In Proceedings of the 2001 International ACM SIGGROUP Conference on Supporting Group Work, New York: ACM Press, pp. 232-241.

Diffusion of a Collaborative Technology Across Distance

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ABSTRACT
Achieving a common set of collaboration tools is a significant challenge for people working together in a geographically distributed enterprise. It requires coordinated technology adoption across geographic distance and organizational boundaries. In this paper, we report on the diffusion of a data conferencing technology in a large distributed enterprise. Two years ago we studied the early adopters; now the technology is widespread. We conducted a company-wide survey and found that it is generally the users, and not management, who are the driving force in diffusing the technology across distance. We discuss the organizational conditions that led to the diffusion, how barriers have changed, and emerging work practices as a result of the diffusion.

Categories and Subject Descriptors
H.4.3 [**Information Systems Applications**]: Communications Applications – *computer conferencing*; K.4.3 [**Computers and Society**]: Organizational Impacts – *computer-supported cooperative work.*

General Terms
Management, Performance, Human Factors

Keywords
Technology adoption, CSCW, virtual collocation, empirical study, distributed work, data conferencing

1. INTRODUCTION
The problems people face when working together across distance have been of intense interest in the CSCW community and in related fields. One of the most challenging problems is that of technology adoption.

Currently, a number of technologies are available to support collaboration across distance, ranging from asynchronous shared workspaces to synchronous audio, video, and data conferencing. As these technologies mature, their potential users face an unusual technology adoption challenge. Typically, the success of a collaboration technology depends on its adoption by all participants in the collaboration. But achieving uniform adoption across geographic distances, and possibly across organizational boundaries, poses significant challenges.

A number of theories have been proposed to explain the failure to adopt collaborative technologies. An organizational culture that promotes competitiveness, and that does not reward cooperative behavior, can hinder technology adoption [8]. At the individual level, it has been argued that lack of common ground, collaboration readiness, or collaboration technology readiness can lead to resistance, or even abandonment of technology used to support distributed collaboration [7]. An imbalance of benefits to costs within a group can also affect adoption [3]. A collaboration technology that has not achieved a critical mass of users will most likely not have value for a potential adopter [5]. In the case of distance collaboration, an extremely complex activity, adoption may depend on the flexibility that a system can offer. Poltrock and Engelbeck [10] argue that distance collaboration requires support for informal communication, opportunistic interactions, and smooth and frequent shifts from one collaboration mode to another.

Nonetheless, some collaboration technologies that support distributed work, such as email and audio conferencing, have been widely adopted. Over the past several years we have observed the diffusion of data conferencing technology in a large distributed organization. In the research reported here we asked how people who are widely distributed geographically adopt a technology that supports their collaboration. How do they learn about it, become persuaded of its value, decide to use it, implement it, and persist in its use?

2. A MODEL OF TECHNOLOGY DIFFUSION
Rogers [11] studied a number of different cases in which an innovation is communicated and adopted by members of a social system. He proposed a model to explain this phenomenon.

There are four elements to be considered when examining the diffusion of an innovation. First, there is the *innovation* itself, which is defined by the adopter's perception that it is new. The innovation we are studying is data conferencing. While not a new

technology (Douglas Engelbart demonstrated a simple version of data conferencing in the 1960's), it was new for the users in the organization. There are three aspects of innovations that are relevant for the adoption case that we are studying. The first aspect is the degree of compatibility of the innovation to practices, values, and needs of the users. As we will discuss later, mergers in the organization that we are studying led to conditions where a technology to support collaboration across distance was needed. The second aspect of innovation is the degree to which users can observe others using it. The problem with distance collaboration is that there may not be many others at a particular site who are using the technology; thus, it is difficult for people at that site to observe others successfully using the technology. The third relevant aspect is whether users perceive a technology as having a relative advantage over other technologies. In our study, the main competitor to data conferencing was audio conferencing and/or web usage.

A second element to consider is the means by which the innovation is *communicated* to others. Mass media channels are the most efficient way to communicate the existence of an innovation to large numbers of potential users, but it is the informal interpersonal channels that persuade others to adopt. Rogers considers interpersonal communication to be primarily face-to-face. However, when we examine the diffusion of a collaborative technology across distance, we must consider alternative means of communication than face-to-face.

A third element is the *social system* in which the innovation spreads. In our study, we are considering an entire enterprise as the unit involved in the adoption process. The enterprise in our study is widely distributed, with sites that have different organizational cultures and practices. The effects that these cultures have on adoption is undoubtedly profound. Unfortunately, studying these effects is far beyond the scope of our current study.

The *length of time* over which an innovation is adopted is another element to take into account when studying adoption. The general form of adoption follows an S-shaped curve. People can be categorized according to when they adopt an innovation. Innovators are the first adopters, and are thus not influenced by others' choices to adopt. Early adopters are influential in getting others to adopt. Most people fall into the categories of early majority, and late majority, followed by laggards. People have different roles in influencing others in the adoption process. An opinion leader is a person who informally influences others to adopt a technology, and most are in the early adopter category. We were interested to learn in this study who the opinion leaders were in the organization. Were they managers, members of the technical support group, or perhaps colleagues who people collaborated with across distance?

Most interesting for us, with respect to time, is that the adoption of an innovation such as a collaboration technology can be decomposed into five steps according to Rogers: (1) Knowledge of the innovation; (2) persuasion to use it; (3) decision to adopt it; (4) implementation of the innovation; and (5) confirmation that adoption was appropriate. Distance between the users of a technology could disrupt any of these steps. For example, distance may act as a knowledge barrier and slow the dissemination of knowledge about a technological innovation (see [6]). The persuasion and decision stages are strongly influenced by interpersonal communication with influential earlier adopters, and distance can disrupt this communication.

Once an innovation is adopted, it may be used in a different way than how it had been used when the user first learned about it or began using it. This process is known as re-invention [2]. Because collaboration can occur in many forms, especially in a distributed organization like Boeing, we were interested to discover the extent to which users may have discovered new uses for the technology after adoption. Strictly speaking, re-invention refers to changing the technology itself, whereas our interest is focused on how the use of the technology may have changed to support different types of collaboration.

2.1 Organizational Background

In the late 1990s The Boeing Company underwent rapid growth both in size and geographic diversity as a consequence of merging with McDonnell Douglas and acquiring the aerospace business units of Rockwell International. Before these mergers, about 80% of Boeing employees were located in the greater Seattle area and could attend most face-to-face meetings by driving less than 1½ hours. Following the merger the company grew to about 235,000 employees and only about 40% were located in the Seattle area; the rest were distributed across the United States, with the largest concentrations in Southern California, Missouri, Washington, and Kansas.

One of us leads investigations of collaboration technologies at The Boeing Company and has explored uses of data conferencing to facilitate collaboration between sites since 1990. Few employees were interested in using the data conferencing technologies available in the early 1990s. They were concerned about the reliability and scalability of the technologies, they valued the social interactions of face-to-face meetings, and driving to meetings was unpleasant but manageable. The mergers suddenly changed the cost/benefit ratio for data conferencing technologies. Following the merger, employees were repeatedly called upon to collaborate with people hundreds or thousands of miles away.

Fortunately, we developed a prototype data conference service in 1996 before these mergers, and this service was transferred to the company's information systems organization in 1997 and 1998 [9]. Data conferencing is a computing technology that enables people to communicate and share information with one another synchronously. Much like using a telephone, a person can use a data conference application to call another person, or they can call a conference bridge to join a session with many other people. With data conferencing, people can work simultaneously in a shared whiteboard, share application windows from one person to all other participants, allow other participants to interact with the shared applications, enable short text messages to be sent to one or all participants, and send files to the other participants.

The core elements of the data conferencing service were Microsoft NetMeeting, the Microsoft Internet Locator Service (ILS), and the Databeam neT120 data conference server. From the point of view of end users, NetMeeting is their desktop application and they may not know about the other infrastructure components. When users start NetMeeting, their names and addresses are registered with the ILS, which acts as a dynamic directory enabling calls to everyone who is currently running NetMeeting. The neT120 conference server acts as a meeting

place. Users can schedule meetings at specific times and reserve the necessary space, much like reserving seats in a virtual conference room. Employees use the data conferencing service with other people in conference rooms and alone at their desks to look at and interact with documents together while speaking to one another over the telephone. It supports collaboration within the company and with external partners, vendors, and customers.

2.2 Early Adopters of Data Conferencing

In 1998, the current authors studied the adoption and use of data conferencing within Boeing to support virtually collocated teams [4]. The users at the time were early adopters of the technology, and the teams faced a number of problems in using the technology. Some teams developed novel solutions to help them adapt, such as a facilitator who focused on the geographically distributed team members. In three of the four teams, the leaders introduced data conferencing to support distributed meetings.

Team members outside of the Seattle area (where the majority of team members were located) were much slower to adopt the technology. In fact, some members participated in meetings only with audio-conferencing. In our 1998 study, barriers in adoption were attributed to the following reasons, based on interviews with team members:

Virtually collocated team participation was not considered a priority by management. Participation on some teams was voluntary and part-time. Managers did not view distance collaboration as important enough to warrant purchasing computers to run data conferencing. Due to the mergers, different sites often had different types of computers, operating systems, and support organizations.

For team members themselves, virtual collocation was not a priority. Many members reported that because team participation was a part-time activity, they acted slowly to get the equipment, download the software, or in one case, obtain a special firewall-spanning account.

Local colleagues discouraged use. Some team members were more influenced by colleagues at their local sites who rarely participated on distributed teams than by distant colleagues who used this technology. For example, one member reported that others at his site discouraged him from using data conferencing by saying that a lot of time would be wasted getting it synchronized.

Local technology support was lacking. Although some people gave on-line help during a meeting, it was often hard to download and begin running the technology without having technical support at their local sites. Members at some sites reported having no one to consult about the technology.

Peer pressure for adoption is weak at a distance. The team leaders felt that team members had a history of slow adoption: they had been resistant to other unfamiliar applications in the past. They also believed that peer pressure and other influences to overcome resistance were weak when the team is distributed.

2.3 The Adoption Curve in the Organization

Data conferencing usage has grown dramatically since our study in 1998. We collect usage data from our neT120 conference servers and we can monitor the ILS directory, which shows all the people running data conferencing and indicates who is actively participating in a meeting. Figure 1 shows the total usage per month in user hours from February 1998 through October 2000. As shown in the figure, usage has grown from 1,872 usage hours to 42,431 usage hours. This is a relatively steep technology diffusion function.

This rapid growth in usage cannot be attributed to advertisement or advocacy by the information systems community. The information systems organization assigned experts to manage the data conferencing service, but these experts were not chartered to advocate its use. They established a web site where users could find information about data conferencing and could download the installation package. Users found and took advantage of these web sites; the term “NetMeeting” was among the top 10 most frequent queries of the Boeing web search engine for nearly two years.

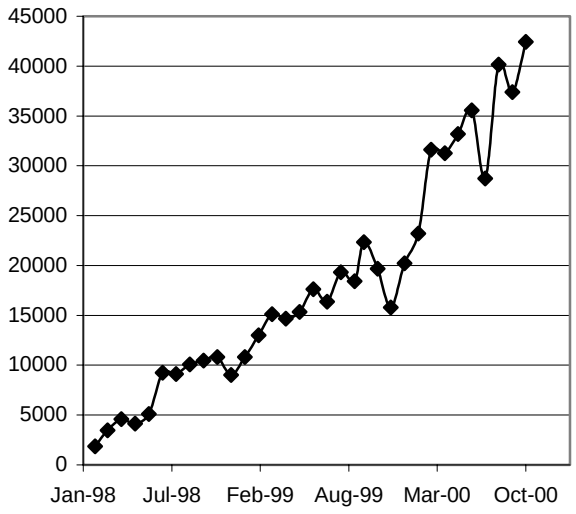

Figure 1. Data conference user hours by month.

3. THE DIFFUSION PROCESS: A STUDY

Given that 2½ years ago the early adopters reported a number of barriers to using data conferencing, we set out to investigate how widespread diffusion of this data conferencing technology across the company had occurred. We have chosen to follow a paradigm commonly used in adoption studies: one-shot interviews and surveys asking users to recall reasons for adoption (see the classic study by [12]). Based on Rogers [11] model of the diffusion of innovations, we conducted a survey which asked users what the primary communication channel was for learning about the technology, how many others they introduced the technology to and for what purposes, barriers they experienced, and what features they use (to determine to what extent the technology is fully adopted).

3.1 Methodology

Two waves of questionnaires were sent out to users across the company who were identified through their registration with the Internet Locator Service (ILS). When they start NetMeeting, their data conferencing client, it registers with the ILS, which also shows who is in a data conference. The questionnaires were sent to every Boeing employee actively participating in a conference on three separate occasions during the mornings (Pacific Coast

Time) of November 6 and December 18, 2000, and January 10, 2001. We deliberately chose users of the technology rather than conducting a random sample across the enterprise. It was our intent to question adopters to see how they came to use the technology, how they overcame barriers, and whether barriers still existed for them.

The first on-line questionnaire was sent by email to 240 people. Based on their responses, we revised the questionnaire and sent it to 146 people. We received 111 responses from the first questionnaire, and 83 responses from the second questionnaire, for a response rate of 46% and 57%, respectively. Altogether we sent questionnaires to 386 people and received 194 responses. Follow-up telephone interviews were conducted with 14 respondents, ranging from 30-60 minutes each, in order to get a more-in-depth perspective on their reasons for adoption.

3.2 Results

As a first step to understand the adoption process, we asked how long ago people began using the technology. Figure 2 shows the distribution of the time elapsed since our respondents adopted the technology.

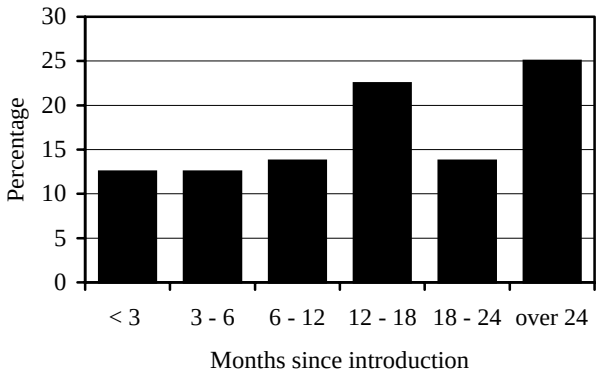

Figure 2. Distribution of times in our sample since respondents began using data conferencing technology. N=83.

Notice that nearly a quarter of our respondents had been using the technology for more than two years. Considering the steep growth in usage shown in Figure 1, we expected fewer early adopters and more recent adopters. While there are many possible reasons for this preponderance of early adopters, one reason we could investigate is that they use the technology more often, and consequently they were more likely to be included in our sample. We compared respondents' frequency of use and length of use, as shown in Table 1. To simplify this presentation of the results we collapsed their length of use into three categories corresponding to early adopters (more than 18 months), early majority adopters (7-18 months), and late majority adopters (6 months or less). We collapsed their frequency of use into infrequent users (once a week or less) and frequent users (at least two times a week to several times daily). As Table 1 shows and a CHI-square test confirms ($\chi^2 = .61$, $p > .05$), our respondents' frequency of current usage is independent of the time since they adopted the technology.

	Infrequent users (less than once a week)	Frequent Users (2/week to daily)	Total
Late majority (6 months or less)	11	9	20
Early majority (7-18 months)	13	16	29
Early adopter (19 months or longer)	14	17	31
Total	38	42	80

Table 1. A comparison of length of usage with frequency of usage.

Focusing on the first phase of the innovation diffusion process, we asked users how they first learned about data conferencing technology. In our first questionnaire this was an open-ended question, and we received wide-ranging responses that often included how they first heard about the technology and how they were persuaded to use it. For example, people reported learning about it from a colleague, seeing it used in a meeting, discovering it on the web, hearing about it through email, using it in a classroom, learning about it from their manager, and using it as part of a distributed team.

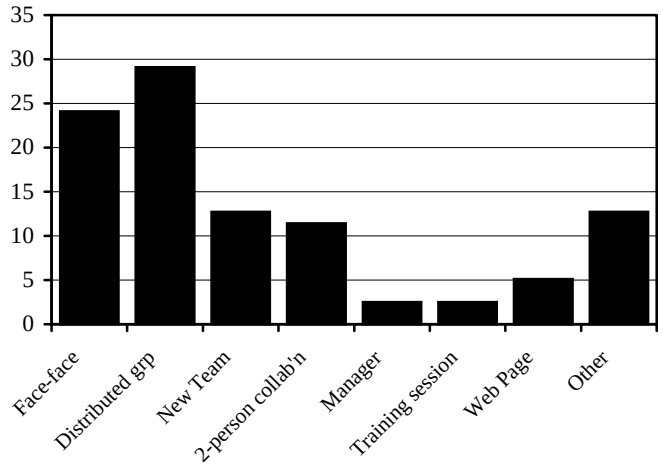

Figure 3. Percentage of users who first learned about data conferencing in a face-to-face meeting, a new team, etc. N=83.

In the second questionnaire we asked respondents to choose from among the most frequent alternatives while being more specific about the location of their source of information. They chose whether they learned about it from a local colleague during a face-to-face interaction, from a distributed team that they were already meeting with, from a new distributed team that they joined, from a

person at another location, from their manager, from a training session, from company web pages, or from other sources. Figure 3 shows the distribution of their responses.

The results show the strong influence of people at other locations. Local colleagues were certainly influential, but a surprising 53% of respondents reported learning about data conferencing from people, either a team or an individual, at other locations (Figure 3). Two years earlier we observed that our much smaller group of early adopters learned about the technology from their leaders or from members of their distributed teams. Among our current respondents, very few (less than 3%) learned about the technology from their managers and the majority learned about it from distributed teams or geographically distant individuals.

We also asked people about their role in diffusing data conferencing technology to others. We asked each respondent to estimate how many people they had introduced to data conferencing. Figure 4 shows the results. The median response was 5 people. Only 13% responded that they never introduced the technology to anyone. Only 10% had introduced it to one other person. Put another way, 77% of the users in our sample reported that they had introduced the technology to two or more others. Nearly 30% reported that they had introduced it to at least ten other people!

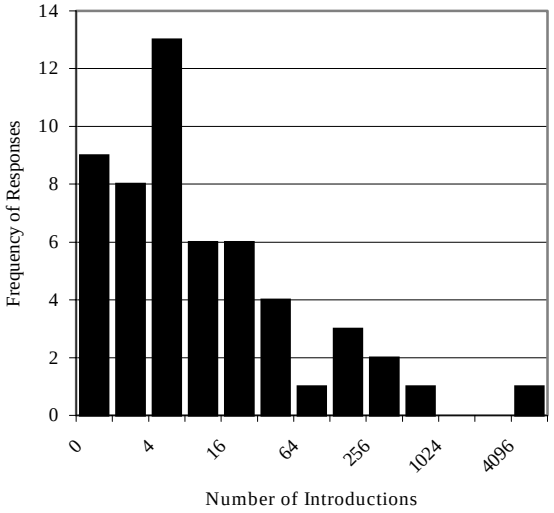

Figure 4. Frequency histogram showing the number of people introduced to data conferencing by the respondents. The first bar on the x-axis represents responses from 0 to 2 and subsequent bars increase by powers of 2. N=83

Previously we discussed the important role of early adopters in influencing others to adopt an innovation. We found that early adopters of data conferencing were more likely to introduce the technology to other people. The length of time using the technology was significantly correlated with the number of people that one informed about the technology ($r = .54$, $p<.001$). Looking more closely at this relationship, Table 2 shows a breakdown of length of use and number of people one introduced the technology to, enabling us to look at new users and early adopters.

	Number of people introduced to the technology by respondents					
	0	**1**	**2-5**	**5-10**	**>10**	**Total**
Late majority (6 months or less)	6	5	8	0	1	20
Early majority (7-18 months)	2	2	15	4	5	28
Early adopter (19 months or longer)	4	1	3	5	18	31
Total	12	8	26	9	24	79

Table 2. Number of people introduced to the technology by respondents categorized by length of time of usage.

The early adopters introduced by far the most people to data conferencing technology. More than half the early adopters claimed that they introduced the technology to more than ten people. However, our data does not allow us to distinguish between whether the early adopters introduced more people because there is something "unique" about early adopters or because they have simply been using the technology longer.

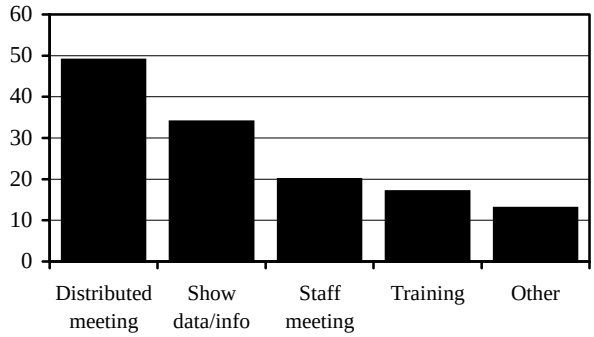

Figure 5. Percentages of each reason why respondents introduced the technology to other people. N=83.

We also asked *why* people introduced the technology to others. Respondents could check more than one purpose. Figure 5 shows the distribution of responses. By far, most people introduced data conferencing to others so they could participate in distributed meetings. The next most common reason reported was to show data or information to a person at some other location. Earlier adopters had more diverse reasons for introducing the technology, presumably because they had discovered more diverse ways of using it. The only reasons cited by late majority (most recent) adopters were for participation in distributed meetings and to show information (the first two bars in Figure 5).

3.3 Overcoming barriers to adoption

Respondents were asked about barriers they experienced in using or adopting the technology and whether they were able to overcome these barriers. We also asked whether they had

experienced any of the barriers we observed in 1998. Figure 6 shows the responses from both questionnaires. About 25% of respondents noted one or more of these barriers. Nobody reported the resistance from management to acquiring the needed technology that we had noted earlier. The most barriers reported concerned different platforms across sites and not having local support, but only 10% reported each of these two barriers. Although the sample of users in 1998 was far lower, nearly all of the users at sites distant from the majority of team members reported many of these barriers. A far greater proportion of these users were included in our current sample (due to the more widespread use of the data conferencing technology), yet far fewer of these same barriers were reported compared to 1998.

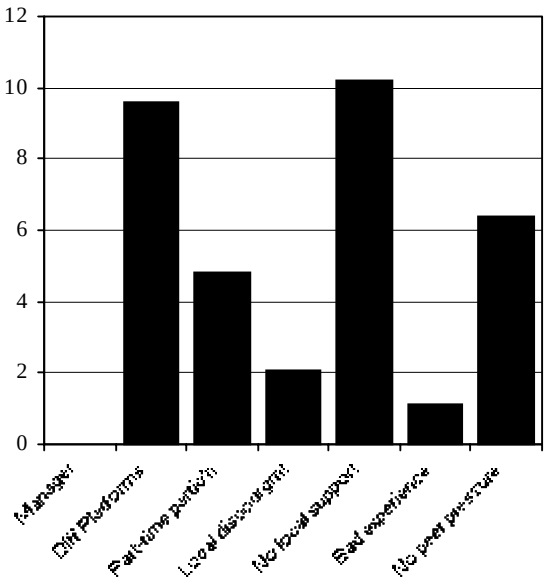

Fig. 6. Percentages of respondents who encountered the same barriers of early adopters from two years prior. N=193.

We asked the users whether they had experienced any other barriers in addition to those we had listed. Reviewing their responses, we identified five categories of barriers. Two coders reviewed every response and coded them into one of the five categories, discussing and agreeing on the category of every response. The categories were: technical problems, getting distant users to join and use proper equipment, not having technical support to help set it up, not enough capabilities in the system to support their collaboration, lack of training and information about use, and other. Figure 7 shows the percentage of respondents who reported barriers of each of these types. The most common barriers reported here were technical problems, and lack of appropriate training or information on how to use the technology.

Interestingly, most of the new reported barriers were problems achieving effective use of the technology rather than barriers to adoption. A typical example of a Remote User Barrier was, "There is always someone who struggles to get their NetMeeting up and running and it delays the meeting start." A typical example of a Technical Problem Barrier was, "The only barrier I experienced was that the other person had a different version of NetMeeting." These respondents were committed to using it and had difficulties using it effectively.

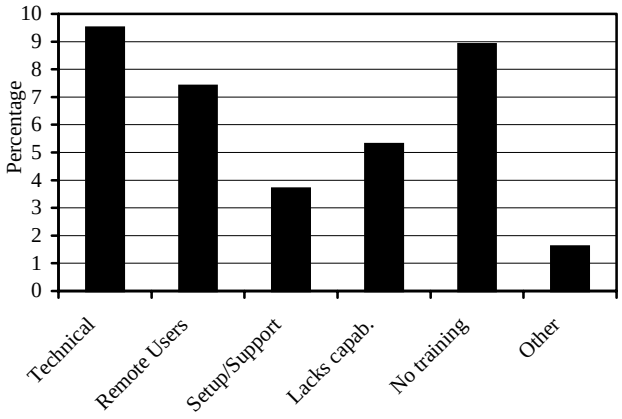

Figure 7. Percentages of respondents who identified other barriers of each category. N=193.

3.4 Functionality and adoption

As described earlier, the data conferencing technology offers functionality to support a number of different types of collaboration. We looked at how frequently the different functionalities were used. Figure 8 shows the frequency of usage of different data conference features, as reported by respondents to both questionnaires. The technology was most commonly used to watch while someone shared a presentation or other application. Nearly 80% of respondents also had shared a presentation or application with others. These are the functions commonly used in a distributed meeting, which appears to have been the business use that drove technology adoption. People learned only those functions needed in these meetings.

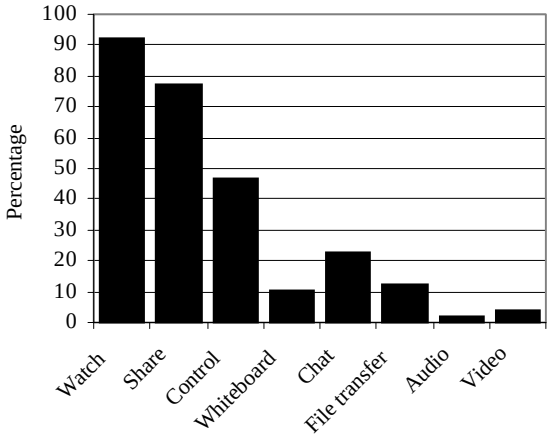

Figure 8. Percentages of usage of data conferencing features.

Respondents passed control of an application from one person to another (described as *control* in Figure 8) much less frequently. They rarely used the whiteboard feature, which allows people to

work together simultaneously in the same shared workspace. Indeed, many people have told us they did not know the whiteboard feature was available or how it would be used. These two rarely used features offer the most opportunity for close collaboration within a small group but are not used in business meetings. Although our respondents had successfully adopted other features of data conferencing, many had not reached the first phase of adoption for these features; they did not even know the features existed.

In contrast, people knew the audio and video features existed, often wanted to use them, but did not know how. For example, one person reported, "We need microphone/receiver headsets with audio capability on our PCs." Another asked, "Are there people using the video/audio portion?" People could see that these features existed in the product, but they were not part of the supported service within Boeing and no information was available about their usage.

The data conference service provided different means for people to connect with one another, and we asked which methods they used. They could join a meeting hosted on a server, call another person listed in the ILS, or host a meeting on their own computers and invite other people to call them. Users are required to know which method has been employed for a particular meeting and properly follow that method. In addition, they could communicate with people outside Boeing through a conference server. As shown in Figure 9, our respondents joined meetings in all three ways nearly equally, and a small percentage participated in meetings with people who were outside the company. Actually, only a third of our respondents used all three methods of joining a meeting, and about 40% used two methods. Most people used only one of these three methods, although the three methods were used almost equally likely. This phenomenon partially explains why respondents reported delays at the start of meetings. As one person responded, "Even now, most NetMeetings I participate in tend to get started late because so many users have difficulty properly logging in." The technology offered alternative ways to set up and join a meeting, and people adopted different practices, resulting in persistent confusion.

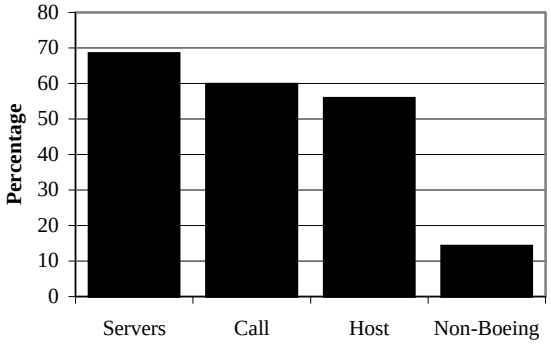

Figure 9. Percentages of usage of methods for joining meetings.

Our overall assessment of this data is that the data conferencing technology is not being used to its full potential to support collaboration. This assessment is shared by many of the respondents in the survey and interviews. It seems that our respondents adopted only a subset of the functionality, and they adopted different practices where there were alternative ways of using the functionality.

4. SCENARIOS OF TECHNOLOGY ADOPTION

The following scenarios of technology adoption are based on interviews of selected respondents. All were actual cases, and real names are not used.

Sarah works at a Boeing site in St. Louis, Missouri. She learned about data conferencing from a colleague who sat at the desk next to hers. Sarah tests a particular software application developed by an independent vendor and teaches engineers how to use it. She instructs them in its use and watches them go through the steps of using it. She meets with people face-to-face almost daily for training. Once they understand how to use it, she then meets with them every couple of months. After learning about data conferencing, Sarah realized she could use it to view the software with her trainees and testers who were located in another part of the city. She finds it very convenient to avoid travel by supervising this training from her desk. She now watches the engineers go through the steps online, and she points out problems in their use of the application. Sarah uses data conferencing 2 to 3 times per week, and about once per month she uses it to participate in meeting of a team distributed in California, Arizona, and Missouri to discuss issues related to her software application. Note that Sarah uses data conferencing for distributed meetings, the most common use within Boeing, but she is gaining greater value through the innovation of using it for distance training. And in so doing, she is informing the engineers and other trainers about the potential for using it in this way.

Joe works on an enterprise team and was an early adopter. He first learned about data conferencing two years ago when it was used in a distributed salary review meeting that he attended. He now uses it for distributed meetings and for ad hoc collaboration. One of his distributed meetings involves enterprise teams of 5 to 8 people. Typical attendees are distributed in sites in Southern California, Arizona, St. Louis, and Wichita. Joe is a frequent user of data conferencing, using it three times per week for a total of about eight hours per week. He frequently introduces it to others for ad hoc collaboration. His work involves analysis and interpretation of numerical data, and he can explain a variety of nuances of the data by using application sharing. Often in a phone conversation he will ask people to launch data conferencing. If they are not familiar with it, he will explain how to use it. However, he decides whether to propose using data conferencing based on his understanding of the person's capabilities. If he feels they are not computer savvy, he will not introduce the technology to them.

At his worksite in greater Seattle, Dan heard someone talk about data conferencing technology. He searched for and found it on the company's web pages. Dan is an early adopter, having used it for over a year and a half. He was motivated to use it by the fact that he was physically separated from the people in his workgroup, who were mostly in Huntsville, Alabama. He uses it several times a week, and he has introduced it to others for use in both ad hoc and group meetings. For example, he frequently reviews schedules with his group and management in Huntsville, and he noted that it was better for everyone to look at the same schedule using data conferencing than for everyone to have their

own file. Dan reported that the management he worked with in Huntsville had been a barrier to usage. They believed that the data conferencing service was not stable and frequently crashed, so they were reluctant to use it, and others at that site followed their lead. Management finally acquiesced to let the team use data conferencing after Dan convinced them of its stability and value. He reported having had difficulty convincing distant colleagues to use data conferencing. Further, he said that getting the computing support in Huntsville to provide resources needed for group meetings (i.e., networked computers in a conference room with projection equipment) was a very slow process.

Graham works at the computer help desk at a small site of 750 people in the southeastern U.S. that makes airplane parts for the entire company. In Graham's words, because their site is small, "every person wears 82 hats". Over two years ago Graham learned about data conferencing from a visitor from another site, which led Graham to search for it on the company web pages. Graham realized he could use data conferencing with users who contacted him for computer support. Even though a user might be in a neighboring building, Graham preferred showing someone how to use Excel from his desktop. Graham introduced it to his computing group, who at first saw no use for it but later realized its value after seeing Graham help users from his desktop. Graham introduced it to about 75 users at his site. He claims the hardest part of introducing it was directing people over the telephone to download it. He uses data conferencing to debug a number of software applications, for Web support, and even to adjust workstations. Graham feels that it was easy to introduce data conferencing to people at his site since everyone knows each other. He felt they were rarely reluctant to use it for receiving computer support.

In these four cases, users learned about data conferencing technology and were persuaded to use it for one purpose. They then introduced it to others for a new purpose. Sarah thought of using it for training with users across geographic distance. Graham thought of using it for computer support. Rather than help his customers solve their technical problems on the telephone (or by walking to their office), Graham looked at their computer screens using application sharing. New work practices emerge as a result of the technology diffusion throughout the organization.

5. DISCUSSION

We see a story in these data that begins to explain the diffusion of data conferencing technology throughout the enterprise. In contrast to mass media or face-to-face channels of communication as a means to inform others about an innovation [11], we have found that users inform others about the technology across distance. Their communication channels are primarily email, telephone, or audio-conferencing. First, we found that 54% of the current users we surveyed reported that they learned about the data conferencing technology through some sort of on-line collaboration, such as a distributed team, ad hoc collaboration, or training session. Technology diffusion was not driven by managers, as less than three percent reported that they learned about it from their manager.

Three-quarters of the users in our sample reported that they had introduced the technology to two or more others in the organization. Nearly 30% reported that they have introduced it to at least ten other people in the company and nearly a quarter said that they had introduced it to more than 20 people. Consistent with Rogers [11], early adopters have introduced the technology to more people, compared to those in later adopter categories. However, we cannot rule out the fact that this may be simply due to early adopters using the technology longer.

Users introduce it to other people across the company so that they can work together more effectively. Half the users said they introduced it to people for distributed meetings, and nearly a third introduced it to others for purposes of ad hoc collaboration. In other words, people introduce others to data conferencing to fulfill a need of being able to collaborate together.

5.1 Influencing opinions from a distance

In the innovation literature, opinion leaders informally influence other individuals to adopt an innovation [11]. In this study Dan (depicted in a scenario) acted as an opinion leader. He invested the effort to overcome negative attitudes halfway across the country. Yet Dan was apparently not unusual at Boeing, given that most users had introduced the technology to at least two others.

We were surprised by how many of our respondents had acted as opinion leaders, encouraging others to adopt this technology *across geographic distance* in order to collaborate. Eighty seven percent had introduced the technology to one or more users, and about half our respondents learned about data conferencing from people at other locations. We regard these opinion leaders as "seeds" who spread the use of the technology to others across distance.

What would motivate opinion leaders to exert the effort to get others to adopt the technology across a distance? The opinion leader was not instructed by management to do so, and did not receive any monetary incentive. One reason is that the opinion leaders were convinced of the relative advantage of data conferencing, compared to audio conferencing, which most distributed teams had been using. This advantage may be strong enough that it motivates people to invest the effort to get their distant colleagues to use it for collaboration.

In their study of a decision-support system, Biksen and Eveland [1] described how the use of an electronic meeting room spread through word-of-mouth. The authors surmise that had people spread negative opinions of the system, it would not have been used. Some users in the current study reported in the surveys and interviews that they experienced difficulties adopting data conferencing at their sites because it was shunned at those sites. Local people discouraged them from using it due to false perceptions, as in the case with Dan who had to overcome the reluctance of a distant manager who believed the technology was unstable. This example illustrates the difficulties that opinion leaders or other users have in convincing people at a distance to adopt the technology. Not only do they have difficulty convincing them of benefits via email or telephone, but they may lack local technical support and peers who can reinforce their introduction of the technology.

5.2 Organizational Conditions for Diffusion

Compatibility of data conferencing to user needs was an important factor in the diffusion. As we discussed earlier, the more compatible an innovation is with existing practices, values, and needs, the more likely it is to be adopted. Events in the organization created conditions where a data conferencing technology would provide value. The mergers in 1997 completely

changed the geographic distribution of the employees. By the second half of 1997 senior management had already begun to form distributed enterprise teams. The change in the geographic distribution of the organization, combined with the emergence of distributed teams, set the stage to make conditions ripe for a technology such as data conferencing to connect people. Thus, the organizational context created a need for collaboration, and data conferencing filled this need.

5.3 Innovation in Work Practices

Adoption of a new technology may give rise to many innovative acts involving changes in work practices and discovery of new ways of using the technology. We found that few people were using the full capability of the technology. For example, few used the collaborative drawing or note taking features of the whiteboard, sent messages during a meeting using the chat feature, or transferred files. Only 45% of our respondents reported that they used the ability to share control of an application.

However, we saw some examples of how people innovatively modify their work practices. The case of Sarah is one example. She was introduced to the technology by a neighboring colleague. She invented a use for the data conferencing, namely, to use it to watch other people's screens while she trained them or tested software. This saved her from travelling, as one of her users was located in another state. The case of Graham illustrates how a computer support person, who learned of data conferencing from a visiting employee from another company site, invented a way of using data conferencing to help his customers. Instead of a telephone consultation, he connected to their computers and debugged their applications from a distance. He also fixed control settings on their computers. In the past he sometimes would go to their office; now he can stay in his office and help them, enabling him to have more time to help more customers. Many of our survey respondents reported how they used data conferencing for ad hoc collaborations. They used it to show data to each other, ranging from spreadsheets to scientific diagrams, and claimed that it was a great benefit for their collaboration.

Work practices must change if people are using data conferencing to conduct their work. First, teammates at a distance can use it to establish common ground by sharing views of documents and data, which aids communication. Second, time saved from travelling will be spent in some other activity. These are just some of the changed work practices that we are discovering, and future research is needed to discover how widespread are these changes, and what effects might result.

5.4 The Disadvantage for Adopters at Distant Sites

Widely accepted models of technology diffusion assume that everyone has the same opportunity to adopt a technology (e.g. [11]). However, when considering the adoption of technologies for supporting distance collaboration, this assumption must be challenged. Users at distant sites in an organization have more challenges in adopting a technology compared to their colleagues at a main site. Critical factors that encourage adoption must exist at these sites. For example, in the case of data conferencing, common computing platforms must be established across the company for everyone to have an equal chance at adoption. Technical support must exist at a site to support these isolated users. In the early stages of adoption in our study, common computing platforms did not exist, and local technical support was missing at many sites. Factors such as these must also diffuse across an organization before a technology can be successfully adopted at distant locations.

Social factors are important in the adoption of innovations. Yet social factors, such as communication, cultural influences, and peer pressure, are different for remote users than for those who are at the same work site. We found that the technology diffused more quickly within the Seattle area than at many other sites. Slower diffusion at those sites implies fewer co-users, and thus less influence of people who are physically collocated. There are fewer people who are visibly using the technology successfully, and fewer people to reinforce the technology usage.

Communication about an innovation is one of the most critical influences on adoption. Potential users at a site with few users of a technology have fewer opportunities to learn about it. Our data suggest that users learned about the technology primarily from someone with whom they were already collaborating. Thus, a communication network was already in place that functioned across distance.

People are influenced by their peers to adopt an innovation, a process known as contagion [11]. Two years ago, rather than being influenced to adopt the technology by peers at their local site, users reported that local colleagues had discouraged use of data conferencing. Apparently the communication network across distance was sufficiently strong that people adopted the technology despite this earlier local discouragement.

5.5 Revisiting Barriers

Compared to our study of early adopters conducted two and a half years earlier, the nature of barriers to data conferencing adoption had changed. Only a quarter of the respondents in the current study reported experiencing any barriers to adoption. About 10% of respondents reported problems of different computing platforms and lack of local support for the technology, a large decrease from the earlier study. About the same percentage reported additional barriers of technical problems and lack of training. In contrast, two years earlier the lack of infrastructure was a major barrier to adoption at some sites. The new barriers reported in our current surveys were largely limitations of the technology and its support and less related to local conditions. One reason for these different types of barriers is that people are now in a different stage of technology adoption then they had been two years ago.

Our earlier study was conducted soon after major mergers that joined companies with somewhat different computing infrastructures. These differences diminished as the infrastructures were integrated and older computers were replaced. Management has grown increasingly supportive of technologies that support distributed teams because they recognize the benefits that virtual collocation has brought to the company. Many managers have become frequent users of data conferencing themselves, and there are few people who would discourage their colleagues from using it. More users at more sites also means that technical support is more widely available. There is now a company-wide help desk that anyone located anywhere in the enterprise can call for assistance.

6. CONCLUSION

This study was a first step in understanding the diffusion process of a collaborative technology across distance. We are still investigating factors that influence the diffusion process, e.g. a person's location, job position, willingness to collaborate, and distributed teamwork experience. Some basic questions still remain that are central to all adoption research. Why are some users willing to become opinion leaders, and even innovators, in spreading the change? What makes users perceive a technology as having a relative advantage over another? How can users be convinced to try out a technology from someone who is at a distance? We are continuing to explore these questions and others in ongoing research.

7. ACKNOWLEDGMENTS

We wish to thank John Kipper for his help.

8. REFERENCES

[1] Bikson, T. and Eveland, J. (1996). Groupware implementation: Reinvention in the sociotechnical frame. *Proceedings of CSCW'96*, New York: ACM Press, 428-437.

[2] Charters, W. W. Jr., and Pellegrin, R. S. (1972). Barriers to the innovation process: Four case studies of differentiated staffing. *Educational Agricultural Quarterly*, (9), 3-4.

[3] Grudin, J. (1988). Why CSCW applications fail: problems in the design and evaluation of organizational interfaces. *Proceedings of CSCW '88*, ACM Press, 85-93.

[4] Mark, G., Grudin, J., and Poltrock, S. (1999). Meeting at the Desktop: An empirical study of virtually collocated teams. *Proceedings of the Sixth European Conference on Computer-Supported Cooperative Work (ECSCW'99)*, Copenhagen, Kluwer, 159-178.

[5] Markus, M. L. (1987). Toward a critical mass theory of interactive media: Universal access, interdependence, and diffusion, *Communication Research*, 1987, *14*(5), 491-511.

[6] Nambisan, S. and Wang, Y-M. (2000): "Web technology adoption and knowledge barriers", *Journal of Organizational Computing and Electronic Commerce*, 10(2), 129-147.

[7] Olson, G. and Olson, J. (2000). Distance matters. *Human Computer Interaction*, vol. 15, 139-179.

[8] Orlikowski, W.J. (1992). Learning from Notes: Organizational Issues in Groupware Implementation, *Proceedings of CSCW '92*, Toronto, ACM Press, 362-369.

[9] Poltrock, S. E. and Mark, G. (forthcoming). Implementation of data conferencing in The Boeing Company In B. E. Munkvold (ed.), *Implementing Collaboration Technologies in Industry: Case Examples and Lessons Learned.*

[10] Poltrock, S. E. and Engelbeck, G. (1997). Requirements for a virtual collocation environment. *Proceedings of ACM Group '97*, Phoenix, AZ, 16-19, November, 1997. New York: ACM Press, 61-70.

[11] Rogers, E. M. (1995). *Diffusion of Innovations*, 4th ed. New York: The Free Press.

[12] Ryan, B. and Gross, N. C. (1943). The diffusion of hybrid seed corn in two Iowa communities, *Rural Sociology*, (8), 15-24.