Amy E. Carlson. Facilitating Scientific Collaboration Across Distance: A User Needs Analysis of a Distributed Scientific Research Group. A Master's paper for the M.S. of I.S. degree. April, 2001. 42 pages. Advisor: Diane Sonnenwald.

This paper describes a user needs analysis of a research and development center consisting of scientists at four geographically distributed universities. Observations and interviews with representative members of a research group within the center were conducted to determine the group's current collaboration practices and to assess how technology might facilitate collaboration among group members. Data analysis shows that members collaborate primarily through informal communication with co-located peers, and they rely on formal presentations at videoconference meetings to maintain an awareness of research at other locations. The technology currently in place has helped to build a foundation for collaboration; now, the Center should augment this technology to better facilitate and encourage collaboration. It appears that the Center could benefit from a system that allows for more frequent updates on individual projects to all Center members such as a virtual bulletin board, and a tool that provides a virtual shared drawing space.

Headings:

Collaboration-- Scientific

CSCW-- Design

User Involvement

FACILITATING SCIENTIFIC COLLABORATION ACROSS DISTANCE: A USER NEEDS ANALYSIS OF A DISTRIBUTED SCIENTIFIC RESEARCH GROUP

by
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A Master's paper submitted to the faculty
of the School of Information and Library Science
of the University of North Carolina at Chapel Hill
in partial fulfillment of the requirements
for the degree of Master of Science in
Information Science.

Chapel Hill, North Carolina

April, 2001

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Introduction

The purpose of this project is to perform a user needs analysis with respect to collaboration technology for members of a geographically distributed scientific research group. This analysis will provide a basis for decisions regarding what kinds of systems should be purchased or developed and implemented within this research group in order to support collaboration. These results may also be generalized to show themes about the ways that scientific groups function when collaborating across distances and the kinds of technological systems that may help them in order to provide further understanding in the greater research framework of computer-supported cooperative work (CSCW).

Specifically, the focus of this analysis is on current communication patterns and collaboration practices and perceptions within the NSF Science and Technology Center for Environmentally Responsible Solvents and Processes. This analysis focuses mainly on one research subgroup of the Center, but results of this study may be broadened to include the whole STC. Methods of data collection include interviews and/or observations of team members in an attempt to see the scientists in their natural working environment in order to better understand their daily work and the communication patterns involved in that work. Data gathered through these observations and interviews provides a picture of the current state of collaboration within the Center and where the problem areas lie. These findings allows for specific recommendations as to the places that CSCW systems could help CERSP researchers and the specific types of systems that would best meet the needs of projects in the Center.

Review of the Literature

1. Methods of Design for CSCW Systems and Groupware

Commonly used information system design methods include participatory design (Kyng, 1994), user-centered design (Norman & Draper, 1986), and contextual design (Beyer & Holzblatt, 1998). These methods all focus on involving the user in the design process, with the common aim of developing information systems that support users' tasks and social traditions, and that allow users to accomplish their work without needing to spend a lot of time or effort concentrating on the information system itself. However, these methods are not specifically geared toward CSCW, as pointed out by Kensing and Blomberg (1998). In fact, there have been arguments within the CSCW community that direct user participation in the design process is too difficult and costly to justify when the target audience is a group (Hughes, Randall & Shapiro, 1992; Bentley, Rodden, Sawyer, Sommerville, Hughes, Randall & Shapiro, 1992).

At the same time, understanding users and their current work practices is a necessary step in designing any type of useful system, including CSCW systems. McGrath (1991) points out that while social psychologists have been studying groups for several decades, traditional group theory falls short in its applicability to CSCW design because groups in the world tend to be far more complex that those that have been created specifically for research purposes. He presents a modified theory for studying groups that he calls TIP: Time, Interaction and Performance. According to McGrath's theory, most of the communication and operational patterns found in groups are temporally patterned; changes in group membership, in the focus of group work, and in

the working environment (such as the physical setting of the workplace and the tools used) therefore have significant impact on the group itself.

Many CSCW designers and researchers use ethnographic studies of groups and workplace studies as a means for gaining an understanding of their target audience (Murray & Hewitt, 1994; Sonnenwald, Berquist, Maglaughlin, Soo & Whitton, 2001; Tang, 1993; Wood, 1997). Fafchamps (1993) presents the "Ethnographic Workflow Analysis" as a design methodology to capture and model behavior related to communication and workflow, and to develop system specifications from this data. Fafchamps' methodology organizes data into a conceptual framework, as follows: professional environments, contexts of work, events, and patterns. In terms of data collection, this theory seeks to incorporate the user into the design process through strategies such as thinking aloud, structured observations, guided tours, and focused interviews. Schmidt (1998) claims that these types of studies are important both conceptually for the theoretical development of CSCW and practically for the requirements analysis phase of CSCW design work.

The challenges of CSCW often extend beyond understanding the user. Grudin (1999) gives an excellent overview of the challenges in designing, creating, and implementing groupware. Grudin categorizes these challenges as follows: disparity in work and benefit; critical mass, Prisoners' dilemma, and the Tragedy of the Commons problems; disruption of social processes; exception handling; unobtrusive accessibility; difficulty of evaluation; failure of intuition; and the adoption process. Finholt, Rocco, Bree, Jain and Herbsleb (1998) discuss a field trial of Microsoft NetMeeting in a globally distributed organization; their findings illustrate the implementation challenges described

by Grudin. Specifically, users encountered difficulties in the adoption process including installation difficulties and a lack of user training; Finholt et al. also discovered difficulties such as differences in accessibility of the software between groups, and users' confusion over who had control within the software product.

In building CSCW systems, many researchers have found an iterative design cycle to be the optimal approach (Nodder, Williams & Dubrow, 1999; Ishii, Kobayashi & Arita, 1994; Guzdial, Rick & Kerimbaev, 2000). Through iterative design, products and systems can evolve to suit users' needs. For example, the TeamWorkStation presented by Ishii et al. eventually matured into their ClearBoard system. With each design revision the product changed slightly in the designers' overall attempt to make it "cognitively seamless." Microsoft's NetMeeting likewise evolved over time and several versions as additional features were added gradually. Furthermore, these researchers found it necessary to also revise their usability testing methods with each iteration because traditional usability testing was not well suited to testing groupware (Nodder et al., 1999). Arias, Eden, Fischer, Gorman and Scharff (2000) support an evolutionary and collaborative design process that allows for system revision according to users and that occurs in a distributed manner. Arias et al. say that collaboration among designers and end-users is necessary in order to take advantage of what they refer to as "the symmetry of ignorance," or the fact that end-users hold different perspectives and important tacit knowledge about the problem that an information system seeks to solve.

2. Research on Collaboration and Implications for CSCW Applications

As discussed above, studying groups is an important aspect of the CSCW design process. To help inform such study and the subsequent design of a CSCW application,

the literature on collaboration, distributed groups, and scientific collaboration was examined.

2.1 Collaboration

In studying work that depends on the collaboration of individuals, there are social aspects of groups that emerge as important factors in the way that groups work together (Grinter, 1997; Dix, Fineay, Abowd & Beale, 1998; McGrath, 1993). Grinter examined multiple workplace studies and found similar, repeated patterns of action occurring in different collaborating groups. Examples of the patterns Grinter found are: group work is dynamic and often departs from what is planned in advance; individuals within a group disclose some of their work to others and likewise keep track of the work being done by others; people judge information based partially on the status of the information provider; people's attitudes toward technology affects their use of it; and spatial information about people and documents affects people's awareness of the group work as a whole. Proctor, McKinley, Woodburn and Mastings (1994) provide a discussion on conversation analysis of face-to-face communication, and the subtleties such as back-channels, eye contact, gestures and body language that are a fundamental facet of communication. In general, users tend to bring all their social expectations of face-to-face meetings into computer-based communication such as via telephone or computer-based media like email, real-time chat, or video-conferencing even though those expectations are often not supported (Dix et al., 1998). In many cases, non-face-to-face interaction results in a communication breakdown of various degrees although users exhibit several common coping strategies to compensate for this lack (Dix et al., 1998).

The concept of awareness is also a key factor in interpersonal communication and collaboration. Awareness is a broad concept that is defined and used differently by many researchers. Steinfeld, Jang and Plaff (1999) discuss the following types of awareness that must be supported for the success of virtual teams: activity awareness, availability awareness, process awareness, perspective awareness, and environmental awareness. Sonnenwald, Maglaughlin, and Berquist (to appear) define situational awareness as "the gathering, incorporation and utilization of environmental information"; they present a conceptual framework for designing systems that facilitate awareness. Similarly, Sallnäs Rassmus-Gröhn, and Sjöström (2000) discusses the importance of social presence in virtual reality spaces; they define this sense of presence as a user's sense of "being there" in terms of both involvement and immersion in the virtual space. Benford, Snowden, Colebourne, O'Brien, and Rodden (1997) found that users' awareness of the location of both documents and of other users affects cooperative work in terms of availability and accountability. Gutwin and Greenberg (1998) discuss difficulties in supporting workspace awareness with groupware since flexibility or control for the individual user is often sacrificed. Erickson and Kellogg (2000) discuss "socially translucent systems" that are aimed at facilitating communication and collaboration among distributed groups; they claim that these systems must support visibility, awareness, and accountability for the users in order to mimic the social constraints that guide group interactions in physical environments. Erickson and Kellogg's Babble prototype, designed to support conversation between groups, attempts to address these three factors with features such as an ongoing textual depiction of the conversation as well as a real-time representation of the activity of participants.

2.2 Additional Challenges Faced by Distributed Groups

Research has indicated that communication and collaboration on a group level becomes more complex and more challenging when the group is geographically distributed (Benford et al., 1997; Hofte, 1998; McGrath, 1993; Tang, 1993; Kraut, Fish, Root & Chalfonte, 1993). For example, work done by distributed groups generally takes longer to complete and this delay negatively affects people's perceptions of their colleagues' contributions to the workload (Herbsleb, Mockus, Finholt & Grinter, 2000). A study by Rocco (1998, cited in Bos, Gergle, Olson & Olson, 2001) found that face-to-face contact, even if brief, is crucial to the formation of trust within a group and this trust contributes to group cooperation. Bos et al. (2001) extended this research and found that groups can develop levels of trust through videoconferencing that equal those reached through face-to-face contact, although the process may take longer via videoconferencing. Kraut et al. (1993) claim that informal or spontaneous interaction is quite important for group cooperation both in terms of productivity and social success; if groups are distributed there is far less opportunity for these types of interactions to occur. In an earlier study, Allen found that even small distances of separation between engineers results in the same decrease of communication that results from separation by many miles (Allen, 1977, cited in Herbsleb et al., 2000).

2.3 Collaboration among Scientists

Alongside research of groups in general, there are a number of researchers who have studied the communication and information sharing practices of scientists specifically (Allen, 1991; Gould & Pearce, 1999; Lubich, 1995). According to Lubich, scientific cooperation has been increasing, especially over the past thirty years as

evidenced by the rising percentage of scientific papers that are co-authored. At the same time, there are several factors that limit cooperation between scientists. Lubich states that cooperation among scientists is more likely to occur between scientists who consider themselves to be of equal status professionally, or between those who have worked together in the past or who plan on working together again in the future. This corresponds to Allen's theory that scientists tend to rely on specific individuals for information and that these "information stars" tend to have high status or prestige within the organization (1991). Similarly, Ackerman's research on organizational memory (1996) identified status of individuals within an organization as a key factor affecting information sharing. Another limitation on scientific cooperation is the desire for personal recognition or gain; Lubich refers to this as the competition-versus-cooperation situation. Finholt agrees that scientists tend to resist dissemination of information that is unregulated or unqualified (1999). This leads to an additional constraint on scientific cooperation. Rosenbloom and Wolek's work from the 1960's found that among scientists working in large corporations, written media such as journal articles, books and technical reports were more often cited as useful sources of information than were interpersonal sources (cited in King, 1994). Similarly, Allen's survey from the early 1980's found most scientists claiming that printed literature was their main source of information (cited in King, 1994). As a means of disseminating information, publication via scientific journals or conference proceedings is notoriously slow with articles often not appearing in print until at least a year after the research has been completed (Lubich, 1995). For this reason, Lubich asserts that scientists often depend on more informal or spontaneous interactions; as mentioned earlier, spontaneous interaction depends on proximity.

Another challenge that scientists face when attempting to work in geographically distributed groups arises from the fact that much scientific work revolves around specialized laboratory equipment. Many of the more common collaborative systems (such as Microsoft's NetMeeting) are designed to support office work that is already closely linked to the computer. For scientists, these types of systems may not solve their collaboration needs; the concept of collaboratories, or laboratories without walls, has emerged to fill this niche. Finholt provides an extensive explanation of collaboratories including background theory and several case studies (to appear). Factors such as increased bandwidth, more network connections, better user interfaces, and the adoption of network use by a broader range of users have contributed greatly to the growth of collaboratories (Finholt & Olson, 1997). Collaboratories and other collaborative systems fall into three categories: those that link people with people, those that link people with information, and those that link people with facilities (Finholt & Olson, 1997). Finholt and Olson also point out that collaboratories have the potential to open up new methods for studying group work. The work of Sonnenwald et al. (to appear) on their nanoManipulator also falls into the realm of collaboratories.

3. Summary

Overall, in researching and designing CSCW systems, it is important to gain a solid understanding of group communication and interaction, as well as the tasks that these systems aim to support. There are several well established and methods of design that focus on involving and understanding the user; furthermore there are methods of design that focus specifically on studying users who function as groups. Finally, the importance of understanding the user can extend far beyond the design phase of a CSCW

system, since these systems face unique challenges during implementation, adoption and evaluation. Many designers have embraced an iterative design cycle that allows a product to evolve over time to suit users.

Communication on a group level happens in ways that are patterned and can be studied; at the same time, studying group communication is difficult and there is no consensus among researchers as to the best way to do it. There are many social aspects of groups that significantly affect the collaboration that occurs within those groups. When individuals in a group are geographically distributed communication and collaboration between them becomes much more challenging, as does the study of that communication and collaboration.

Collaboration trends are on the rise for scientific researchers, but scientists in particular face additional and unique challenges in their collaboration due to the nature of their work and the social constructs of their organizations. Collaboratories are, in general, aimed at facilitating the cooperation or collaboration of scientists who are geographically separated from one another. In addition to facilitating interpersonal cooperation among scientists, collaboratories can allow scientists access to equipment and tools that would otherwise be unavailable to them.

Research Approach

Research Setting

The National Science Foundation Science and Technology Center for Environmentally Responsible Solvents and Processes (CERSP) is a multidisciplinary research group that brings together chemists and chemical engineers, as well as social scientists, from several geographically distributed locations. CERSP officially began operation in November of 1999; as described in their mission statement, the purpose of the Center is "to identify and enable a generation of economical and energy-efficient, clean and safe processes, especially for improved products, by developing and exploiting a robust body of fundamental knowledge in CO_2-related science and technology" (Science and Technology Vision, Mission and Goals). A full description of the goals and research activities of CERSP is available on-line (http://www.nsfstc.unc.edu).

The core membership of CERSP is composed of scientists at four universities. This includes faculty, visiting scientists, research associates, post-doctoral associates, graduate and undergraduate students in the Chemistry department at The University of North Carolina at Chapel Hill (UNC-CH), the Chemical Engineering department at North Carolina State University (NCSU), the Chemical Engineering department at North Carolina Agricultural and Technical State University (NCA&T), and the Chemical Engineering department at The University of Texas at Austin (UT-Austin). Additionally, social scientists from UNC-CH are involved in studying and facilitating collaboration within the group, and psychologists at NCSU are studying and facilitating innovation and technology transfer in the Center. Table 1 shows the breakdown of members by location and position as indicated on the Center's website. Significant distances may separate

team members within each university setting. For example, at NC State CERSP participants are located in three separate buildings, two of which are situated on a remote campus. All scientists in the Center are organized into four project teams; each project team is associated with one major research focus. There are between eight and ten individual projects within each project team; each project has between one and three faculty members (primary investigators) and an average of one to five students and/or post-docs associated with it. The composition of these teams has been in a state of flux over the past year as the Center has been defining its current and future strategic goals.

Location	**Faculty**	**Post-doctoral Associates, Research Associates & Visiting Scientists**	**Graduate Students**	**Under-graduate Students**	***Total***
UNC-CH	11	15	21	2	*49*
NC State	13	11	20	2	*46*
NC A&T	5	0	5	8	*18*
UT-Austin	5	1	6	0	*12*
Total	*34*	*19*	*49*	*12*	*126*

Table 1: CERSP Membership by location and position

Data Collection and Analysis

This study focuses on identifying CERSP members' current collaboration and communication practices and channels in order to discover group members' perceptions about what is working well in terms of collaboration and where the problem areas lie. The purpose of this user needs analysis is to involve end users in the process of specifying features of a CSCW system that will benefit the group; as indicated in the

literature, this type of user involvement in the design process is a fundamental step in creating a successful CSCW system. From these findings, I will make recommendations as to the places that CSCW systems could help CERSP researchers and the specific types of systems that would best suit the Center. Results from this study may be further generalized to aid other NSF Science and Technology Centers as well as other distributed scientific research groups.

As discussed, the NSF Science and Technology Center for Environmentally Responsible Solvents and Processes has over one hundred participating members. For the purpose of this study, one project team was chosen as being representative of the group as a whole. This project team includes members from each of the four locations. Specifically, the project team consists of ten faculty members (primary investigators) and eighteen other researchers. Roughly two thirds of these members are based out of either UNC-CH or NC State. The remaining one third is split between NC A&T and UT-Austin. The group includes chemists, chemical engineers; there are also experimentalists as well as theorists involved in the Team.

Semi-structured interviews with team members and observations of their workspaces made up the basis of data collection. All team members were initially contacted by email to request their participation. Team members who responded to this request were provided with further information about this study. Interviewees agreed to participate in the study by signing consent forms (see Appendix A). In all, I conducted sixteen semi-structured interviews; nine of these interviews were with non-faculty (including visiting scientists, post-doctoral associates, graduate, and undergraduate students) and seven were with faculty members. Of the non-faculty participants, three

were theorists, three were chemists, and three were chemical engineers. Of the faculty, three were members of the Center's management team. Fifteen of these interviews occurred in person in the laboratory or office where the participant works. Interview questions were formulated to get information about project management, daily workflow, problem areas, and attitudes toward and perceptions about collaboration (see Appendix B). In cases where a visit to the participant's workplace was not possible (such as with participants in Texas), interviews were conducted via telephone. The interviews ranged in length from twenty minutes to an hour, with an average time of thirty minutes. These interviews were taped recorded and notes were taken. Additionally, observations about the physical workspace were noted in cases where the interviews were performed face-to-face.

Once the interviews were complete, recordings were transcribed for more in depth analysis. Transcribing both allowed me to listen to the interviews in full again and to have written documents of the interviews to augment the notes I had taken during the interviews. Through detailed examination of these materials, I extracted common themes about daily workflow, communication patterns, attitudes toward collaboration and specific examples of collaboration, as well as specific collaboration difficulties and problem areas. Altogether, I have acquired an understanding of the present state of collaboration within the Center, including the current work practices and collaboration trends, and common communication channels and collaboration tools currently being used by members. I have also formulated an overview of the strengths and weaknesses of the Center with respect to collaboration. This information allowed me make

recommendations on what types of technology the group needs at this point to support and improve collaboration within this group.

Research Findings

Overall, Center members tend to fall into two categories in their characteristics of daily work and perceptions toward collaboration: faculty members and non-faculty members (including post-doctoral researchers, visiting scientists, graduate and undergraduate students). Within the category of faculty members, there is a subgroup of management team members who have additional needs.

Current Work Practices

From the data gathered in this study, it appears that non-faculty members generally tend to be more explicitly focused on their individual research projects than do faculty members in their daily work. Many of these non-faculty members are involved in only one project at a time; furthermore, many of these researchers are working primarily alone on their projects with their faculty advisors. Other non-faculty are involved in group projects composed of small teams that are collocated within the same university and often within the same lab. One ramification of this organizational schema is that for non-faculty members, daily work rarely involves communication with any Center members at other locations. Most of the students with whom I spoke claim that they do not feel they are doing much collaboration with others outside of their individual project groups. Many of them stated that their projects are in beginning stages and that once they get the results they are hoping for, future collaborations are a likely possibility. Therefore, for non-faculty members, collaboration at this point consists mainly of maintaining a basic awareness of the other research projects that are underway in the Center. On a general day-to-day level, this also seems to be true for those faculty

researchers who are not involved in the Center's management team. While there are some projects with multiple principle investigators from separate locations, by and large the individual projects are headed by single faculty members or teams of faculty members at the same university. Of the seven faculty members I interviewed, only two of them were currently working on research projects that involved additional primary investigators at a different location

Another main difference between faculty and non-faculty is that faculty members in general are involved in more individual projects. These projects tend to be related but distinct. Also, faculty members seem to be more likely to be involved in looking ahead to future projects, planning for new students or new research interests of their own. For faculty members who are on the management team, the daily work also involves tasks associated with running the Center and ensuring that the work of individual members is contributing to the overall goals of the Center. For example, one management team member summarized the daily management work as follows:

> "We talk about planning board meetings, we talk about the research directions overall for the Center and how they're moving along and planning for modifications, we talk about proposal writing to outside agencies for more money, we talk about personnel within the Center, particularly within the management group, and how they're doing and what they're doing so that we can keep track of progress within the Center. We talk about faculty researchers in the Center and the ones that are doing well and not doing well. We talk about students."

These researchers tend to have a broader view of collaboration in general, and they also tend to have more specific needs.

Current Communication Channels and Collaboration Tools

In addition to their specific scientific research goals, collaboration is a fundamental focus of the Center. According to the Center's director, Dr. Joe DeSimone, "collaboration across distance and among diverse disciplines is essential for the success of the CERSP" (DeSimone, 2000). At present, there are several collaboration tools in place to facilitate communication among Center members. Common tools currently being used to facilitate communication include telephone and email, physical bulletin boards, a Center web site, and online discussion board, teleconferences and videoconferences.

It appears that informal interactions and face-to-face meetings are both the most common and the most valued communication channels at this point. The non-faculty members with who I spoke all told me that when they face problems or questions in their daily work they are most likely to seek advice from someone else in their lab first. Non-faculty members also value informal discussions that occur without the presence of advisors. At least one advisors' group of students meets weekly to discuss their research independent of their advisor. The students seem to value the informality of these meetings and the absence of the advisor; as one student described:

> "It's not slides or anything. It's like you just say it and you just use the chalkboard. People can ask like 'stupid questions' and we can make suggestions. We'll get a lot more interaction just between the group members."

These meetings help students to maintain awareness of the other projects that are going around them and are valuable as a method for sharing knowledge. Informal discussions also appear to be quite important according to faculty members. According to one:

> "If we've got technical issues that need to be discussed, the best mechanism is to sit around a table in a small group, let the student make a presentation, have the discussion be spontaneous."

In terms of facilitating collaboration, face-to-face meetings and informal discussion are especially valued by faculty members. One participant described the importance of a face-to-face meeting as follows:

> "It has a tremendous psychological effect of raising the priority of that project in the eyes of everybody at the meeting and also it produces a lot of new ideas, things you didn't understand before come clear, and so on."

Faculty members also value informal meetings; as one participant explained:

> "I particularly learn from the private times of discussion… when I can talk to people, you know lunch or dinner or whatever."

Lack of face-to-face contact with members in remote locations seems to be especially problematic for beginning new research collaborations.

Members also cite the telephone as a means of contacting one another directly; however, phone contact can be difficult to establish due to hectic and varying schedules of most members. Management team members are also involved in teleconferencing for their weekly management meetings. The management team includes members at each of the four locations. For the teleconferences, members at each location may gather in one location or they may phone in from their personal office. Prior to these meetings, any pertinent documents are emailed out to all management team members so that members in all locations may view the same documents during the meeting. Satisfaction with the teleconference seems widely variant. For at least one faculty member, the teleconferencing works very well; being able to do other things during the meetings is a positive for this member, and the practice of emailing documents out to team members prior to the meetings so that they may print them and have the physical documents present during the meeting is completely satisfactory. For at least one other team

member, these meetings are less effective than they could be because they occur via telephone with no face-to-face contact or ability to see other members. Also, as the participant explained:

> "There's a great tendency to be distracted by what's going on in your office."

Also, teleconferencing does not allow management team members to work on the same document at the same time; several members though they would benefit from something that would allow them to make sketches during these meetings that everyone could see and that they could then capture, save and manipulate later.

Email appears to be a very important tool, both for short communications as well as for sharing information via attached files that may include text document, graphs, charts, output from computer programs, photographs of experimental results either taken with a digital or scanned into the computer, and sketches or drawings of various things. Participants cited email as the most common format for sharing documents, and overall they are satisfied with this method of document sharing. As a means of communication, email is also seems to be quite useful since Center members are all very busy and have schedules that make direct or synchronous contact difficult. One participant explained:

> "Sometimes we don't answer the phone very often because we are doing all kinds of stuff, and email to me is the best way to communicate."

At the same time, communication via email does have drawbacks; specifically, participants made the following comments on the weaknesses of email communication:

> "Email can often be misinterpreted. When you're short it's interpreted as being terse, and if you get over a hundred emails a day you can't help but be short."

> "You don't really get to make that people connection with email; it's just words on a screen."

> "It's not worth emailing because it's much easier to explain the problem and just kind of toss it back and forth."
>
> "Emails tend to be a little bit superficial, you tend to exchange a lot of emails before you really get to the nub of something."

Despite these difficulties, participants cite email as a valuable tool for some communications such as setting up meetings, asking or answering simple questions, or as a follow-up to telephone or face-to-face meetings. Overall, email seems to be most valuable in facilitating document sharing and as a complement to other forms of communication.

In addition to these methods of direct communication, Center members utilize several methods of maintaining awareness of the activities of others within the Center, including the weekly group meetings held via videoconference, the Center's website, and local, physical bulletin boards. Knowing what other individuals are doing is a key to beginning new collaborations. As one participant explained:

> "A main part of collaboration is knowing all of what's out there."

In general, members tend to be most familiar with the work that is going on in their same location.

People overall seem to have at least a basic idea of the other kinds of research going on in the Center; the weekly video conference meetings are by far the most common source for gaining this knowledge. All members are involved in the weekly videoconference group meetings to some degree. Although every group meeting is open to all Center members, each week's meeting focuses specifically on one Project Team, with one to three students presenting their work. Abstracts of upcoming presentations are

linked to the Center's web site from the group meeting schedule. Students use PowerPoint slide shows in their presentations; these slides are subsequently linked to the Center's web site so that they are available for review. These presentations can be effective in producing new ideas among researchers. One participant described the way that a presentation led to further communication with the presenter that greatly aided a research project that initially seemed unrelated. The participant explained:

> "The real thing that sort of stimulated us to look at our own back yard was hearing this thing that was a televised, output that came from [a different location]."

Every member I spoke with mentioned that technical difficulties are sometimes an issue with the videoconference meetings. For members at one university, the most common complaint was that the TV screens on which they view the video feeds from other locations are too small. This university's facility also lacks a Smartboard. These two issues are known and are being addressed. Technical difficulties also tend to constrain participation, as indicated by one participant:

> "The quality of the videoconference isn't up to snuff yet so we're all kind of inhibited as to whether or not you're going to be understood if you interrupt with a question."

Another complaint about the videoconferences is that the presentations are too formal. As one participant explained:

> "The group meetings have completely lost spontaneity as far as I'm concerned."

Too much formality in the presentation restricts the rich kinds of question and answer interaction that can be greatly beneficial in terms of collaboration. For example, one participant said in reference to the videoconference presentations:

> "I think I know what people are doing on a somewhat superficial level. I think the ability to really understand what they are doing on a technical level has been constrained."

Several participants indicated that the formal presentations of the videoconferences would be much more useful to them if they included better introductions or overviews aimed at people who are not experts in the specific project area. Although several participants indicated dissatisfaction with the formality of presentations at group meetings, at least one primary investigator believed that a polished presentation was important and believed that good results would speak for themselves. Additionally, participants commonly expressed difficulty in maintaining awareness of what other groups are doing since each specific project only presents to the group as a whole roughly twice a year.

The CERSP website also provides information both to members of the Center and to the public. At present, all of the information available on the site is open to the public, with one exception: there is an online discussion board included, access to which is restricted to CERSP members by means of a username and password login. The discussion board has been available since September of 2000. Thus far, postings on the board consist mainly of summaries of recent group meetings. I did not find a single member who uses the discussion forum with any regularity or who viewed it as a valuable tool. Common reasons given for not using the forum include:

> "I haven't found it useful because it's an extra task that I have to perform. You have to consciously make a decision to log on, so I just don't."

> "If I want to ask somebody a question I'd much rather just do email to them personally or talk to them on the phone or in person. It's too general, I think, the web-board is."

> "People just usually ask the question when they are at the group meeting rather than saying 'okay I'll just wait and ask the person on the web-board instead of just asking the person directly.'"

> "Maybe it's like teaching an old dog new tricks, but I don't know the value of it independent of email. And I haven't had any need that I know of to use it."

The website also provides other information aimed mainly at Center members such as outlines of Project Teams membership, including an explanation of the specific overall research focus of the Team and titles of individual projects. Additionally, individual members may choose to have their own homepages linked to the Center's website in order to provide information about their individual research interests and activities to others.

Bulletin boards in or near the various laboratories display information about current projects that researchers within each location may browse in order to monitor the status of their coworkers' research. These bulletin boards allow researchers to peruse information about other projects at their leisure. The types of information posted may include recent publications, overviews of current projects, graphs, charts, or photographs depicting project results, sketches and photographs of laboratory equipment in use, and information on plans for future research.

Discussion and Recommendations

In general, it appears that there are three areas where Center members would like additional or different systems to encourage and facilitate collaboration across distances. First, members want richer and easier interactions with scientists at other locations. Second, a system or mechanism to allow members to maintain a better or more detailed

knowledge of other current research projects appears to be very important. Third, the management team especially seems to need a system or mechanism to allow shared drawing space for visual interaction in meetings. In terms of what is important for the Center and what is most likely to be adopted by members, I propose that a mechanism for sharing information about individual projects more frequently and a system to provide a shared drawing space are the top priorities at this time.

Facilitating richer and more spontaneous interactions with others is especially difficult; although there are a variety of technological solutions, all of them will involve a departure from the familiar daily workflow. One suggestion was that a semiannual or annual meeting of at least all the faculty members, where they all physically came together, would greatly enhance the overall work of the Center and the interactions that they are able to have remotely during the rest of the year. In addition, there are a variety of technological tools that can facilitate interactions that more closely resemble face-to-face communication. Examples include desktop videoconferencing tools such as Microsoft NetMeeting that use desktop cameras. At least one participant in this study indicated interest in experimenting with desktop cameras; however, these types of tools will not solve the issue of needing spontaneous meetings. Also, desktop cameras may not solve issues such as availability awareness (Steinfeld, Jang and Plaff, 1999) and other social expectations that users bring to remote communications (Dix et al., 1998).

Faculty members may benefit from additional videoconference meetings that are more informal and do not include students. Several participants in the study indicated that informal interactions with other faculty can be a good step in beginning new collaborations; this corresponds to previously discussed research by Lubich, which

indicates that scientists tend to collaborate with others who are of equal status professionally (Lubich, 1995). At the same time, adding additional meetings may be difficult in light of the fact that most faculty members' schedules are already quite hectic.

Online discussion forums can be a valuable means of facilitating informal interactions between people; it would be possible, for example, to create a discussion forum that was only open to students where these non-faculty members could freely discuss research concerns without feeling inhibited by the presence of advisors. However, considering the attitudes toward the existing discussion forum, it seems highly unlikely that members would adopt and use such a system. My general sense of the participants leads me to believe that what they really need is stronger social links to other members rather than further technological access to one another. Once members become more familiar with their colleagues and more knowledgeable about the work that their colleagues are doing, they will probably be more open to experimenting with alternative means of communication. As one participant stated:

> "We lack communication not because the technology isn't there but because people don't show up to use the technology that's already available."

Confidence in the videoconference meetings is growing, and as members become more comfortable with this technology they will probably be more likely to accept other new tools or systems. Also, as previously discussed, the formation of trust within a group that allows for high levels of group cooperation may take longer to develop via videoconferencing than it would in a face-to-face setting (Bos et al., 2001). Therefore, Center members may still be in the process of developing this group trust.

A system or mechanism to allow members to monitor the other types of research going on and identify possible collaborations may include several aspects. One thing that may help in this area is for the Center to settle on Project Team organizations that bring together the right mix of scientists. Project Team organization has been in flux over the past year and throughout the period of time in which this study's interviews were conducted. However, at the time of this writing the Project Team organization seems to have settled into a schema that makes sense. One faculty member claimed that the latest reorganization of project teams is the first one that really made sense and that finally it has become clear the value of a project team. As this participant explained, by previous team organization all the theorists were isolated in a sense, and working or discussing things amongst themselves; now they have thrown experimentalists into the mix as well, and that is very important. As pointed out by one participant, team organization can be seen as divisive to the group as whole, but if organized well it can also bring together researchers who have commonalities they might not have otherwise found. Especially since many Center members primarily attend only those group meetings aimed at their Project Team, this organization is especially important.

Another thing that may help to facilitate this awareness of other research is to provide more frequent updates on individual projects. As discussed, each project is presented in detail roughly twice a year at this point; as the Center grows to include more research projects, this problem will be exacerbated. As one participant suggested, providing more frequent project updates could be accomplished by having occasional videoconference group meetings that consist of short overviews or updates of all projects within a team. The benefit to this method would be that no additional equipment would

be necessary; the drawback would be that it would necessitate either having more meetings or further spacing out the detailed project presentations that already occur. Also, overview meetings would become problematic as the Center grows to include more projects.

Another method for facilitating this type of awareness would be to extend the Center's website to include a virtual bulletin board system. Ideally, the system would allow researchers to easily input information in a variety of formats including text documents, graphs, charts, spreadsheets, photographic images, and drawings or sketches. In this way each individual project could have a section on the website that gave an overview and current details or preliminary results. Security of information would clearly be an issue, but it would be possible to restrict access to this section of the website to Center members. This type of system would provide the benefits of a physical bulletin board that was accessible to researchers in remote locations as well. At present, researchers are able to post information about their projects on local physical bulletin boards. Figure 1 shows an example of one of the existing bulletin boards for the Center.

Figure 1: Bulletin board depicting project information.

If each research project had its own homepage linked from the Center's website, scientists could browse information about other projects at their leisure. Each homepage could have the same basic format, with an overview of the project, the names and contact information of researchers involved, and links to whatever information those researchers submitted. Links to other information could include titles and document formats. In this way people viewing the page would get a sense of the information included from the top level, and they could follow links to find more detailed information. An important key to success of a system such as this would be that researchers would need to be able to input their information easily.

Augmenting the management teleconferences to include a system that would allow participants to make drawings or sketches that everyone could see, and that could be captured and manipulated later may be the easiest issue to solve at this time. There are a variety of products available that would facilitate this. In fact, Microsoft NetMeeting, which is available to members at present, has a function to allow for this, although members have not been using it thus far. It may be that a demonstration of NetMeeting's capabilities would be enough to bring this feature into use by the Center's management team. One other choice would be to incorporate an additional Smartboard as is used with the videoconference. Another option is a product called eBeam (www.ebeam.com). eBeam is an add-on to standard whiteboard; sensors attach to the whiteboard itself and to a standard dry-erase marker, and connect to a PC. Information written on the whiteboard is then captured into the PC in much the same way as a Smartboard. Incorporating technology such as eBeam or NetMeeting may introduce new difficulties to the management team meetings; a large display would be needed for those locations at which

several team members gather together to participate in these meetings. Also, groupware such as this brings in the factor of passing control over the software, which adds another layer of complexity to the meeting. Adding new technology to the management team meetings first has several advantages. First, these members seem to have the greatest need at this point for additional tools since they are doing more intensive inter-location collaboration than anyone else. Also, if this core group of members adopts a new technology and finds it to be useful, they will be able to encourage others in the Center to also use the new technology and thus encourage more widespread adoption of the system.

CERSP has thus far succeeded in laying the groundwork to encourage collaboration among researchers indifferent fields and from various locations. Participants are generally favorable toward collaboration; they see the value in it and they feel like they are willing to do it. The main difficulty at this point is that Center members either are not able to identify where mutually beneficial collaborations could occur or they do not feel able to easily begin those collaborations. As one participant explained:

> "We are in frequent communication. You could question the quality of that communication—I do question the quality of that communication but I think that the communication does exist and people have bought into the need to communicate on a regular basis and run the Center as a single entity."

The tools currently in place to facilitate communication have been useful in building a foundation for collaboration; now, the Center should to augment these tools in order to better facilitate further collaboration. At present, it appears that most Center members would benefit from a system to allow for more frequent updates on individual projects to all Center members such as a virtual bulletin board. While scientists in the Center have accepted the notion of collaboration in general, most of them are not yet in a situation where they have identified specific collaborations they would like to pursue for which

they need additional tools. This difficulty seems to exist for both faculty and non-faculty members, although at this point it is the faculty members who are more concerned with establishing these collaborations. In introducing new tools, it will probably make sense to start with the faculty members as they are more likely to adopt them since they better recognize the need for such tools. One example of this is the management team meetings; a tool to provide a shared drawing space for management team meetings is something that is currently recognized as a need by members, and would therefore may readily be adopted. This type of tool may also be useful for small faculty meetings or other small group meetings. Overall, I think it is important for the Center to progress slowly with adding technology to their collaboration infrastructure. In many cases, such as in using email to share documents, members are satisfied with their current practices and do not feel that they need additional tools. As members become more familiar with using videoconferencing and more confident of technology to support their collaboration needs, and as researchers begin to identify more specific places where these technologies would be of use to them, it will make sense for the Center to begin looking into more elaborate CSCW systems.

Acknowledgements

This research would not have been possible without the gracious cooperation and participation of the members of the National Science Foundation Science and Technology Center for Environmentally Responsible Solvents and Processes. I would like to thank all members of the Center, and especially those who allowed me to interview them. I would like to thank Diane Sonnenwald for the guidance, input and support that led this project. Finally, I would like to thank Noriko Haran, Paul Solomon, and Reto Bollinger for their insights and assistance in completing this study.

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Appendix A: Interview Consent Form

This study is part of the research project for the NSF Science and Technology Center for Environmentally Responsible Solvents and Processes. Members of the social science research group, including Amy Carlson, Noriko Hara, and Diane Sonnenwald, may be interviewing you periodically about your work associated with the Center. The interviews will be scheduled at your convenience and for a duration and frequency that seem comfortable to you. During these interviews, we will be asking you questions about your work, expectations, perceptions, and experiences collaborating with colleagues and using technology. The purposes of the interviews are to learn about factors that may facilitate and/or impede collaboration and how technology may support collaborative scientific/engineering work. If you agree, we will make an audio-recording of the interviews and/or take notes during the interviews. The tapes may be kept for a period up to ten years. We estimate that on the order of 30 people will be participating in this research.

If you have any questions about the project at any time, please call Diane Sonnenwald at (919) 962 8065, or send her a fax at (919) 962 8071, or e-mail at dhs@ils.unc.edu.

Thank you for your willingness to participate in this study. Your participation is very much appreciated. I would like to assure you that as a participant you have the following rights:

. Your participation in this study is entirely voluntary.
. All data will be kept confidential. Your individual data will not be shared with other participants and it will not affect your job, grades, or performance rating.
. Excerpts of the data may be made part of research reports but under no circumstances will your name or identifying characteristics be included in the reports.

If you have additional questions about your rights as a participant, you may contact:

Academic Affairs Institutional Review Board
Dr. Barbara D. Goldman, Chair
CB #4100, 201 Bynum Hall
The University of North Carolina at Chapel Hill
Chapel Hill, NC 27599-4100
(919) 962-7761
e-mail: aa-irb@unc.edu

Please sign and date both copies of this form to show that you agree to participate. Please retain one copy for your records.
Thank you very much.

_____

Participant Date

_____

Researcher Date

Appendix B: Typical Questions for Interviews

Project Management

- How many people are involved in that project?
- From how many locations?
- What are the various locations (what is the distance between locations)? Are there multiple locations within each university?
- How many people per location?
- Duration of the project (month, years)
- Who are the project leaders (student and PI)?
- What is the breakdown of #students, #PIs…

Details of project / daily work

- What kind of tasks does your typical workday entail?
- What kinds of tasks does the project entail?
- What specific tools do you most often use?
- What tools are necessary (is there equipment that you cannot function without?)?
- Is the group using the same equipment on several locations?
- What part of the daily work do you most enjoy?
- What part do you find most challenging?
- What part do you enjoy least?
- How are group members dependent from the work of the other group members?

Interaction/Collaboration

- With whom does the group discuss their work progress
    a) student – student
    b) student – PI
    c) PI – PI
- How do you share their results /How do you keep others aware of their progress?
- At this point, is most of the collaboration or information sharing occurring locally versus across distances?
- Is most of the information sharing that is currently occurring happening "by chance" or through formal channels?
- What kinds of information would group members like to be sharing with others?
- What kinds of information would they like to know from other group members?
- Who do they ask to solve a problem
    a) Discussions in the local group?
    b) Discussions with PI's?
    c) Discussions with other NSFSTC groups?
    d) Discussions in the weekly group meeting?
    e) Web board
    f) Others?
- What "interaction-tool" do they prefer for solving problems (e.g. face to face, phone, email, Web Board etc.)?
- If they do have access to electronic means such as web boards or file-sharing tools that they are not using, what are their reasons for not using these tools?

Where could technology help?

- What kind of problems exist (e.g.: something going to slow, what and why)?
    - too many steps
    - too complicated
    - too expensive
    - Communication problems
    - Organizational problems
    - Problems with externals / suppliers etc.
    - Others
- Where do these problems happen?
    - In project management part
    - In the daily work
- What is the most difficult or challenging aspect of their current work practices with respect to collaborating?
- What is currently working best when it comes to collaboration?
- What additional technologies do the students and PIs wish they had in order to do a better job/ better research?