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Creating Virtual Teams for Engineering Design*

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Virtual teams for engineering design are becoming more commonly used in industry and the engineering education community must prepare graduates to be employed in such work environments. It is widely understood that successful design is often a highly collaborative team-based activity. To be effective, a virtual team must be able to communicate, collaborate and coordinate, all at a distance. However, the same set of skills that guide design teamwork for a team where all members are in one location is different from that set of skills needed to lead virtual teams. This paper presents communication, collaboration and coordination tools necessary for a virtual team and identifies the skills needed to guide virtual teams to success. Collectively, the team organization, web-based collaboration tools, and virtual project management techniques provide a template to create virtual teams for engineering design.

INTRODUCTION

IT IS INEVITABLE that multidisciplinary teams for product design, with members located in different geographic locations, will become more commonplace in the future. Though some corporations are practicing a form of distributed design, a documented procedure for conducting distributed design and product development has yet to be created, tested, and distributed. In the absence of such guidance, engineering educators who want to use virtual teams often must design the communication methods and protocols themselves for each application.

To illustrate the infancy of distributed virtual design, the method of distributed team members working on any project currently lacks a universal name. Terms such as virtual teams, collaborative learning groups, non-collocated teams, geographically and temporally dispersed teams, globally distributed teams, computer-mediated groups, Internet-based teams, distributed design, geographically dispersed collaboration, e-design and e-teams, are all used to describe various Internet-based design activities [1–7].

Engineering educators must prepare today's students to participate in this new work environment. While a number of researchers have documented innovative methods to create virtual design teams in engineering education, these individual efforts have often been conducted using a learn-by-doing method of creation [8]. These learn-by-doing methodologies can be successful but the success comes at the expense of the experience [9]. As noted by Robey, 'Researchers have studied virtual teams using a variety of theoretical concepts and research methods, but no general framework has yet been produced to guide research on situated learning in virtual teams' [10]. Similarly, a general framework has not yet been presented to guide the formation and management of Internet-based design teams within engineering education.

The pervasiveness of e-mail provides an example to put the status of distributed teams in perspective. E-mail is a technology that has developed into a widely used management tool. Yet despite its ubiquity in daily information exchange, instruction in *management of and with e-mail* is not a skill taught to professionals. Instead of a universal approach to working with e-mail, each user learns and defines their own standards, etiquette and file management system to handle this aspect of their profession. This form of on-the-job instruction is an inefficient process and cannot be the model for developing virtual teams in engineering education.

If industry continues to use virtual teams, engineering students must be prepared to work on such teams. The capstone design course presents one opportunity to involve students on virtual teams. To guide the creation of virtual teams, a methodology is proposed to illustrate the technology tools and management skills that can improve the performance of virtual teams. The presented methodology details a process to create a virtual team and manage the group's endeavors.

These methods for creating a virtual team for engineering design are based on experience gathered developing and refining this model at the US Coast Guard Academy's Department of Engineering and Department of Management. The authors have adapted Internet-based methodologies to support engineering design teams, public management consulting teams, and educational accreditation processes. While the identified techniques are not a panacea for enhancing virtual teamwork, the methods illustrate a general framework that can help ensure a distributed team's success.

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VIRTUAL TEAMS FOR DESIGN

A case study is used as a tool to present the methods and management of virtual teams working on an engineering design problem. This case study is based on the authors' experience leading virtual teams and the illustrations in this paper are artifacts of that experience. Specific information on the projects that this case study is based on are detailed in a later section of this paper.

In this case study a capstone design team is formed with members located at different geographic locations. In addition to the team's full-time members, the team also includes contributing members who are recruited for specific components of the project. As such, a core group is responsible for leading the project and a subgroup is involved in specific components of the project.

For this example, the team's assignment is to design and build a remotely controlled robotic device. While the full-time students form the central core of the team, experts in control systems, electronics and programmers are also team members. With such an organization the virtual team needs to communicate on two fronts: one front being the core members of the team, and the second front being the less involved subject matter experts.

For this scenario, the design process would include defining and understanding the problem, developing a strategy to solve the problem, determining possible solutions, creating concepts for the system's subcomponents, building prototypes of the subcomponents, detailed design of the subcomponents and finally fabrication, integration and testing of the completed system. This design process, illustrated in Fig. 1, is the compilation of a number of existing design processes which work well for team-based projects [11–13]. Using this structure of the design process, the virtual team members would be required to work independently yet constantly communicate concerning interfaces and logistics. Like teams with members in the same location, the virtual team must not only solve the problem at hand but also manage itself and its information.

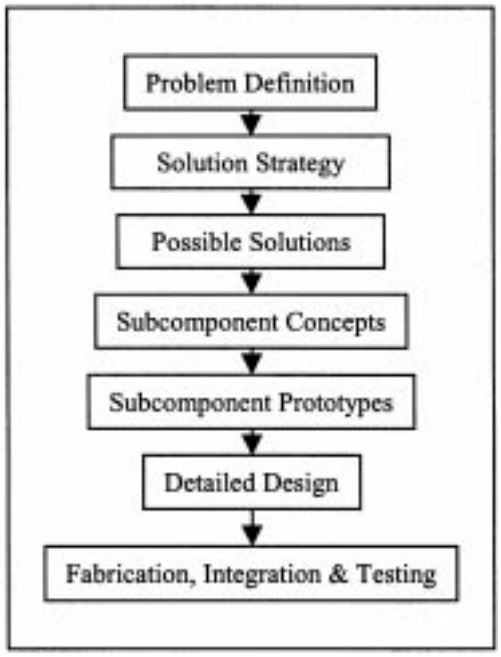

Fig. 1. Sequential steps in the engineering design process.

To ensure the success of virtual teams, participants need collaboration tools, an articulated project management philosophy, and support tools to train members and direct the process. To accomplish this task with a distributed team, a set of communication tools must be adopted, the team must be trained on the use of the tools and the solution process, and most importantly, the team leadership must closely manage the entire process.

In this case study, the entire team never joins together in a single location but rather all of their communication is conducted using electronic means. The solution process requires careful and specific leadership with clearly defined roles, schedules and responsibilities. Managing the solution process is a much more critical function for virtual teams compared to that required to keep co-located teams on track.

WEB-BASED COLLABORATION TOOLS

Before discussing the types of collaboration tools necessary for success, it is imperative to realize that the team members must understand how to use these tools before they are needed. As an analogy, a person cannot be considered a craftsman just because they have a fully equipped toolbox. It is only when the person has been trained on the use of each tool in the toolbox and has practiced with the composite set of tools can they be considered a craftsman. So too is the case with virtual teams. It is simply not enough to provide students with a set of electronic tools, but rather they must be instructed on their composite use and monitored in the course of the design process for them to be effective. Following a discussion of the set of tools needed for remote teams to collaborate, the training and use of the tools will be discussed.

Web-based collaboration tools for virtual design teams include:

- project discussion forum;
- project file depository;
- real-time data exchange;
- instant messaging (augmented with voice and e-mail);
- training and project management documentation.

Figure 2 illustrates some of these collaboration tools in use. The communications and information infrastructure are the key components of the

Fig. 2. Web collaboration tools including a team web page, project file depository, instant messages and images.

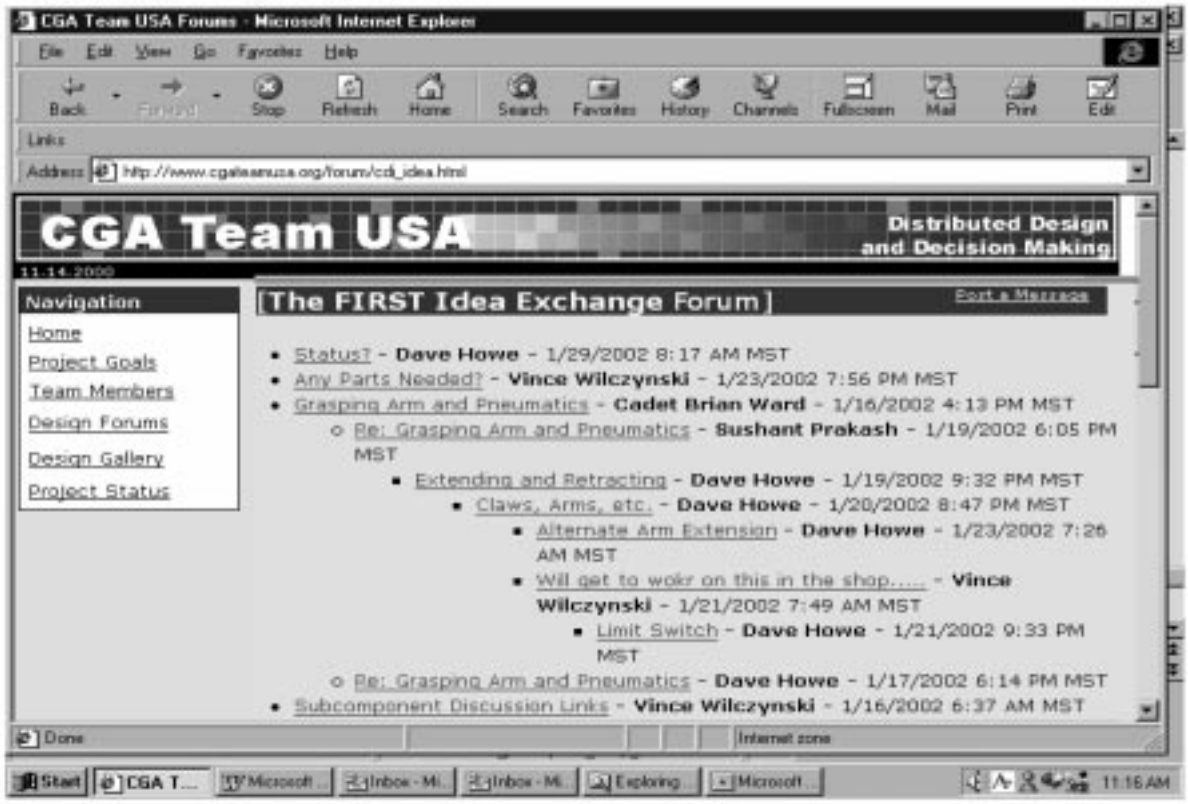

Fig. 3. Web-based project discussion forum: sub-component section and page layout.

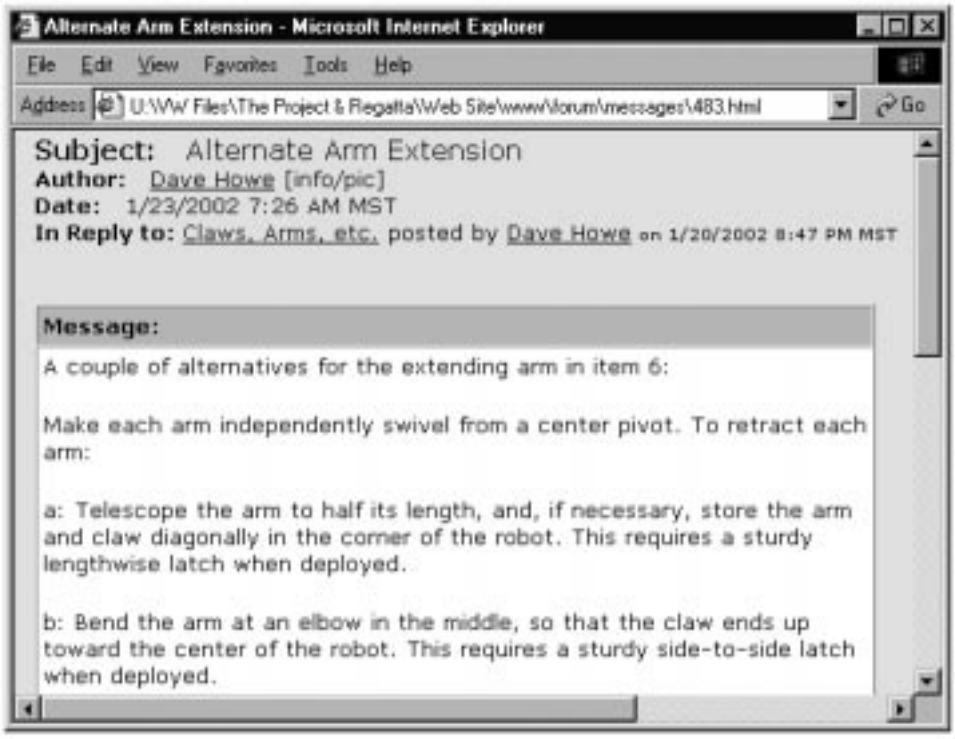

Fig. 4. Threaded discussion on the web-based project discussion forum.

Internet collaboration toolbox. Collectively, the archived documents from these collaboration tools become the 'digital documentation' [14] of the team's design decisions and serve as a historical record of the design process.

Project discussion forum

Web-based discussion boards have become the 'virtual campfire' where group members gather to discuss items of common interest. In general, these asynchronous discussion forums are the principal medium for the virtual team to discuss the project and its solution. The discussion forum (see Fig. 3) may be broken down into sub-forums for each phase and sub-component of the project, such as project administration, solution strategy, sub-components for the various parts the design, and design integration. The forums operate as a series of threaded discussions (see Fig. 4) where members contribute to posted comments. It is suggested that the forum includes a *Design Decisions* discussion thread that summarizes the decisions made in each sub-forum.

Project file depository

Hand in hand with the threaded discussions, design documentation needs to be exchanged between team members using a common project file depository. These documents could be any file that resides on a team member's computer, including text files, graphics, spreadsheets, programs, or drawings such as the CAD drawings in Fig. 5. While some web-based discussion boards allow discussion thread authors to post documents within their message in the discussion forum, it is more useful if the files are categorized by topic and stored in common folders as one would on a personal computer. By doing so, one need only look at the folder for the project design (as in the background of Fig. 2) and need not search through numerous messages (as in Fig. 3) looking for a posted document.

Engineering educators have developed their own web forums and project file depositories [7, 15] and use commercial software such as *Lotus Quickplace* [6], *WebBoard* [8], and *ipTeamSuite* [16]. Web services that provide a communication and information infrastructure include *buzzsaw.com* (comprehensive collaboration and secure file server tool), *intranet.com* (team-based collaboration), and *forum.snitz.com* or *vbulletin.com* (discussion forum templates). Common to all these approaches are the ability to post information and documents, add to discussions, and serve as a project file depository to exchange documents. The forums can be secure with access limited to team members. While these packages may have features well beyond file exchange and discussion forums, it is recommended that new teams limit themselves to using these simple features during their initial work.

When posting documents for other team members to view, attention should be given to file size and formats that enable all team members to access the information. For example, a figure in a CAD-specific drawing format might be converted to an enclosure within a word document. Such formatting tricks allow the image to be

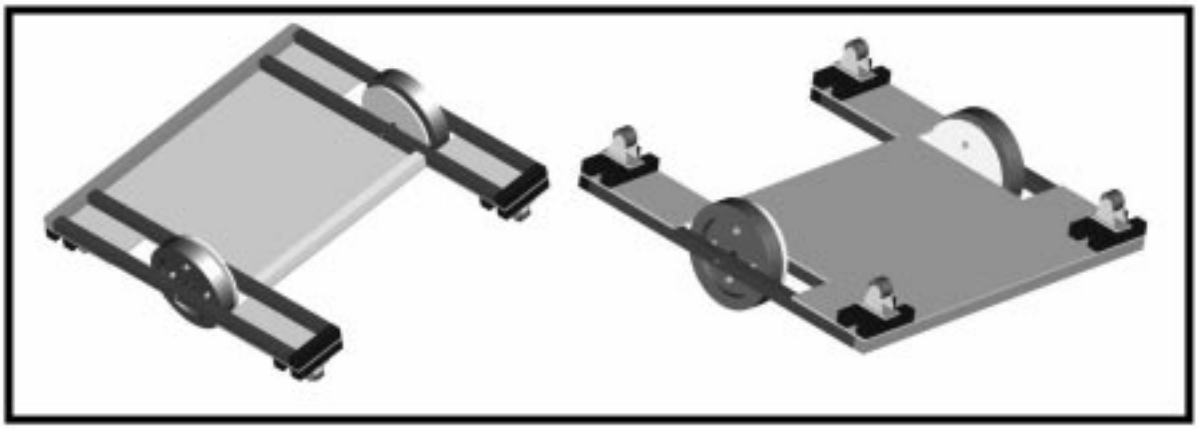

Fig. 5. CAD drawings, typical of files that should be stored in the project file depository.

viewed, though not fully manipulated as in the native CAD format, with readily available software and much quicker transmission periods.

Real-time data exchange

Real-time data exchange is a synchronous communication feature that is beneficial to many remote teams. The types of real-time data transferred for a virtual team project could include files, images (still and video) and audio. Microsoft *NetMeeting* is one program that offers these features and is readily available as a free download on the Internet.

While such synchronous communication software offers advanced features such as peer-to-peer video conferencing and voice communication, these advanced features are often not needed for a new virtual team to be successful. Instead, such advanced features may interfere with productivity and impede the team's success. While it is recommended that new virtual teams do not use Internet video conferencing, Internet voice communications may be useful if users do not have a phone line available for traditional voice communication.

Real-time file sharing is a necessity for successful virtual teams. With real-time file sharing, individual users can view the shared document on their screen, manipulate the file, and have the results immediately viewed by remote team members. *NetMeeting* enables users to share information and mark up images through a whiteboard option where all users see, and can manipulate, a common screen image. Expertise is needed to conduct such operations efficiently, and file sharing is best done with Internet connections that are not modem based due to the increased efficiency with greater available bandwidth.

Instant messaging

Instant messaging is a useful tool for virtual teams. Many instant messaging programs such as MSN *Messenger* can be configured to allow other team members to see when they are logged on to the Internet. By knowing who is on-line, synchronous communication can begin using text-based chat discussions or peer-to-peer Internet voice discussions. Multiple team members can join a discussion and documents can be exchanged in this synchronous version of asynchronous e-mail.

Of course phone conversations and e-mail are also useful tools for virtual teams. Regularly distributed e-mail, say for example every Monday morning, can alert all team members of the project progress and impending deadlines. Such broadcast e-mails have been demonstrated as very effective tools to keep all team members informed and connected [7].

Training and project management documentation

As discussed earlier, the availability of these tools is only part of the set of tools needed for a virtual team to be successful. As many researchers have noted, these tools must be augmented with training to enable the team to use the technology effectively. In addition to the training documentation, the virtual team needs management documentation to ensure all understand the design process and the responsibilities of individual team members. Additional details on this documentation are provided in the following section.

VIRTUAL TEAM LEADERSHIP AND VIRTUAL PROJECT MANAGEMENT

The availability of web collaboration tools is not enough to ensure the success of virtual teams. Like all teams, virtual teams require proper leadership and management to establish clear objectives, define project procedures, and promote team communication and collaboration. The remote nature of the virtual team requires special attention be paid to the 'importance of good clear, team-level leadership in a dispersed team' [6]. Virtual team leadership and virtual project management need to apply both traditional project management techniques as well as additional guidance to keep the distributed team informed and engaged.

Typical aspects of teamwork, including defining goals, team formation, project planning, task direction, controlling budgets and logistics, and taking corrective actions, are common attributes of project management that must be applied to virtual teams. Though traditional project management software can be helpful to define tasks, assign resources and track progress, virtual team managers require additional resources. Also, individual activities must be clearly articulated and highly structured to be sure all are aware of the assigned responsibilities and deliverables.

Before the virtual team project begins, the team must establish a management structure, articulate the team's organization and develop a plan for operations. It is essential that the virtual team establish the procedures before the project begins and provide adequate training to team members concerning the use of web-based collaboration tools. Thus in addition to the web collaboration tools, the virtual team must establish and apply the following management tools:

- roles and organizational structure;
- organization and operations manual;
- web collaboration tools training handbook;
- project overview;
- daily project plans and assignments;
- team update communications and contact information.

Roles and organizational structure

Two levels of management are needed to ensure the success of virtual teams. A core of the virtual team needs to serve as the project leaders with others contributing to the project solution as team members. These leaders must direct team functions on two levels, referred to as *back of the house* and *front of the house* activities.

Such vernacular is based on entertainment venues that require tremendous activity behind the stage (i.e. the *back of the house*) for the audience to enjoy the production. For virtual teams, *back of the house* activities are those needed to coordinate the leadership and operations of the team, while *front of the house* activities are those aspects of the project that are seen and applied by all members of the team. As an example, developing and posting training procedures would be a *back of the house* activity, while the availability and use of the training procedures would be conducted as a *front of the house* activity. The leadership core of the team must realize that it first has to organize and manage itself before it can lead and manage the entire team.

An organizational structure to lead the virtual team is presented in Fig. 6 where a group of distributed students design and construct a remotely controlled robotic device. The team consists of a core *Leadership Group* as well as other student members and subject matter experts participating in the *Design Group*. The leadership core is responsible for managing the entire project and members of the leadership core are active participants in the design activities. For example, the overall team leader might manage all aspects of the team and serve as the lead for the electronics aspects of the *Design Group*. Similarly, the individual coordinating the many aspects of information technology could also be the lead member of the propulsion team of the *Design Group*.

Organization and operations manual

All aspects of the team structure and individual responsibilities should be specified in the team's Organization and Operations Manual. This document identifies the team's operating plan both by

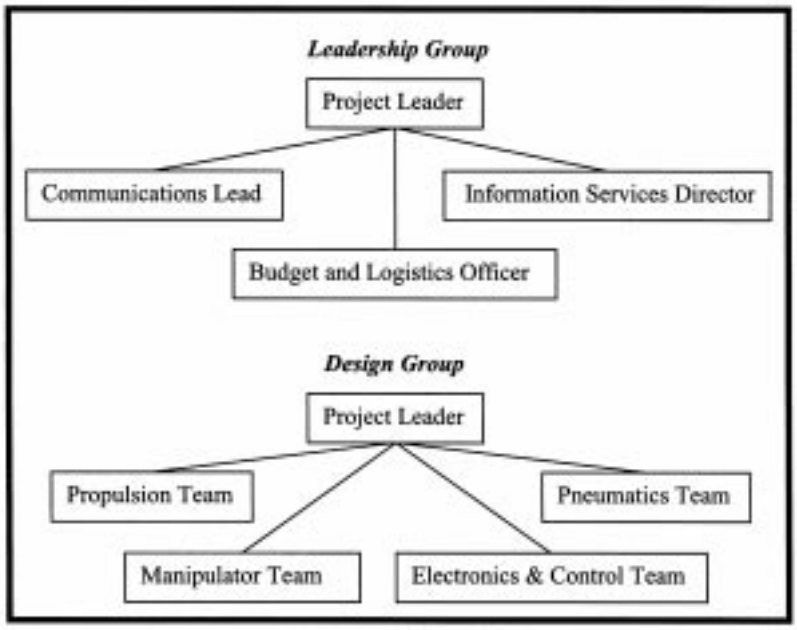

Fig. 6. Team organizational structure for leadership and design.

task and by individual. For task assignments, the Operations Manual specifies how the design problem will be presented, discussed, and ultimately a decision made for the team to pursue. For example, the manual could detail how a concept design can be determined and how the team will progress into prototype and final design for the project's subcomponents. This document should be posted in the team's project file depository on the team website.

These task assignments include detailed responsibilities of the project leader, communications and scheduling lead, budget and logistics control officer, information services director, and individual activity leaders (for example the activity leader for team building exercises). A few examples of responsibilities are provided:

- **Project leader**—Responsible for overall management and serves as the principle decision maker. Manages all resources and directs a schedule to achieve the team's mission. Assigns responsibilities for work products, organizes the team and monitors team performance to make sure all members have the tools needed for success. Communicates with all team members, directs project delegation, responds to contingencies and manages all aspects of the team's final deliverables.
- **Communications and scheduling lead**—Ensures all team members can communicate with each other. Establishes communications protocols, coordinates synchronous activities, and trains new team members on web-based collaboration tools and procedures. Creates and executes web-based team building activities to allow remote team members to know and trust one another. Prepares and publishes a weekly *Front of the House Activity Schedule* and a *Back of the House Activity Schedule*. Serves as an ambassador for the project to keep all team members connected and motivated
- **Budget and logistics control officer**—Manages all aspects of spending, shipping and inventory tracking. Ensures shipping addresses and billing information for individual team members and accounts is correct (especially important if the project involves purchases over the Internet to be shipped directly to a third party).
- **Information services director—**Establishes web collaboration portals and protocols, debugs and tests communications infrastructure and maintains team website. Provides help desk functions for team members having difficulty with communications and researches all hardware and software associated with the project.

Web collaboration tools training handbook

It is imperative that all virtual team members receive training on web collaboration tools. To accomplish this training, a step-by-step tutorial should be created to instruct all team members how to collaborate with other members of the team on the Internet. Specifically, the Training Handbook should introduce the communication tools and provide all details needed to get individuals on-line and communicating. In addition, the Training Handbook should include a method for members to test the operation of the communications methods. The Training Handbook must be created and shared in an electronic format and stored in the team's file depository on the team website.

The Training Handbook must be prepared as a standalone document that enables the new user to complete all tasks without the aid of another member of the team. As such, the Training Handbook should include numerous screen shots with annotations to highlight instructions. The text should be conversational in nature and be explicit in all directions. A delicate balance must be maintained in that the document must be exact in detail and complete in information, but it cannot be overwhelming in content. This document will be each member's first introduction to the virtual team, so great care must be exercised in its creation.

The Training Handbook must convey all information for team members to access the team's project discussion forum and project file depository. Screen shots of what the first-time user will see are required to walk users through each stage of the process (see Fig. 7). Should access to the project discussion forum need to be secure (thereby requiring an additional registration step by the site administrator to enable a specific user to sign into the site), it is suggested that the Training Handbook be written to demonstrate and allow access for a visitor to the secure site. Details associated with navigating threaded discussions, posting information in an established discussion, initiating new discussions and posting files to the project file depository should be included in the tutorial.

The Training Handbook should provide instructions and figures that illustrate how to download any needed communication software (such as Microsoft *NetMeeting* and MSN *Messenger*) and install that software on their computer. The Training Handbook should also include an explanation and example of how the software is used. For example, instructions on initiating an Internet conference and sharing a document in real-time should be included in the documentation.

The Training Handbook should conclude with a means to test the operation of each web collaboration tool the team will use. While asynchronous tests can be conducted very readily (i.e. post a message and see it posted), conducting the initial tests of synchronous communications methods requires coordination and patience. One means of testing the system could include an invite for the new team member to participate in a web-based team building exercise.

Project overview

The Project Overview is a document that describes the project, presents the design

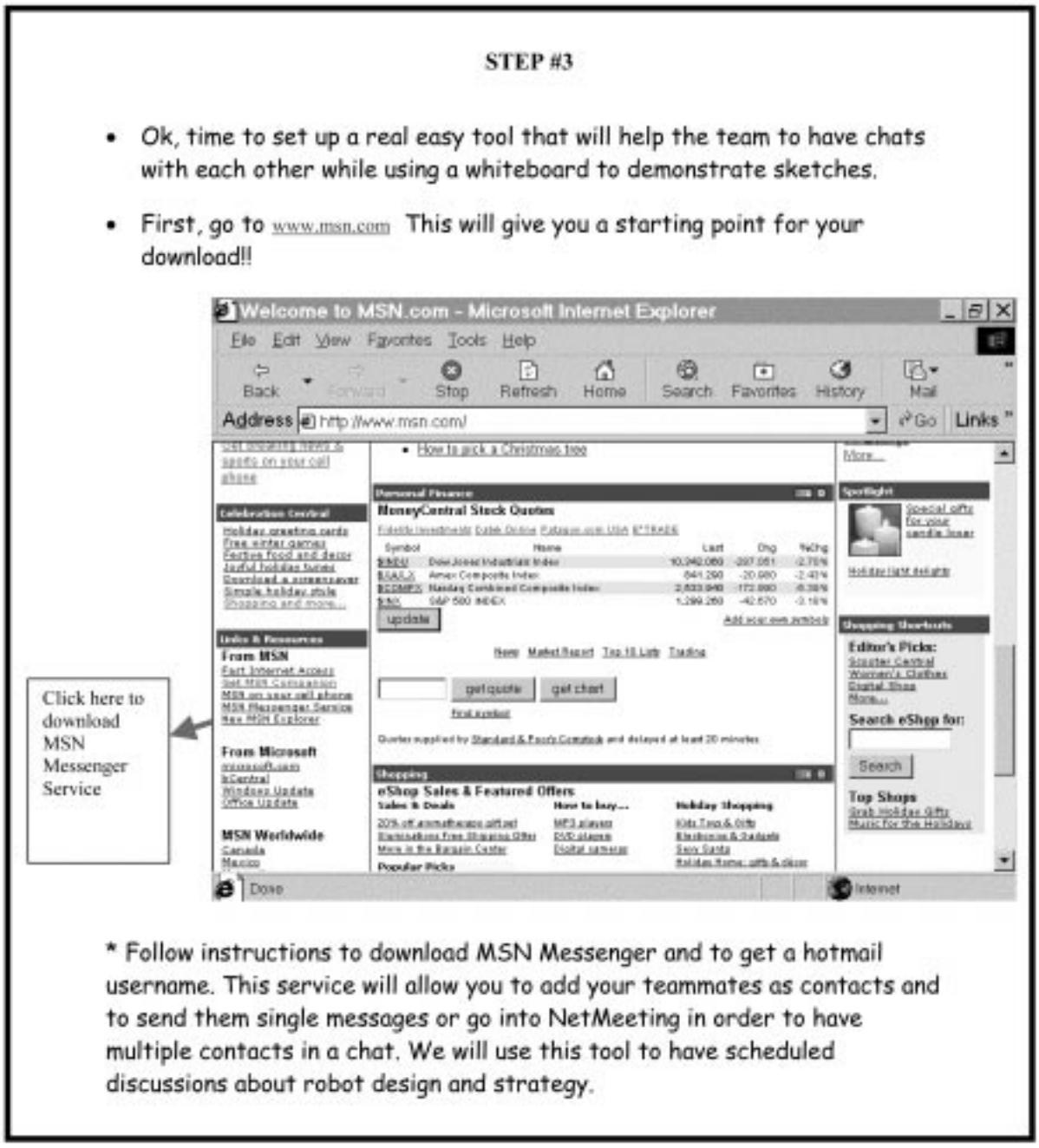

Fig. 7. Excerpt from a Training Handbook illustrating the step-by-step instructions, use of screen shots and narrative format of the Training Handbook.

methodology to solve the problem and presents an initial plan of action to guide the team's work. The overview should be written with the understanding that it is the first material a potential team member or an interested party reads about the work. The concept of how the virtual team will work should be presented, along with links to the Training Handbook to get new members started on the project. The schedule for the work in this section should be presented as weekly blocks that guide the team through the seven steps of the design process illustrated in Fig. 1. The Project Overview should be prominently displayed on the team's web page so it can be easily accessed.

Daily project plans and assignments

The single greatest challenge for virtual teams is keeping all members informed of the progress of the project and the deliverables expected from each team member. The daily project plans and assignments list should be developed and shared with all team members. This schedule allows every team member to know what functions they and other members of the team are executing for the current week. As illustrated in Fig. 8, by listing the activities for each day the team members have a clear set of instructions of what they need to do and how to move forward in the project. It is suggested that daily project plans be

Phase One: Daily Activity Plan

Date	Activity	Notes
3 January	Team Updated on these Project Plans for FIRST Competition	Via post on CGAteamUSA site in "Project Set-Up" file, and in FIRST forum file, and as a word post in the Design Gallery. Discussion to follow on "Project Set Up" location.
4 January	MSN Messenger discussion on project	8PM - 11 PM EST for informal real-time discussion of the project. Simply sign on to MSN and look for CGA Team USA members on-line.
06 January	FIRST Kick Off	Project unveiled at www.usfirst.org/thecomp.html – complete rules, component photos and kit of parts contents. Each team member must read this information.
06 January – 09 January	Strategy discussion on CGAteamUSA site: Design Forums: FIRST Competition	Purpose: to have team select a strategy to play the game. Individual team members should post ideas/thoughts to the website and to trade ideas with one another via MSN. Site monitored by activity leader to keep discussion on target. Also, activity leader will post a list of topics that should be included in the decision matrix, by 0000 08 Jan.
09 January: Noon EST	All possible strategies must be posted by this time	
09 January 8PM EST	All votes on the decision matrix must be completed by this time.	Activity leader will announce the chosen strategy via a post to the site.

Figure 8. Daily Activity Plan for a phase of the project to inform all team members of the scheduled activities and responsibilities.

Fig. 8. Daily activity plan for a phase of the project to inform all team members of the scheduled activities and responsibilities.

developed for each of the natural phases of the project.

While such level of detail could be described as *micro-management* for traditional teams, such attention to detail is essential for virtual teams. As opposed to traditional teams where members can visit one another and leaders can informally drop in to check on the status of the project, members of the virtual teams do not have that option. The daily project plans and assignments list is a necessary tool to keep all members aware of the project development.

It is important to note that schedules must be developed on separate fronts for the team leadership and for team members. As a *back of the house* schedule, the team leaders will need to keep each other aware of the processes and support that needs to be developed to keep the team on track. For example, at the early stage of the project the *back of the house* schedule could detail the dates

when the Training Handbook needs to be developed, when the logistical details for shipping need to be finalized, and when the web page must be finalized. Later in the design process this schedule could identify the sequence of events needed to integrate the individual sub-components into a composite design. The *front of the house* schedule illustrated in Fig. 8 presents those tasks that all members of the team are involved in.

Team update communications and contact information

In addition to the above tools, two other communication documents are needed for virtual teams. Regular *broadcast e-mail* to all team members provides a routine method for members to stay connected with the project. These announcements deliver project updates and solicit feedback from members. In essence, the *broadcast e-mail* presents written updates on the project. By archiving these announcements on the team website, the historical record of the project is more complete.

Contact information for team members must be collected, posted and shared with all members of the team. This contact information includes each member's name, affiliation, project role, e-mail address, instant messaging screen name, and phone number. It has also been suggested that each individual list their availability for the project on this document so that all know when they can contact one another for synchronous communications [1]. This contact information must be kept current and archived in the team's project file depository.

THE INSTRUCTORS' VIRTUAL EXPERIENCE

As noted earlier, the methods and techniques described above were developed based on the authors' experience with virtual teams for engineering design, management consulting, and educational accreditation. The virtual engineering design teams and management consulting teams were both established to support senior capstone projects in their respective majors.

The example case study depicted in this paper was based on a cross-curriculum project involving both engineering and management majors [7]. The goal of the project was to design and build electromechanical devices that could successfully compete in regional and national robotics competitions [18]. These competitions partner high school youth with engineers and colleges to design, build, and compete sophisticated robots.

Typically, the team participants would all be from the same school, thus enabling the engineers to personally meet with the students during the course of the project. The team formed for this project at the US Coast Guard Academy was not typical. It was a distributed team comprised of 28 youths from across the country, US Coast Guard Academy cadets and several external agents such as technicians and computer programmers.

Members of this team were located in 12 different geographic locations. For this project, the instructors were located in the same location as the team leaders and the interaction between faculty and students was both in-person during normally scheduled class time and on-line. The faculty oversaw the work of the team leaders and provided direction for the project. In comparison with typical capstone design teams, the faculty and student workload are nearly twice that of a normal project due to the amount of coordination and training that needed to take place to introduce students to this new form of teamwork.

The task for the Management Majors in the first semester of the project was to develop the infrastructure to support the team and communications protocols. At the beginning of the project's second semester, the Engineering Majors guided the team through the design and build phase. Despite the time constraint and the challenge of coordinating activities, the team successfully completed the project and constructed two devices that were tested at regional and national robotic competitions (see Figs 9–10).

The lessons learned during this particular project were applied and refined on subsequent virtual team projects. The following summary highlights the best practices identified from these virtual team projects.

SUMMARY AND CONCLUSIONS

Significant challenges face educators who wish to incorporate virtual design teams within capstone design or other team projects. Yet with a detailed plan and proper attention to training, planning and accountability, virtual teams can design successful engineering products

The importance of effective leadership and careful management cannot be over-emphasized for virtual teams. The team must be autonomous and well organized, and the tasks assigned to individual team members must be clearly explored.

It is suggested that virtual team leaders create *back of the house* activities to coordinate management functions. The project execution functions, which serve as the interface to the rest of the team, should be viewed as *front of the house* (i.e. in the pubic eye) activities. Like in theater, flawless productions viewed by the audience require careful and deliberate attention from behind the curtains. Virtual team leaders must be aware of the dual responsibilities to guide the design process and manage the virtual design infrastructure.

Web collaboration tools such as bulletin boards and instant messaging services are only half of the set of tools needed for virtual teams to be successful. These tools must be augmented with an organization structure, operations plan, training

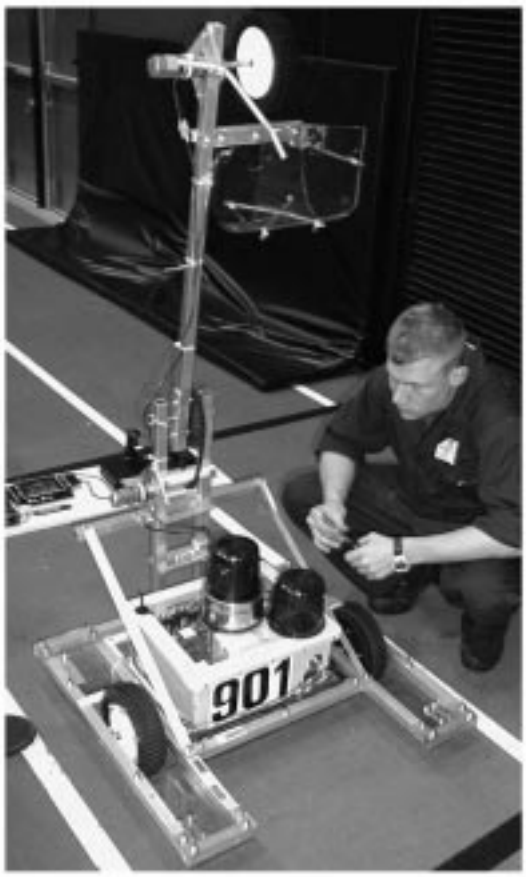

Fig. 9. Robotic device created using a virtual team for a regional robotics competition.

documents, and other virtual project documentation needed to plan and orchestrate team functions. These tools need to be developed before the design phase of the project begins.

Asynchronous communication provides a means for virtual team members to contribute to the project on schedules that are unique to each individual. Synchronous communication requires careful coordination, planning and execution. For synchronous communication, tasks such as establishing and sharing agendas for meetings, creating and posting detailed meeting minutes, and deferring tangential discussion topics to off-line communications are extremely important to ensure the success of on-line meetings.

Establishing a project schedule, both as an overview and as a daily plan of activities, is necessary for team success. Virtual teamwork requires individual team members to initiate communication and action. The detailed schedule allows team members to know all phases of the project and provides a clear road map to get the team to its final destination.

The project documentation that is a by-product of virtual teams is a valuable history of the design and decision making process. These artifacts (which include correspondence, engineering drawings, calculations, sketches, photographs and program code) are the project's digital documentation. This searchable record of the design process is an imbedded attribute of virtual team projects.

Using the Internet as the primary means for communicating appeals to some individuals more

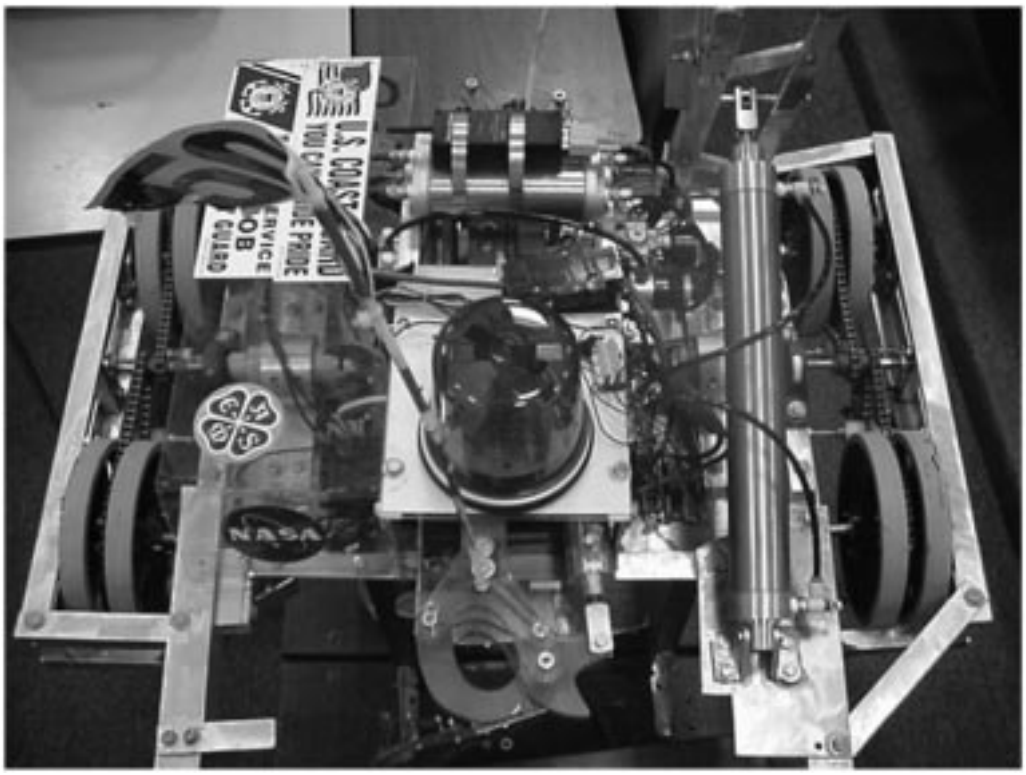

Fig. 10. Robotic device created as a capstone design project in Mechanical Engineering using a virtual team for the nation-wide FIRST Robotics Competition.

so than others. Individuals that excel in web collaboration are those who are self-starters, independent, and display initiative. They must have an affinity for technology and have high levels of persistence. Team members must understand the value of virtual teams and not be daunted by facing new challenges.

Significant research remains in the area of virtual teams within engineering education. Included in the list of topics for research are the need for establishing evaluation methods to forecast *a priori* if individuals are well suited for virtual team activities. Also, the current set of traditional project management software needs to be augmented with features to better serve virtual teams.

The success of virtual teams is heavily dependent on the preparation of the project leaders. Effective virtual teams and the processes that support their existence cannot be developed during the course of a project. The infrastructure to support virtual teams must not be 'designed by doing' but rather must be carefully organized, planned and executed.

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