AC 2007-1863: HOSTING/PARTICIPATING IN GLOBAL COLLABORATIVE PACE PROJECTS

Nicole Giullian, Brigham Young University
Nicole Giullian is an undergraduate student in Mechanical Engineering at Brigham Young University in Provo, Utah. She will graduate with her Bachelor of Science Degree in Mechanical Engineering in April 2007. While at BYU, Nicole has worked as a research assistant in the ParaCAD lab and as a teaching assistant. She also completed two internships in Hartford, Connecticut with the Structural Methods group of Pratt and Whitney.

C. Greg Jensen, Brigham Young University
Dr. C. Greg Jensen is an Associate Professor of Mechanical Engineering at Brigham Young University. He has also worked for Boeing, Lockheed, and United Technologies. His current research interests are in the area of integration, optimization and customization of CAX tools, with a second focus in the direct machining of CAD topology.

Jason McCammon, Brigham Young University
Jason McCammon holds a Bachelor of Science Degree in Mechanical Engineering from Brigham Young University in Provo, Utah. He also coauthored a paper accepted at the International Association of Drilling Contractors/Society of Petroleum Engineer’s Drilling Conference in February 2006.

Brad Brooks, Brigham Young University
Brad Brooks graduated from Brigham Young University in April 2007 with a Bachelor of Science Degree in Mechanical Engineering.
Hosting/Participating in Global Collaborative PACE Projects

Abstract

Certain obstacles must be overcome in order to realize the benefits of large-scale collaboration projects. Undergraduate engineering curricula currently do not include projects of sufficient scope and diversity to introduce students to the challenges and lessons inherent to participation in global collaborative design projects. Engineering students today largely graduate with little or no skills or experience working on an international team. Universities need to take steps to institute international collaboration projects that prepare undergraduate students for engineering work in the twenty-first century.

Participating in an international collaboration project is a daunting task for a school that has never worked globally before, and launching or hosting such a project likely seems almost impossible because of the numerous obstacles. In 2005-2006, GM/PACE (Partners for the Advancement of Collaborative Engineering Education) sponsored the first international vehicle collaboration project, a senior capstone project that demonstrated how global-scale projects effectively prepare students for future exposure to large-scale collaboration projects in industry. The most important results of this pioneering project were the lessons learned about global collaboration. Sharing these lessons with other schools will facilitate participation in or hosting of global projects.

Using the international vehicle collaboration design project as a case study, this paper will focus on the requirements needed to either host a global collaboration project or be a participant. Because the success of the project depends on effective communication, it will be the primary focus of the recommendations. First, the necessary software and hardware requirements will be outlined, with a focus on collaborative tools. Next, the various types of training needed for students to become completely involved will be described. Finally, other keys to success will be explained: defining overall and local objectives early in the project and tailoring the project requirements at each site to the school’s resources and goals.

Introduction

In recent years there has been a movement among large universities to offer students a global experience. However, this movement has been stagnated in the engineering arena by the lack of available resources and instruction in collaboration and working together in a global context. Typically, mechanical engineering capstone classes place students from one school with an industrial company. It has been generally thought that the design and build nature of engineering capstone is so complex that adding multiple companies or teams from a variety of universities would only add chaos to confusion. However, this challenge is faced daily by real world engineers as they work with colleagues, suppliers, subcontractors, etc. from around the world. The “future of many firms will depend upon their flexibility and quick responsiveness”\(^1\), especially in regard to global collaboration\(^2\). Engineering students who are able to hone collaboration skills during their university experience will have a great advantage in the workforce.
The steep learning curve and amount of uncertainty in beginning a global project are two of the primary reasons for the lack of international collaboration projects. The lessons learned about collaboration in this project can be applied to any global project to ease the entry into such a project. These lessons learned are from the unique perspective of a global project host, so all aspects of the project are comprehensively understood. Using the international vehicle collaboration design project as a case study, this article will explicate the specific requirements needed to either host a global collaboration project or be a participant, thus providing a vital reference for any university or professor wishing to host or join an international collaboration project.

This paper will explicate specific requirements needed to either host or participate in a global collaboration project. This paper discusses and proposes PLM hardware and software requirements, minimal organization, a generic project schedule, strategies for component parametric design and analyses, and approaches to system integration for a successful project. In addition, the advantages and disadvantages as well as the strengths and weaknesses of all the aforementioned areas will be analyzed so those preparing to participate will be fully aware of the challenges they will face.

Though the process of collaboration was more time consuming than the students initially expected, the rewards were likewise beyond expectations. This paper will become a guideline to aid universities in their entry into global engineering projects. The lessons learned from large-scale collaboration projects become essential building blocks for improving future projects.

**Background**

The ever increasing trend of economic globalization necessitates dynamic and meaningful collaboration between engineers, designers and executives transcending political and cultural boundaries. Traditional design theory has been expanded and adapted to include collaboration, and this adapted collaborative design involves accessing shared data across borders and sharing both engineering and design knowledge. A variety of technologies are being used in new way to aid collaboration. The use of the World Wide Web “…has found wide applications in product design and manufacture.” While such collaboration can potentially accentuate the individual efforts of the discrete groups involved, significant obstacles inherently accompany such efforts. However, once the obstacles are overcome, effective collaboration significantly increases the overall performance of the team.

In response to the challenge of global collaboration, the GM/PACE organization sponsored a global vehicle collaboration project in the fall of 2005. A project involving so many universities and of a global scope had yet to be attempted by undergraduate students. The global vehicle design collaboration project involved thirteen different universities from eight countries:

- Brigham Young University (USA)
- Virginia Polytechnic University (USA)
- University of British Columbia (Canada)
- University of Toronto (Canada)
- University of Waterloo (Canada)
- Hong-Ik University (Korea)
Teams from BYU, Virginia Tech, University West, Monash and Hong-Ik included both engineers and industrial design students and teams from all the other universities included engineers. A visual representation of the collaboration sites is shown in Figure 1.

The goal of the project was to collaborate in the design of a vehicle that is both affordable and attractive to a college-age individual. The students were encouraged to stretch their capabilities and those of the software being used to create an innovative and aesthetic design. In addition, the students were challenged to incorporate the ideas of parametrics and modularity into the vehicle design. The organization of the project was similar to that of GM, with BYU acting as the vehicle integrator, Virginia Tech acting as the power train integrator, and all others schools working on specific parts of the vehicle. Each group of engineering students was responsible for a particular component of the vehicle such as the brakes, suspension, or steering assembly. Four industrial design schools were assigned to create individual exterior designs for the vehicle, and BYU industrial design students designed interiors for each of the exteriors.
Another goal of the GM/PACE vehicle design collaboration project was to incorporate the PACE tools as much as possible and learn novel ways to apply them. The PACE suite of tools includes a variety of engineering, manufacturing, and industrial design software packages. The chassis design at BYU incorporated a number of these tools, allowing students to apply engineering principles in a real-world situation.

The results of this project included countless sketches, renderings, models, analysis results; however, the most important results of this project were the skills and understanding gained by the students involved.

**Host Site Requirements**

Before deciding to host a global collaboration project, a university must first be sure that it has the resources necessary to effectively head such a project. Supervising such a large project is not a task that can be taken lightly. The following resources are crucial before even considering hosting:

- Support of the department, college and university administrators
- IT group capable of maintaining software and servers
- At least one faculty mentor with sufficient time to devote to the project

Once all these resources have been identified and confirmed, the host site should choose a problem sponsored by industry as the basis for the project. In doing this the host site should insist that the industrial partner identify project experts and mentors to help with the initial project formulation, provide ongoing mentoring and conduct design reviews. Students will invest much more time and effort if they know that the project has an industry sponsor that participates over the course of the project. Often the host site will need to reformulate the industrial project in the context of course and academic requirements. Regardless, it is the host site’s unique responsibility to provide the overall direction and vision for the project to the other schools. This is true of both the professors involved as well as the students at the host site. The host must also respect the balance between providing an overall vision for the project and unnecessarily strapping the other participants with requirements and parameters that stifle creativity.

Although the host school should leave as many decisions as possible up to the participant schools, certain requirements simply must be set—even if the decision to do so seems arbitrary:

- Software versions
- Start and end dates
- Interim review and report dates
- Master project schedule
- Overarching project objectives
- Necessary project parameters

Setting these requirements will eliminate confusion between participant schools and speed the start of the project. In respect to the project objectives particularly, the host must ensure that the participants have correctly interpreted the master objectives into local objectives, goals and requirements. Certain project parameters, such as wheelbase in the case of a vehicle project, must be set firmly to give direction to the project.
Before inviting the other schools to participate, the host site should have a PLM system like Teamcenter Engineering (TcE) and a collaboration tool like Teamcenter Community (TcC) running on servers that are outside any academic firewall. As a web-based application, TcC is extremely useful “for bringing new team members up to speed”. Because the project is being worked around the clock, these servers need to be maintained 24 hours a day. The host should provide these resources such that connection bandwidth can be maximized at all locations while providing a secure and reliable database.

The primary reason that TcE and TcC must be running before the project begins is because one of the most important roles of the host school is that of a communication facilitator and without these programs, facilitating communication is virtually impossible. The host school must shoulder the responsibility of being the communication catalyst. Within this role the host has the responsibility to foster and support active communication and to provide the central infrastructure for this communication. Regarding the first responsibility, the host school must be active in communicating with other schools by attending all project design reviews, frequently interacting with members of other teams and encouraging other teams to contact each other on a regular basis. As mentioned above, in addition to hosting and maintaining the TcE and TcC servers, the host school must also manage other project databases and develop and host lists of all participants’ profiles, Instant Messenger accounts, email addresses, etc.

The host school acts as the model school, setting the expectations for each of the other schools on the projects. They must be prepared to fully participate in the projects in a participant’s role as well as a host’s role. Therefore, a host school must fulfill not only these requirements but also the participant site requirements described below. In addition to selecting team members in the same manner as participant schools, the host school must pick a student as a liaison for each participating school. This liaison is the primary channel of communication for the participating school to the overall leader.

**Participant Site Requirements**

Like the host university, a university considering participation in a global collaboration project must also ensure the support of the department, college and university administrators as well as the IT group, because a number of software packages will likely need to be installed and maintained. The first step a participating school should take is collaboration with the host school. Through this collaboration, the key information is passed down from the host school to the participant: software versions, start and end dates, interim review and report dates, the master project schedule, overarching project objectives, and other necessary project parameters. This information must be dictated from the host school or confusion will result.

Once the general information is received, the participating school will have the responsibility to make many of the same decisions as the host school, only on a local level. With this information and other decisions made, the participating school should then determine how their students will receive grades for their involvement. The participant school must decide whether their involvement will be an extracurricular/student club (hence no grade), a capstone team, or an entire class, and also decide whether it will be done strictly with undergraduates, graduate
students, or a combination. In answering these questions the instructor can quickly determine how big his team will be and the type of component that would work best.

Participating schools (in collaboration with the host school) select or are assigned a component of the project consistent with their local needs. For example, if a local curriculum requirement states the students must design a mechanism as part of a kinematics class, the school should be assigned a component that can fulfill the requirement. The participant school must effectively communicate its strengths to the host school so the host school can assign an appropriate project.

Once the project is clearly defined on the local level, the next task for the faculty mentor is to form the best team possible. The chosen team must be excited about getting involved with students from other countries/cultures and where possible speak the languages of the participating schools. The students should also have an appreciation and understanding of the type of engineering project being done, whether automotive, aerospace, or otherwise. In addition, some CAD experience will be highly beneficial. A team leader should be appointed or elected from among the students; this leader will have primary responsibility to ensure the team is working effectively. It is recommended that participating schools appoint at least one student to be the master of each software application that will be used. The student assigned to each tool should actively seek as much training as possible and become the tool expert over the course of the project. It is recommended that these tool experts train the other team members to improve the tool readiness of the whole team.

With a component chosen and a team created, each participant school should create an individual schedule in conjunction with the overall schedule. This schedule should include frequent design reviews with the host school and other schools working on related components. Barring extenuating circumstances, each school should maintain and revise their schedule — realizing that falling behind may cause the entire project to fall behind schedule. Along with this schedule, a spreadsheet should be created with student and faculty contact information, pictures, and biographies.

As the project progresses, each participating school must realize that changes may be required to conform to project recommendations. For example, each school exercises equal right to request changes to another team’s components that they feel are beneficial to the overall project. The teams should work together to balance their required parameters to create the best overall design.

**Collaborative Tools**

*Teamcenter Community*

At the heart of the collaborative effort should be Teamcenter Community (TcC), a PLM collaboration tool developed by UGS. The TcC servers generally should be provided by the host school. All individual users are able to log in using an internet browser. TcC should serve as the central location for information storage and sharing for a project. Besides being easy to use, it enables the students to manage part files and documents, make general announcements, coordinate calendars and update other students on progress.
The TcC interface is modeled after Microsoft Office and any user familiar with this set of programs quickly feels at home in the TcC environment. Figure 2 shows the main TcC interface page.

With only minimal training, all students can quickly learn how to navigate TcC and take advantage of its functions. TcC does not require local software installation for simple navigation and requires only a handful of small plug-ins to fully function. TcC is also easily accessible away from campus, enabling students to stay up to date while at home or traveling. This is especially important because of the inevitable time differences between participating schools. A school in Asia may be closed and locked for the night when a student wants to join in an application share with a school in Mexico. The ability to connect to TcC from virtually any location enhanced the frequency and volume of communication between schools. The key built-in features of TcC that should be heavily utilized in a global collaboration project are discussed in more depth below.

One important feature of TcC is the sub-site: essentially a miniature TcC within the overall environment. The main TcC site should not contain all the required folders; such an organization would be far too spread out to be effective. Main sub-sites should be created for major areas of the project to efficiently organize the data. This design streamlines the calendar and announcement pages so only events related to the page category were displayed, eliminating
superfluous and unnecessary information. Figure 3 shows the main interface for one of the sub-sites. Notice the similarities between this and the main page.

Figure 3  Sub-Site Interface

Modeling - Previous

- Draw on the chassis to consider all mount
- Consider positions of all panel (upper/lower frame)
- Parametric study
  - thickness of floor panel
  - fire wall height / width
  - floor pan width / length
  - trunk pan width / length

Figure 4  Application Share
TcC also allows real time application sharing between any number of users. This functionality was used in lieu of typical application sharing systems like Microsoft NetMeeting or XTV because of its improved capabilities. In order to initiate or join a conference, a basic plug-in must be downloaded from the server and installed. Any single user can initiate a conference, and the person who starts the conference can either share the entire desktop or only select applications. All participants in the conference can then view on their screen the applications that the host elected to share. Figure 4 shows an application sharing screening taken during a design review between Hong-Ik University and BYU. Notice the application sharing control window in addition to the screen shown. This screen shot was taken on a computer at BYU but the images originate on a computer at Hong-Ik.

During an application share, the host can also surrender control of the screen to any other user. Similarly, the host can allow another user to take over the conference as host and share their screen. In this way, users a half a world away can share files as if they are in the same conference room and work on applications together as if they are at the same workstation. This capability helps to overcome the major obstacle of distance.

Routing slips, another key feature for collaboration, provide messaging and file management capability in a straightforward way. Within TcC users can initiate routing slips to remind others of meetings, request review of files and inform other users of changes made to files. In addition to allowing text messages to be sent, routing slips can include pointers to files stored on the TcC database. The person initiating the routing slip can ask the receiver to review a file that has been updated and respond with any changes. Routing slips can be sent requiring no action or requiring a response from the recipient. If a response is required the routing slip will appear incomplete on the list of routing slips of both the recipient and the initiator until the requested action is complete. The initiator can therefore be notified when action is taken in addition to requesting action.

To store files, TcC has an integrated database to allow users to share files. The database is organized much like Microsoft Windows, with multiple folder levels that allow users to customize how they organize their information. This central storage method allows users across the world to view the latest parts and analysis files being completed by another school. It also allows users to retrieve their own files while away from their primary workstation. This is particularly useful when team members travel to other locations.

A key to collaboration is a clear knowledge of exactly who is working on what. TcC contains a built-in directory of all the users with login accounts to the system. During the collaboration process, students often realize they need to contact team members they had not contacted previously. When such needs arise, the built-in TcC directories allow a team member to quickly locate and contact another team member. As mentioned in the participant requirements, each university should have a folder within the database where a picture and a short biography of each team member were stored. This gives the other team members a face and a personality as well as a name.

Finally, TcC contains a calendar where members can enter meetings and events. The calendar is a central feature of the main TcC interface page. This central calendar allows for efficient time
coordination between users spread across the globe. Figure 5 shows one of the calendars within TcC.

![Figure 5 TcC Calendar](image)

Although Teamcenter Community was the central collaboration tool, the project experience brought out a few weaknesses. This project would be somewhat more streamlined if TcC were to have integrated voice and video conferencing capabilities. Also, though the viewer is able to view CAD files, there is no integrated viewer for text files and spreadsheets. Finally, it would be convenient if each user could set their offset from standard time and the calendar would appear in local time at each location. This would eliminate significant confusion. However, while there are some weaknesses in TcC, it is overall a very powerful and effective program. Most of the weaknesses were overcome by using other tools described below.

**Video Conferencing**

Video conferencing was essential to collaboration during the project. In general, schools that had available video conferencing equipment were more productive and more capable of receiving and completing project goals. Additionally, a contrast in school participation was visible when schools were actively participating in meetings via video conferencing. However, some schools had limited access to video conferencing equipment, thus making such communication difficult.
Being able to see others on video and hear an audio feed was nearly as good as meeting them in person. Figure 6 shows a video conference between VT and BYU. The picture was taken at VT and the BYU lab can be seen on screen.

**Conference Calling**

Teamcenter Community does not have the capability to relay voice conversations while application sharing. In order to more effectively use application sharing feature of TcC, a conference line can be established for the schools involved on this project. Any number of schools could call in at the same time and communicate with each other. When coupled with application sharing, this allowed users to not only view each others’ screens but to speak with each other as well. Though not every school had video conferencing capability, virtually all of the schools were able to utilize the conference phone number to communicate when needed.

**E-mail**

One of the most frequent means of communication was e-mail. Utilizing the TcC directories, each student had access to the email address of all the other students. Email was also useful because of the time differences between locations.

**Instant Messaging**

Along with e-mail, instant messaging was a universal method of communication for most schools. At the beginning of the project MSN Messenger was chosen as the messaging program of choice. Yahoo, AOL, Gtalk and Skype were also considered. When deciding to use a messaging program the major factors were the programs ability to conference chat, audio conference, application share, video conference, and file share. The host school should pick the type of instant messaging program to be primarily used. This quick informal means of communication allowed for an easy method to quickly reach other team members. At peak times communication likely reached hundreds of messages per day between schools. Messaging
contributed greatly to the project by serving as the most easy and informal means of communication. In most cases, a telephone was not needed because of a messaging program.

**Travel**

Travel was by far the most effective time spent communicating with each school. A faculty mentor and at least one of the team members from the host school should visit each of the other participating schools. One or more days were spent with each school to give training on software, explain the project vision, and answer any questions the students or faculty had about the project. In addition to the training opportunities, collaboration through email or telephone was much more meaningful after the students had some opportunity to work directly with each other. Travel is lengthy and expensive and certainly had to be limited, but the effect of students working directly together for a few days were felt for the duration of the project and should not be underestimated. The effectiveness of these visits was clear by the amount of change in each school’s participation after the visit.

**Collaborative Activities**

**Scheduled Design Reviews**

The students should participate in a variety of collaborative activities, both formal and informal during the course of the project. However, a formal design review should be scheduled every other week for each team. These reviews update other teams on the progress and collaborative needs of the host team as well as creating a record of team progress. The host team should prepare a PowerPoint presentation outlining their progress and any collaboration needs and upload it to the TcC database 24 hours prior to the scheduled time of the meeting to enable the other participants in the meeting to review the material beforehand. The host team is also responsible to initiate routing slips to all the teams who needed to be at the meetings. During the actual meeting the host team initiates an application sharing conference on TcC, allowing other schools to view the presentation via TcC. A conference phone line can be used for audio communication. These conferences were an effective opportunity for all the schools to discuss their progress and collaboration needs. It also provided accountability for each team as they regularly reported to the other teams on their progress.

**Regular Update Meetings**

In addition to the formal design reviews with multiple schools, liaisons should meet weekly with their schools. These meetings more informal in nature and may be completed using the video conferencing unit, instant messaging or the conference line. These meetings also help provide accountability. Because of these meetings, the liaisons will likely develop personal relationships with others on the project and thus encourage the other students to be more involved.

**Informal Communication**

While working in their respective labs, team members should be available for others to contact via instant messaging software. Webcams and microphones connected to students’ computers
will facilitate these quick meetings. While informal and short, this type of communication was key—the teams who participated the most in such communication were far engaged. An example of informal communication is shown in Figure 7. A BYU student is interacting with students at UIA while sharing an NX screen using TcC and using instant messaging software.

**Figure 7** Informal Communication

**Challenges**

All schools interested in participating must be aware of the challenges inherent in a global collaboration project before the project begins. This awareness will help the schools decide whether or not to participate, and if a school decides to participate, it will allow the faculty and students to take steps early to help overcome these challenges. Some of these challenges were recognized before the project began; others were only discovered in the course of the project.

*Language and Culture Differences*

A large challenge of this project was that of language and culture differences. If possible, the faculty mentor should recruit students who know the languages and respective cultures of the schools involved. This skill is extremely helpful when highly technical subjects must be relayed to the various schools. When traveling, the knowledge of the culture and language was vital to effective communication with the schools. This also ensured that the participating schools received the best training and understanding of the project vision. The language and culture barrier can be overcome by the students’ experience and knowledge.

*Time Differences*

Several scheduling problems will occur when project members set up meetings and design reviews because of different time zones. A morning meeting for one school corresponded to an evening meeting for another. In some cases, this was the only way that a meeting could be
convenient for both schools to meet. Time differences are a challenge, but with careful planning the challenge can be overcome. Despite the awareness of this challenge before the project begins, one factor that may throw off scheduling of meetings was daylight savings. Again, however, careful planning was the most effective remedy; sending an email or routing slip out the night before to warn all members of the change can avoid confusion. Another way this challenge could be dealt with would be to find software which supported time zone changes.

**Software Training**

Software training is needed throughout the project, especially at the beginning. This challenge may seem daunting but generally can be overcome with one-on-one time during travel visits to each school or through video conferences. If a school needs additional, more specific, training later, a specialist should be sent from the company to train the students at the host school; they can then relay the necessary information to the participating school.

**Computer Firewall/Connections**

Firewall and network connections could be a cause of unanticipated problems. Schools should check their internet port settings and ensure that their facilities are adequate for the project. As mentioned before, the TcC server should be moved outside a school firewall. Slow connection speed also affected video conferencing capabilities. Schools that did not have fast connections were noticeably slower during video conference sessions. The audio and video speeds would pause and sometimes stop for seconds at a time. Inadequate connection speed can greatly inhibit collaboration and retard progress, so this issue should be resolved beforehand. The connections also may not be adequate for transferring large files.

**Lack of Software**

Schools should ensure that they have the entire suite of software tools or they will be limited in the amount of analysis that can be done. A surprising issue that many schools many not consider is the lack of Microsoft Office software. Most documents uploaded to TcC are initiated using Microsoft Office, so schools without this software could not read the files from TcC. As mentioned previously, installing other software can be an issue because not all schools give such privileges to their students. Lack of software was generally accepted by students as faculty attempted to get a hold of the necessary software. It would be a great advantage to the students to have the entire PACE software suite of tools available before the initial project start date.

**Competing Engineering and ID Objectives**

During the course of the project, the collaboration between schools may not always go smoothly because team members from various schools could have different ideas of project goals and optimal parameters. It must be ensured that the project goals given by the industrial sponsor are understood and defined on both the engineering and industrial design side. Otherwise, several months of engineering and design can be lost. Industrial design and engineering students should bring up their concerns at the beginning of the project so they can be resolved immediately and not adversely affect the project.
Three Case Studies

The rest of this paper presents the collaborative work of students using the previously mentioned PACE project as an example. This project was the basis for all of the above results, so three different schools were chosen as case studies. Specific results are reported for each school to give a broad perspective of possible school situations.

University Iberoamericana

University Iberoamericana (UIA) had a team composed of a group of over 30 students. These students had a commitment to a teacher who taught an automotive design class. They were therefore assigned the most complex subsystem on the vehicle, the engine. The communication distribution is shown below:

- 10% Email
- 30% IM
- 60% Video Conferencing

Being one of the more technologically advanced schools, they had a state of the art Video Conferencing system. Much of the communication was done on this system, including weekly meetings and bi-Monthly Design Reviews. This video conferencing ability greatly improved the communication and collaboration with BYU.

One problem with software installation was that students were not allowed to diagnose IT issues or install any software on their machines. This delayed the installation of Teamcenter Community client software. The installation of TcC software did not happen until the host school visit, and when it was finally installed, another issue was found. A network problem was discovered somewhere between BYU and UIA. These issues were overcome with IT help, and eventually models and electronic engineering information could be transmitted successfully. This delay, however, complicated the progress of the engine team.

Shanghai Jiao Tong University

Shanghai Jiao Tong University (SJTU) had a smaller team consisting of several students which were assigned the braking subsystem. This team of students was given fewer parts than other schools; however, the subsystem was still complex due to the students advanced engineering capabilities. Communication with this school was often plagued by international firewalls resulting in limited file size attachments in email and restrictions on file transfer to and from the United States. Voice and video transmissions were also limited because of the time differences. Consequently, the communication distribution was as follows:

- 70% Email
- 20% IM
- 10% Video Conferencing

Video conferencing did not contribute much to the communication between SJTU and other schools because the conferencing unit was in an administration building within the school and students were not given access. MSN Messenger had difficulties, much of the time, when
attempting to voice chat and share files because of international firewall issues. Therefore, e-mail was the primary form of the communication between SJTU and other schools even though it was often unreliable.

Despite these difficulties in communication, the end result of the students’ work was outstanding. The students were hard working and completed their task long before other schools had finished. Much of their work could be finished early because the braking sub-system was independent of other components. They did not require much information from other schools. This was an example of assigning components to a school based on its capabilities; appropriate assignments allow the students to work to their full potential.

*University of Sao Paolo*

At the University of Sao Paolo (USP), the team consisted of one to several students throughout the course of the year. The situation was unique with this school because they were on the southern hemisphere. During part of the school year in the United States, they were on summer break. Because of this, they started several months later than the rest of the schools. This worked out well because they had a part that was relatively simple, the bumper. They were able to complete their component with relative ease and provide several iterations including a tubular version of the bumper to be used in the final analyses.

The communication distribution for USP was:

- 40% Email
- 50% IM
- 10% Video Conferencing

The students from this school were not able to participate in Video conferencing because they did not have the equipment to connect. The only means of viewing a conference was via Microsoft NetMeeting. This means of communication was only uni-directional as they could only view the presentation, not give any feedback. They had a considerable amount of e-mail and instant-messaging was fairly regular after the student’s initial visit to Brazil.

**Conclusion**

Hosting and participating in a global collaboration project provides students, faculty, and academic institutions invaluable information and skills that are becoming increasingly important in the engineering world today. The 2005-2006 PACE Global Vehicle Collaboration Project was the first of its kind, and the firsthand experiences and lessons learned can be effectively applied to other global collaboration projects. This basic list of host and participant requirements and the list of inevitable challenges provide a resource for schools with no collaboration experience. It removes the uncertainty and trepidation at beginning such a project.

Frequent communication was necessary to keep the project running smoothly. Distance and difficulty aside, one of the most important things for the students to realize prior to the next project is the importance of this informal communication. Much benefit can be derived if students communicate frequently from the very beginning—even if they don’t feel there is much need to exchange project information. Establishing effective communication lines early is
critical. Communication, while key to effective collaboration, is also the biggest challenge. While technology can enable individuals to communicate across distance—distance is not the only problem presented by communication. Aside from language and culture, differences in thought and opinion sometimes become obstacles in communicating. It is precisely these differences of opinion that make collaboration an effective exercise that introduces additional creativity into projects. For this reason, certain difficulties are inherent in collaboration, but the end result is worth overcoming these obstacles.

The results of this project apply to all collaboration projects, whether academic or in industry. Industries who apply these same principles in their own global collaboration will experience more effective collaboration and better results.

Bibliography