advanced digital mockup (DMU) and visualization capabilities of Unigraphics and apply these capabilities to further enhance the documentation of their joint team project with TUD.

Transatlantic Joint Lectures

The joint component of the course, which coincides with the TUD Winter Semester, consists of a lecture series and a comprehensive team project. The lecture series consists of weekly lectures given live and simultaneously in the morning at VT and in the afternoon at TUD due to the 6-hour time difference (Figure 2). Each lecture period lasts

1. October 18, 2004
   Course welcome & organizational kickoff meeting
2. October 25, 2004
   Introduction to collaborative engineering; definitions, terminology, roles
3. November 1, 2004
   Project management
4. November 8, 2004
   Team building; task allocation
5. November 15, 2004
   Product data management; PDM fundamentals
6. November 29, 2004
   Collaboration methods
7. December 6, 2004
   Collaboration using a PDM system (Teamcenter Engineering)

Figure 2 The 2004-2005 lecture series.

for about 45-50 minutes. Of this period, approximately 30 minutes is spent on the core lecture material, while the remaining time is used for faculty-student interactions with regards to the course in general and the ongoing team project. The lectures are alternately presented from TUD and VT to both locations simultaneously, while the pre- and post-lecture interactions are bidirectional as in a regular videoconference.

These lecture sessions are given via high-end H.323 videoconference equipment (Tandberg 990 MXP IP-only with NPP and MS). Typical connection speed between TUD and VT is 784 kbits/sec over IP. This permits smooth, continuous video and clear audio without feedback or noticeable transmission delay or dropouts. The system permits simultaneous transmission of Microsoft PowerPoint presentations and other software demonstrations at 1024x768 resolution on one projector, with NTSC or PAL quality video of the presenter and/or participants on an optional second projector. Hence, the only real difference from a conventional Microsoft PowerPoint based lecture is the use of a stylus pen on a tablet PC in place of a laser pointer on the screen because the latter can only been seen locally.

Two backup presentation systems are in place in case the H.323 videoconference system should fail: The first backup presentation system consists of a Centra symposium system, which enables the participants to view the presentation on their individual PC instead of via a local computer projector. Centra includes Microsoft PowerPoint, PDF, WWW, or whiteboard presentation capabilities; and it enables the participants to hear and speak with the presenter over IP. Headphones with microphones have therefore been made available to the students for use with their computers. The Centra sessions are also recorded and placed online so the students can review and re-listen to the lectures on their own time. The second backup presentation system consists of a conventional speaker telephone at each site. This enables the remote site to receive the audio while viewing the lecture slides that have been transmitted separately. Thus far neither of these two backup systems have been needed.

Reading Materials, Lecture Notes, Team Documents, and Team Communications

At this point there is no appropriate textbook for this course. Hence, the assigned reading materials consist of a collection of instructor-generated notes, selected book chapters, and articles. These reading materials, together with their associated lecture materials, were placed online within the Teamcenter Community site that is used in the course as they where generated. Teamcenter Community is a WWW based system that is designed to support synchronous and asynchronous team collaborative activities. The site has places for announcements, file depositories, calendar management, discussion boards, and basic workflow management (e.g., tracking of routing slips and task orders). It also incorporates Microsoft SharePoint to permit desktop and application sharing in the case of Windows XP users. During an instant application sharing conference, the other participants can follow along by viewing a live image of the host's computer desktop. The host can also surrender the control of his or her desktop to another participant, or turn over the entire host role to another participant. Hence, it serves as an excellent synchronous collaboration facility, short of providing audio and video communications.

Skype, a voice-over-IP (VOIP) freeware product (http://www.skype.com), was made available to provide the missing audio communications during the Teamcenter Community instant application sharing conferences. Skype permits up to four users to join in a simultaneous conference call with an audio quality that rivals and often exceeds regular telephones. To maintain this excellent audio quality, each workstation was outfitted with a low-cost, integrated headset and microphone (Altec Lansing, model AHS502). The alternative of using standard, built-in or freestanding PC-style speakers and microphones is generally not acceptable because they more often than not will degrade the audio quality by picking up significant feedback and background noises.

Finally, the students have access to the high-end videoconference systems that is used for lectures, at their convenience on a 24/7 basis. The typical startup time for a videoconference session using this equipment without attached computers is in the order of seconds. In contrast, the setup time for attached computers (in order to show their display within the videoconference) is several minutes. This is temporary situation because the current equipment configuration is experimental as we explore its many uses and configuration options: Currently, the only usage that does not require any setup or re-configuration prior to a session is the regular videoconference usage. We will shortly finalize the installation the equipment installation to facilitate instant display of laboratory and laptop computers as well as camera images within the videoconference sessions, at which time this capability will be available to the students as well.

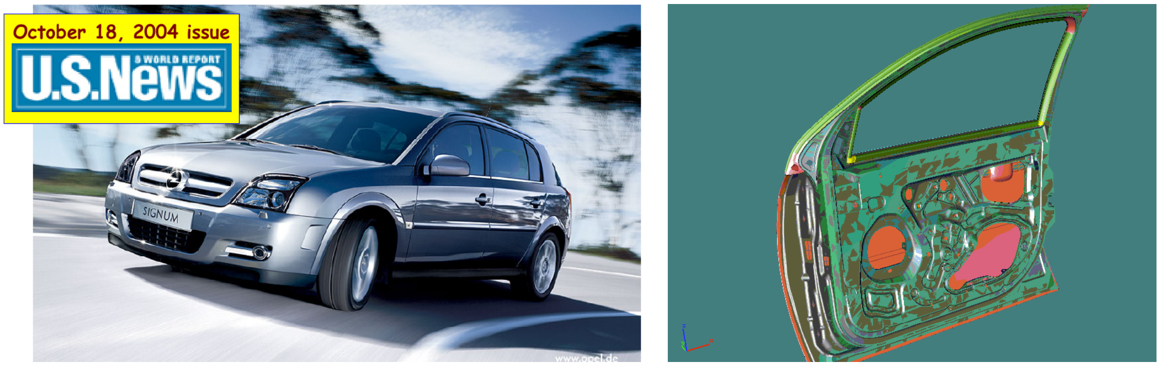

Figure 3 The 2004 Opel Signum (General Motors Europe) and its right-font door.

Transatlantic Team Project

The team project is organized around teams of three transatlantic sub-teams working together on a joint engineering design problem. The ideal team consists of twelve students, with four students on each sub-team, and two students from each school on each sub-team. Each of these sets of three sub-teams are assigned the tasks to design the window locking mechanism, the door locking mechanism, and the structures and panels, respectively, for the right-font door of the 2004 Opel Sigmum (General Motors Europe). The CAD model of this door, less the parts the students are to design, is provided to the students and is shown in Figure 3. Hence, the students must not only collaborate within their transatlantic sub-teams, but the sub-teams themselves must collaborate to coordinate the location and operation of their three respective sub-designs.

This particular year, however, the class consisted of six TUD and four VT students. These students were therefore organized into two sub-teams: Team I consisted of three TUD and two VT students designing the door locking mechanism, while Team II consisted of three TUD and two VT students designing the window locking mechanism.

COLLABORATION WORKFLOW

The underlying objective of the team project is for the students to explore and relate the lecture materials to the ongoing team project activities. Hence, the students were not given strict workflows to follow or strict regimens of meetings and communication technologies and methodologies to be adhered to. Rather, they are to work together to explore, identify, and develop appropriate workflows, project schedules, and systems of meeting and collaboration methodologies using available technologies as appropriate. They are not forced to use one technology or another, but they are introduced to a variety of available options from which they develop their solutions.

Figure 4 shows the project schedule that the students developed, effectively reflecting the TUD Winter semester starting October 18, 2004 and ending with final exams in early February 2005. For instance, during the Working Phase I, each team had to investigate several possible solutions for their respective mechanisms, select the most promising concept, analyze this mechanism, create the black boxes approximating the parts of this mechanism, identify the resulting bill of materials, and distribute the workload between the team members (Figures 5 and 6). Then, during the packaging stage, the black boxes of both teams were brought together inside the Opel Signum door and the available workspace was allocated (Figure 7-a). And, finally, during Working Phase II, the individual parts are detailed designed (Figure 7-b), before they are all virtually assembled.

RESULTS

Planning and Technical Logistics

This course was implemented during the 2004-2005 academic year and scheduled with the expectation that the technologies would be available when needed. The planning process started in April 2004, and significant time was allotted to ensure a timely deployment of the necessary resources. The following critical item were identified by late June 2004:

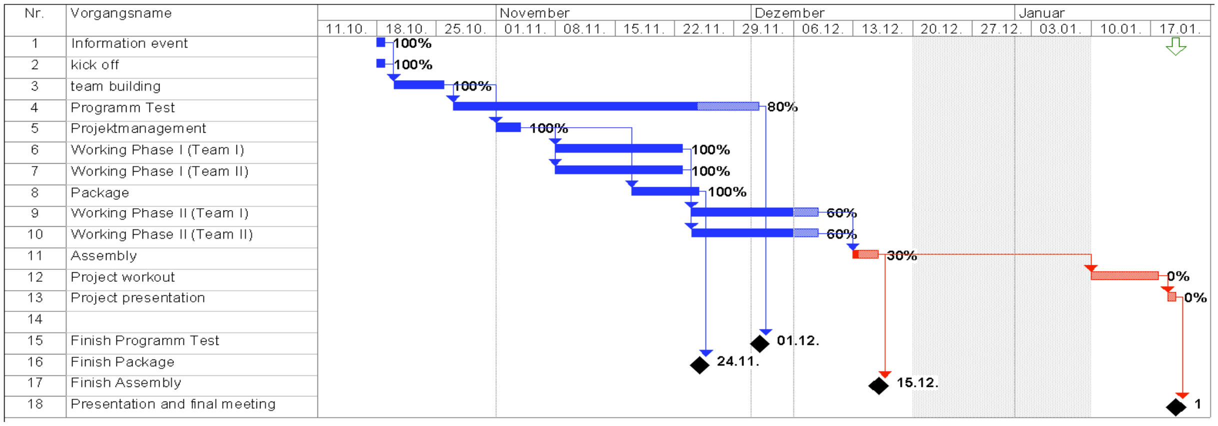

Figure 4 Student-generated project schedule.

Figure 5 Existing systems are examined, and concept solutions are generated.

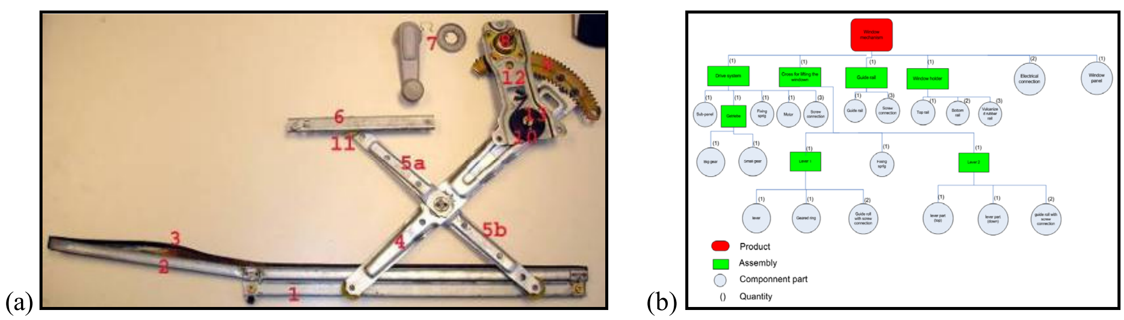

Figure 6 Existing systems are dissected, bill of materials (BOM) are generated.

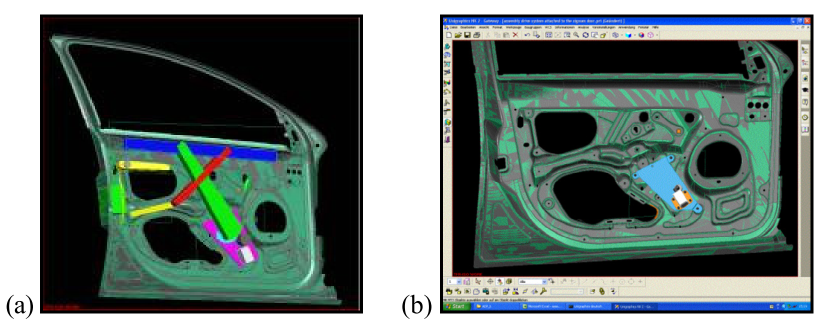

Figure 7 Black boxes are assembled inside the door space, and the detailed design commences.

- → The computer laboratories at TUD and at VT both had new workstations that would need to be installed and loaded with many complex engineering software systems. It was expected that these systems would need to be run under Windows XP SP2, which was scheduled to be released in August 2004. Windows XP SP2 represented a major security upgrade, and it was expected that many software systems would break as a consequence. Hence, we expected to have to invest significant time in testing and patching our systems. The systems were expected to be fully operational by end of August at VT and by early-September at TUD, which would be well in time for the October start of the joint portion of the course.
- → Both Teamcenter Engineering and Teamcenter Community would need new, dedicated servers to be brought online. The hardware was on hand, and no significant delays were expected in these regards.
- → The videoconference systems had been ordered and delivery was expected in July 2004. And, again, no significant delays were expected in these regards.

Hence, we were not particularly concerned that the systems would not be up and running by the time they would be needed. We were tracking the issues, we were pursuing several alternatives to serve as backups if needed, and we had allowed some time for a few unanticipated delays—which arrived soon enough: Both TUD and VT slipped a few weeks with their respective workstation upgrades. The media and license keys for Teamcenter Community arrived in late September. One of the new file servers that were to be support Teamcenter Engineering at Virginia Tech required a near-complete hardware replacement due to faulty parts that caused it to sporadically crash multiple disks within minutes of each other. Windows XP SP2 did indeed introduce problems that took time to resolve (e.g., Unigraphics, Centra). And finally, the videoconference system orders were delayed due to model changes in mid-July, thus causing the units to not arrive until late August (not counting the 12 days the VT unit was "lost" in receiving).

Still the most significant delay had not been anticipated: Both the videoconference systems and the Teamcenter Engineering client/server system were being blocked by network security measures. Identifying the source of these problems was not obvious. The systems were new, they had not yet been operated, and there were limited, easy-to-launch opportunities available for comparison. Then, once we discovered the source of the blocking, we also discovered the challenge of overcoming the problem. As most places, out of necessity and to ensure their mission is met, the networking security organizations within universities maintain strict, rigorous processes for making non-standard changes and exceptions to its networking configurations. Consequently, valuable time was lost, and the videoconference capability was not operational until early-October.

Disabling the network security measures on the ports for a videoconference system is generally considered an acceptable risk because it is difficult to break into and use the firmware-based servers built into the videoconference system for malicious purposes. However, it this risk is not accepted, then a H.323 gateway or H.323 proxy needs to be established to enable the videoconference to overcome the network security measures. In our case the problem was solved by disabling the network security measures for the ports serving the videoconference system.

However, disabling the network security measures on the ports serving the many workstations that were attempting to connect to the Teamcenter Engineering server was, understandably, not deemed to be acceptable for two reasons: First, workstations are easier to break into and reconfigure for malicious purposes; and second, the number of exceptions would be much higher due to the large number of workstations that were affected. The solution here, therefore, was to use a virtual private network (VPN) to connect the clients with the Teamcenter Engineering server.

Connecting a client/server system across firewalls and network address translators is trivial in principle. It simply requires the use of a virtual private network (VPN) to make the client appear on the local area network (LAN) of the server. However, this becomes more challenging in a general laboratory environment where the clients need to simultaneously access local servers as local machines (i.e., not going through the VPN) to access local files, LDAP servers, etc., and remote server via the VPN. This can be achieved by configuring the workstations for split-mode VPN access; that is, if a resource cannot be reached via the local network, then an attempt is made to reach that resource via the VPN. This can be configured under Windows XP as follows once configured for VPN access:

> Internet Protocol (TCP/IP) Properties → General tab → Advanced…
> General tab: Select "Use default gateway on remote network"

Student Work Habits

This course presented the students with a wide array of communication options, many of which enabled the students to collaborate and operate the workstations in number of alternative ways. They could choose to exchange audio by high-end videoconference, by Skype VOIP, or by telephone (too expensive); and they could choose to exchange video by high-end videoconference or by inexpensive webcams, or by some combination thereof. They could choose various means of text exchanges, including e-mail, SMS, AOL/MSN/Yahoo instant messages, and Teamcenter Community. And, finally, they could share each others desktops via instant application sharing inside Teamcenter Community, thus enabling one student to reach out and show another student how to operate a given software product. Their preferred means of communication was by videoconferencing using the high-end systems, and by posting announcements and documents within Teamcenter Community.

In reviewing their activities within Teamcenter Community, it is clear that the students did not stray far from the obvious, top-lay capabilities of Teamcenter Community, such as posting announcements and shared documents. They did not actively use the discussion boards, routing slips, or the issues and task tracking capabilities. One apparent reason for why they did not dig very deep into the Teamcenter Community system is that they received minimal feedback from their teammates the few times they did. And conversely, they did not provide feedback because the postings there were were minimal, and because it inconvenient to continuously browse to see what was new. Unfortunately, they also did not discover how to have Teamcenter Community generate daily e-mail reports on what is new.

However, as they discovered new means of communications, and they grew more comfortable with these new means, they expanded the diversity of tools used. For instance over time, the use of Skype and instant application sharing became more common as they got used to this mode of collaboration.

CONCLUSIONS

Planning ahead is a necessity for technology-intense courses such as the one described here. Based on our experiences, it would be prudent to begin the hardware and software deployment six to eights months prior to production start. While in concept a deployment should take much less time, this added lead time is effectively necessary to overcome the very same challenges that are typical today when any two separate organizations need to synchronize that hardware and software systems, including the networking security issues. Firewalls and network address translators frequently block H.323 videoconference network traffic, and overcoming such problems should be planned for. Possible solutions include removing such security features for particular network lines, or installing a H.323 gateway or proxy system. Similar concern must be taken to enable the use of a common Teamcenter Engineering database. Where firewalls or network address translators are installed, it will generally be necessary to implement a virtual private network (VPN) for the clients to reach across the barriers to the server. However, this is not necessarily a trivial configuration if the clients need to simultaneously access resources inside their security domain. Solutions to these networking challenges will typically require complex collaborations between multiple organizations within the two universities, and they will take quite some time to decipher and complete.

Once these technical challenges have been overcome, and with the availability of state-of-the-art collaboration technologies, it is amazing how the transatlantic teaching and team project environment becomes similar to one within a single university. The dynamics of lecturing via high-end videoconference systems become similar to lecturing in a mid-sized, conventional lecture hall; and the challenges students face in bonding with their overseas teammates and finding common out-of-class meeting times, are very much the same that are observed in single-university student teams of similar sizes.

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