A NATURALISTIC JOURNEY INTO THE COLLABORATORY: IN SEARCH OF UNDERSTANDING FOR PROSPECTIVE PARTICIPANTS

A DISSERTATION

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BY

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To the Associate Vice President for Research and Dean of the Graduate School:

I am submitting herewith a dissertation written by joanne twining entitled "**A Naturalistic Journey into the Collaboratory: In Search of Understanding for Prospective Participants.**" I have examined this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Library and Information Studies.

John D'Angelo, Ph.D., Major Professor

We have read this dissertation and recommend its acceptance:

Joy McGregor, Ph.D.

Don Edwards, Ph.D.

Accepted

Associate Vice President for Research
and Dean of the Graduate School

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ABSTRACT

A Naturalistic Journey into the Collaboratory: In Search of Understanding for Prospective Participants

joanne twining
December 1999

This study is a three-phase naturalistic probe of the information environment of the collaboratory and is intended to support the expansive, ecological research of others. The collaboratory is a "center without walls," or a virtually collocated, collaborative laboratory where scientists, instruments, and data come together via computer network technology without regard to geographic location. In Phase One, an objective reality of the collaboratory is constructed from the documents made accessible through the world's libraries. Taxonomy construction and quantitative and qualitative data analysis are used to investigate and prove as practiced principles the assumptions of relative equality of contribution to collaboratory research by the hard and soft sciences, and the inherent interdisciplinarity of the collaboratory environment. An emergent theory of the collaboratory as an ungendered environment is developed. Phase Two creates a subjective reality of the collaboratory based on experiential immersion in the online environment. An evaluative instrument, the CIRAL matrix of criteria for inclusion as a collaboratory, is developed and tested, and four collaboratory site visits are developed. The collaboratory is found to be an instrumentally determined social environment, with each implementation unique in its combinations of communication modes and media, and each generating unique types of data stores. Phase Three constructs an intersubjective reality of the collaboratory during an electronic Delphi among collaboratory pioneers. The Delphi determines the "rules of the road" for the collaboratory and identifies skills collaboratory pioneers value in prospective participants. Phase Three identifies cognitive dissonance between the intersubjective reality of collaboratory pioneers and Phase One's findings of relative equality of contribution to, and ungenderedness of the collaboratory environment. Size of collaboratory is explored as a determining factor in preferences for balance between formal and informal communication modes, and structured and fluid experiment planning. The three realities are intertwined to construct a holistic, synoptic survey of the collaboratory as an emergent knowledge environment in which old science is done with new tools, but from which new science has yet emerged. This dissertation and its subsequent research are published on the web at http://www.intertwining.org/dissertation

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CHAPTER ONE

Introduction to the Study

This study explores the information environment of collaboratory from three perspectives --the objective, the subjective, and the intersubjective--to create a synoptic survey in support of expansive studies of the collaboratory's larger information ecology. Information ecologies are "responsible, informed, engaged interactions among people and advanced information technologies" (Nardi and O'Day 1999, 24). The key constituents of an information ecology are people, practices, values, and technology (Nardi and O'Day 1999, 60). An information environment is the aggregate of surrounding things, conditions, or influences. This study assumes the collaboratory is an information ecology, and therefore has a discernable information environment worth investigating.

The collaboratory is a "center without walls," an online, electronic environment where scientists, instruments, and data come together via computerized networks (NRC 1993); where production and dissemination of scientific discovery will be quickened (Wulf 1988); and where the capabilities of the human intellect will be amplified (Lederberg and Uncapher 1989). The collaboratory has been a part of the information research agenda of the United

States for a decade: since 1988 when the word "collaboratory" was first coined. The Internet, or global network of networks, is, in part, a product of collaboratory-funded research. While the collaboratory uses Internet technologies, it is not the Internet, and the Internet is not it. Both are part of the larger National Information Infrastructure (NII) and the Global Information Infrastructure (GII). While all digital initiatives are ultimately intertwined, the collaboratory is a unique and distinct ecology with a unique and distinct environment. To date, no general environmental survey of the collaboratory has been undertaken. This study addresses that need.

Research Agenda

This study takes three distinct approaches to the collaboratory environment. In Phase One, an objective reality is constructed based on the documents made available through the world's libraries. In Phase Two, a subjective reality is constructed during immersion in the online environment of the collaboratory. In Phase Three, an intersubjective reality is constructed based on interaction with Collaboratory Pioneers. Together, the objective, subjective, and intersubjective approaches construct a general environmental overview of the collaboratory.

Phase One creates an objective reality by consulting the only enduring public record of the collaboratory's first decade: the publications held by the world's libraries. Two taxonomies, or quantitative classification schemes, based on collaboratory foundation documents (Wulf 1988, Lederberg and Uncapher 1989), and a third based on Haddow's (1997) types of publications, are constructed. The collaboratory literature (n=86) is analyzed and cross-analyzed by discipline, focus, type, topic, and approach of research and publications. The assumptions of relative equality of contribution to the literature reflecting development of the collaboratory, and the interdisciplinarity the collaboratory environment are explored and proved as practices principles. Phase One concludes with a synoptic analysis of a subset of Theory-Type Research publications (n=22) from which a theory of the collaboratory as an ungendered environment emerges.

Phase Two creates a subjective, experiential reality during prolonged immersion in the online environment of the collaboratory. Criteria for inclusion as a collaboratory are developed and aspects and elements of four collaboratory environments are explored and discussed. Phase Three creates an intersubjective reality of the collaboratory during an electronic Delphi among collaboratory pioneers to determine the "rules of the road" for the collaboratory and identify skills collaboratory pioneers value in prospective participants.

This environmental survey serves the progress of collaboratory science by creating a resource to aid general understanding of prospective participants. Understanding the concept of the collaboratory is important to the advance of virtual science generally, and so is of interest to higher education, libraries, business, the professions, as well as to scientists and individuals who may come to participate in this new scientific environment.

The once distinctly sequential document-based, experience-based, and colleague-based information environments converge in the collaboratory. This convergence has logical consequences for the process of collaboratory science beyond the claim that constraints of time and space will be overcome. New information environments may require new knowledge processes. Examining the environment should shed light on those processes. The relative newness of the collaboratory provides a unique opportunity to explore the convergence using the traditionally sequential objective, subjective, and intersubjective approaches.

Phase One's objective reality determines how the collaboratory is represented in the library literature. Knowledge created in Phase One should reflect what any researcher consulting the cultural record might come to know and understand about the collaboratory's first decade. Phase Two determines if the collaboratory exists as an environment as it is represented in the library literature. Knowledge created in Phase Two should reflect what any researcher experiencing the online collaboratory might come to understand. Phase Three determines the "rules of the road" for the collaboratory and identifies skills collaboratory pioneers value in prospective participants. The "rules of the road" are a previously unaddressed information need identified in the National Research Council's (1993) *National Collaboratories: Applying Information Technologies for Scientific Research*. Knowledge created in Phase Three reflects what any researcher engaged in collaboratory science with collaboratory participants might come to know and understand about working in the collaboratory.

Isolating the three distinct approaches is significant for several reasons. Understanding is a human process by which information is transformed into knowledge (Nitecki 1993). There are many philosophies to guide how knowledge is constructed (Crimshaw 1986, Wilson 1999). Traditionally, scholarly research is accomplished in a three step process: by studying the literature, as in library research; by praxis, as in the laboratory experience; and by interaction and exchange with individuals and groups, as at conferences or in the scholarly peer review process. Granted, these processes, by necessity, overlap in the traditional scholarly environment. How knowledge is created in an environment purposively constructed to simultaneously intertwine the objective, subjective, and intersubjective approaches should shed light on the new processes the collaboratory intends to facilitate.

A triangulated approach (Nitecki 1995) provides a logically balanced intellectual alternative to the more traditional dichotomous and disproving approach of the scientific method (Wilson 1999). The notion of triangulated thinking is reflected in the "see one, do one, teach one" ideal of American education and in the older Chinese wisdom:

> Tell me and I forget.
> Show me and I remember.
> Involve me and I understand.

As access to the collaboratory becomes more widely available, this study serves by providing a general introduction for prospective participants. A synoptic, environmental exploration will be useful on other fronts, as well. Historians, toolmakers, and other researchers may use this study to support inquiry into other aspects and elements of the collaboratory's larger information ecology. Librarians and information professionals may find this study useful as they enter the collaboratory environment to work. Business, economics, publishing, and the social sciences may find it useful as the concept of virtual work spreads to their less instrument-dependent environments and they become part of the intellectual stew the collaboratory intends to produce.

The cycle of traditional scholarly publishing produces a significant delay between discovery, understanding, and dissemination of findings. The collaboratory is often represented as a way to speed up, if not side step, portions of this process and hasten the research-to-shrink-wrap cycle. The delay in scholarly publishing is regularly a year, and frequently several years, by which time, particularly in the fast-paced world of technological development, publication may serve primarily as historical background rather than to practically inform ongoing research of scientists and scholars (Schrage 1991). No general investigation of the collaboratory's alleged ability to sustain and facilitate productive exchange and co-manipulation of active datasets while facilitating mutual discovery, and continuous real-time problem solving, exists. This study is a first step in that inquiry.

To an item, every scholarly account of the collaboratory is from an insider's perspective; from someone involved and vested in some aspect of the collaboratory's creation or development. There is no scholarly account of a journey into the collaboratory by someone from outside its walls. This study provides that perspective.

Phase One seeks to understand what the collaboratory says it is, and so provides a foundation from which the published account and the actual experience of the collaboratory may be evaluated. In Phase One, three taxonomies are constructed and the collaboratory literature is classified, then analyzed within and among these taxonomies. This taxono-bibliometric analysis represents a type of tacit collaboration of minds across time reached by searching, reading, and analyzing the published literature. It counts no experience of the environment, nor does it count on the bilateral exchange of ideas, or formal collaborations over time, all three of which the collaboratory, by design, intends to simultaneously foster.

Phase Two seeks to understand the technologically-enabled environment of the collaboratory, and to determine whether and to what extent the collaboratory vision has been achieved. Phase Three seeks to understand the personality and emergent culture of the collaboratory through purposive interaction with collaboratory pioneers.

Statement of the Problem

The larger agenda of this research is understanding, and the motivation is curiosity. What is the collaboratory? Does it exist? What are its elements and attributes? What is its nature? What does the collaboratory do? What can you do in a collaboratory? What is it like to participate in collaboratory activities? What types of research are being conducted in the collaboratory? For what other activities might collaboratory technologies be used? Will the collaboratory indeed change the way science is conducted? How might it change the way science is conducted? Why do scientists collaborate online?

The problem delegated to Phase One of this study is: How does the library portray the collaboratory? Does that portrayal reflect the ideals put forth in the collaboratory's foundation documents? What are the collaboratory's theoretical foundations? What does the published record of collaboratory research reveal?

The problem delegated to Phase Two of this study is: Is the collaboratory as the library portrays? Are the ideals and philosophies put forth in the literature reflected in the actual environment?

The problem delegated to Phase Three of this study is: What do collaboratory pioneers say are the "rules of the road" for the collaboratory? What skills do collaboratory pioneers value in prospective participants? What does the bilateral exchange of ideas about the collaboratory with collaboratory pioneers reveal?

Taken as a whole, these perspectives provide a general, environmental overview of the collaboratory. The process of probing the environment in search of understanding should shed light on how knowledge might be created as the objective, subjective, and intersubjective fuse online.

Paradigm of the Study

This study employs the naturalistic/constructivist paradigm (Erlandson, et al. 1993), and rests firmly on the notion that

> shared constructions, developed collaboratively by empowered individuals, are the basis for significant cross-cultural and interpersonal understandings. (xvii)

The naturalistic/constructivist paradigm assumes no single reality exists and admits ungeneralizable, context-specific subjectivity as an appropriate process of inquiry. The aim of the naturalistic paradigm is to illuminate a single, specific context and provide assumptions, principles, working hypotheses and emergent theory for the expansive research of others. Naturalistic inquiry allows methods to evolve during the course of research rather than requiring that methodologies be determined ahead of the research. Naturalistic inquiry must meet the criteria of "trustworthiness" (Erlandson, et all 1993) as defined by credibility, transferability, dependability, and confirmability (Guba 1981, Guba and Lincoln 1981, Guba and Lincoln 1989, Lincoln and Guba 1985).

Credibility is defined as the "degree of confidence in the 'truth' that the findings of a particular inquiry have for the subject with which--and context within which--the inquiry is carried out" (Erlandson, et al. 1993, 29). Credibility is achieved by strategies including prolonged engagement, persistent observation, triangulation, referential adequacy materials, peer debriefing, and member checks.

Transferability is defined as "the extent to which its findings can be applied in other contexts or with other respondents" (Erlandson, et al. 1993, 31). Transferability and generalizability are not the same thing. Generalizable findings must apply across all environments while transferability allows knowledge gained to be applied to other environments. Transferability is achieved two ways: through thick description of sufficient detail and precision that it brings the reader vicariously into the environment under investigation, and through purposive sampling governed by emerging insights and information achieved during the course of the investigation.

Dependability is defined as the extent to which, if the inquiry "were replicated with the same or similar respondents (subjects) in the same (or similar) context, its findings would be repeated" (Erlandson, et al. 1993, 33). Dependability is achieved through a "dependability audit" which includes construction and maintenance of an archive facilitating access to all documentation as well as a running account of the process of inquiry in the form of researcher logs.

Confirmability of an inquiry is defined as "the degree to which its findings are the product of the focus of its inquiry and not of the biases of the researcher" (Erlandson, et al. 1993, 34). Confirmability is achieved when constructions, assertions, and facts can be tracked to their original sources and when the logic behind their construction leads to an explicit and implicitly coherent and corroborating whole. Confirmability is achieved via a "confirmability audit" which allows external reviews to judge the conclusions, interpretations and recommendations of the inquiry. The Dependability Audit and the Confirmability Audits are facilitated by the construction of a project library using commonly available relational database, spreadsheet and word processing software, and Internet technologies.

Methodology

Phase One of this study begins with a comprehensive, electronic search of the world's libraries for documents pertinent to the collaboratory, and proceeds without further design, trusting the document retrieval set to reveal how best it might be understood. Therefore, specific methodologies emerge during, and are discussed as part of, the analysis of data. Phase Two chronicles the journey into the online environment of the collaboratory using thick description during prolonged immersion, and is also guided by discoveries made during the course of the research. Phase Three relies on an electronic permutation of the Delphi Technique (Linstone and Turoff 1975) which employs the process of iterative interrogation and reduction to consensus, stasis, or understanding among purposively selected authorities who are most likely able to answer the questions raised.

Phase One

Toward an Objective Reality of the Collaboratory

CHAPTER TWO

FOUNDATION DOCUMENTS

The philosophical, intellectual and instrumental foundations of the collaboratory are provided by three key documents. Two of these documents are examined in detail in this chapter. They provide the foundation on which Phase One's analysis rests. Three taxonomies, or quantitative classification schemes, are constructed, and the collaboratory literature (n=86) is analyzed and cross analyzed by discipline, focus, type, topic, and approach of research and publications. The assumptions, practices, and principles of the collaboratory, as put forth in its foundation documents and reflected by the library literature, are explored. The content of a subset of Theory-Type Research publications (n=22) is qualitatively analyzed and an emergent theory of the collaboratory as an ungendered, environment is put forth.

The first key document, *The National Collaboratory – A White Paper* (Wulf 1988) sets the philosophical foundation of the collaboratory and identifies the disciplines that need to contribute to, and the focus of the research needed for development of the collaboratory. The second document, *Towards a National Collaboratory: Report of an Invitational Workshop at the Rockefeller University*

March 13-15, 1989 (Lederberg and Uncapher), provides the intellectual foundation for the collaboratory. It outlines the National Science Foundation's National Collaboratory research agenda, and identifies three topics and three approaches of research needed for development of a National Collaboratory. Neither document is published, nor is either available from any lending library. Nevertheless, they are the most widely cited publications in the collaboratory literature.[1]

The Collaboratory Literature

For the purpose of this study, the collaboratory literature is defined as resources available through the intermediation of the library. The collaboratory literature includes print and electronic papers and journals, books, reports, and microfilm and microform documents, as well as electronic databases of collected documents, or document surrogates. It does not include private, uncirculated

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[1] The Wulf *White Paper* was first identified as cited in the Lederberg and Uncapher report in a footnote to one of the retrieval set documents. But, neither document was cataloged as held by any lending library in the world, nor were they indexed as available in any database. Neither was either available directly from the National Science Foundation, or from the authors. The Lederberg and Uncapher report, which contains the *White Paper* as an appendix, was eventually tracked down by an enterprising access librarian at TWU, Joe Natale, who called upon a librarian at Rockerfeller University, who gladly descended into the bowels of the library, located a dusty box of documents remaining from the 1989 workshop, and thumbed through the entire contents until she located the report, which she duplicated and delivered.

documents or correspondences, interactive online environments, or documents published and available without library intermediation, such as commercially available books not held, and documents on the World Wide Web or other parts of the public Internet. Documentary evidence is revealed during interaction with the objects or artifacts of the library during the process of library research.

The documents included in the collaboratory literature are those to which access is gained by use of the unadulterated search string "collaboratory." This study did not use truncated or wildcard derivatives of the word. The use of truncated or wildcard derivatives produces a huge field of documents that are closely related, or relevant to the concept of the collaboratory, but not pertinent to this study. Such documents are, for instance, those dealing with the act of collabora*tion*, the collabora*tive* attitude, or people who are collabora*tors*. While these and other concepts are certainly relevant to the development and use of the collaboratory generally, and will be helpful as this agenda progresses, they open a literature base beyond the intent of this study. This study focuses exclusively and sharply on the collaboratory as an information environment. The boundaries of that environment are negotiated as the study progresses.

There is also substantial preceding, succeeding, simultaneous, and derivative literature with strong relational ties to the collaboratory. Those documents are also not included in this study. Barua (1995) provides an analysis of the near meteoric development and evolution of the vocabulary, concepts, and technologies leading to the collaboratory. Access to this substantial literature may be achieved using keywords and phrases including Decision Support Systems (DSS), Computer-based Systems for Cooperative Work (CSCW), Group Support Systems (GSS), Group Decision Support Systems (GDSS), GroupWare Systems, Computer Mediated Communication (CMC), and others. Related concepts may also be accessed using the words and phrases DARPA, ARPA, NREN, World Wide Web, Internet, Digital Library, National Information Infrastructure (NII), Global Information Infrastructure (GII), and their associated concepts.

The intent of Phase One is to focus sharply and exclusively on those documents that are highly pertinent to and specifically address the collaboratory as an environment. The documentary evidence of the collaboratory begins in May 1988, when Wulf coined the word, and, for the purpose of Phase One, ends in December 1998. Pertinent documents obtained outside library research, or outside the time frame of Phase One, are addressed, when appropriate, in Phases Two and Three of this study.

Philosophical and Intellectual Foundations

The documented story of the collaboratory began in March 1989 at an invitational workshop convened by Dr. William A. Wulf, then Director of the National Science Foundation's (NSF) Directorate for Computer and Information Science and Engineering (CISE). Wulf gathered twenty-nine scientists and researchers to Rockefeller University in New York, and charged them with developing a research agenda to actualize a National Collaboratory.

Wulf developed the notion of the collaboratory in a December 20, 1988 *White Paper* for the NSF, which he presented to the conference (Wulf 1988, Appendix A in Lederberg and Uncapher 1989). Wulf footnoted in the *White Paper* that the word collaboratory was "invented to combine the words collaboration and laboratory" (2).

Much in the same way that H.G. Wells' (1938) *World Brain* visualized a "central intellectual organism" (Rayward 1999), and Vannevar Bush's (1945) *Atlantic Monthly* article visualized the memex machine and the hyperdocument environment we now recognize as the World Wide Web, Wulf's collaboratory vision promised fundamental changes in the way science is conducted. Wulf incorporated access to and remote manipulation of rare and expensive scientific instruments along with interactive human knowledge networks incorporating real-time and document-based communication of various sorts. The collaboratory is a work environment that brings geographically dispersed scientists, instruments, and data together in a simultaneously live and archived technologically-enabled environment.

The vision of the collaboratory did not wholly spring from Wulf, however (Banks 1993, Robbin 1995). Yet unnamed, the concept spawned almost simultaneously in several quarters of government and military research in the mid-1980s. Computer and information scientists working on the logistics, languages, architectures, and technicalities of what would eventually emerge as the Internet began to imagine potential uses and use-based environments distinct from, but enabled by the technology. This new science environment demanded separate recognition. Wulf named it the "National Collaboratory."

The National Collaboratory -- White Paper (Wulf 1988)

Since 1988, William A. Wulf has been the AT&T Professor of Engineering and Applied Science at the University of Virginia. Wulf concentrates on undergraduate computer science education, research on computer architecture and computer security, and assisting humanities scholars in the exploitation of information technology. From 1988 to 1990, Wulf served as an Assistant Director of the National Science Foundation, specifically as the Director of the NSF Directorate for Computer and Information Science and Engineering (CISE).

In May 1998 he wrote his widely-cited but still largely unavailable *White Paper*. It was not published nor made publicly available.

In March 1989, Wulf convened a select group of twenty-nine researchers and scientists for an invitational workshop at Rockefeller University, and presumably read or otherwise delivered the *White Paper's* message. The convention produced Lederberg and Uncapher's (1989) report, *Towards a National Collaboratory,* which includes the *White Paper* as Appendix A. The Lederberg and Uncapher report was also not published. Neither document is catalogued as held by any lending library in the world, nor are they available from the National Science Foundation, or from the authors. Because the *White Paper's* "center without walls" quote is perhaps the most frequently repeated and often miscited passage within the collaboratory literature, and because neither of the documents was ever published, an in-depth look at both of them is warranted.

The Wulf's *White Paper* is a two-page, single-spaced document with two sections: "Background" and "The Proposal." In the Background section, Wulf contends that

> The health of the United States, economically and militarily, depends on technology... [which] ...depends on the number, quality, and productivity of the nation's research scientists and engineers... [which] ...depends on such things as adequate facilities, stimulating colleagues, and the open exchange of ideas. (1)

Wulf describes the emergence of geographically situated interdisciplinary centers, institutes, and laboratories which had already produced a "disproportionate share of the advances of their respective fields" (1). He describes the coming trend in which such centers will no longer be geographically determined, but will be "freed from the constraints of distance" producing research teams for which "opportunity and choice will determine the composition, size, and duration" (1).

Wulf warns that it will no longer be necessary for such centers to share a common administrative structure. He foretold a fundamental shift in the way science is conducted. Remote interaction with instruments, colleagues, and data will not only be possible, but mandatory. Interaction with remote instruments will be necessary either because the instruments are too expensive to be widely held (space telescopes), or the environment in which they function is inhospitable to humans (deep ocean vehicles). Interaction with remote colleagues will be mandatory because the talents necessary to address interdisciplinary problems will not be collected in any one place. Remote access to data will be necessary because the data is too vast to be replicated. Finally, some of the most pressing scientific challenges facing us, such as that of the global change, are inherently distributed and exhibit all of these properties; remote interaction with instruments, colleagues, and data is essential to solving them. (1)

Wulf proposed a

> major, coordinated program of research and development leading to an electronic 'collaboratory', a 'center without walls', in which the nation's researchers can perform their research without regard to geographic location—interacting with colleagues, accessing instrumentation, sharing data and computational resources, accessing information in digital libraries. (1)

The enabling technologies, Wulf wrote, are "high speed information processing and communication" (1). By 1988, a national research network was already underway; high performance computers were becoming ubiquitous; and open system standards were making these facilities more accessible to the research community.

In a sense, the collaboratory was an inevitable outcome of these developments. However, much as a 'center' is enabled by the building that houses it but is not just the building, the collaboratory is not just interconnected computers.

> A complete infrastructure is required: software that facilitates collaboration, simulation tools that can substitute for some aspects of the traditional wet laboratory, 'smart instruments' that can be used effectively remotely and interchangeably [sic] with simulated experiments, digital libraries and software to access the information in them, accessible (usable) repositories of raw data, etc. (1)

A great deal of research still needed to be done "to exploit the enabling technologies and build this infrastructure" (2). Some of the research, Wulf said, was needed in the areas of traditional computer science and computer/communication engineering (network speed, security and integrity of communication, smart instrumentation), but some of the research was essentially social, behavioral, or economic:

> How do people collaborate, and how can we exploit technology to amplify the effectiveness of this collaboration, especially when the collaborators are not colocated? (2)

Wulf explained that while much of this research was underway, it was not coordinated and hence was not easily combined; that

> when viewed independently, aspects crucial to the total concept are not perceived to have an especially high priority. By setting ourselves a concrete goal we can focus the energies of the research community in a way that will ameliorate both of these problems. (2)

Wulf asked workshop participants to imagine the impact the collaboratory would have on the productivity of the nation's scarce human resources. He argued that while it could be said that the collaboratory "would not enable anything new—anything not now possible, albeit more slowly or at the cost of moving people..." that, "the quantitative increase in ease of collaboration will have a profound qualitative effect" (2). That qualitative effect would:

- enhance the productivity of the individual researcher by providing access to information and instrumentation now available only at prohibitive cost in both time and money.
- increase the number of nimble minds and diverse perspectives far beyond those available at the researcher's home institution.

- enable both inter- and intra-disciplinary research that simply isn't being done now because the best people to do the research are not collocated and the scale or duration of the project does not justify a megacenter and the associated relocation of people.
- increase the pool of researchers available to work on the problem. The faculty at four-year and predominately minority institutions are an essentially untapped resource. The collaboratory will permit them to be full and effective partners in research projects, and increase the quality of instruction at those schools at the same time.
- speed the transition of new ideas into industry, into products—and increase the relevance of research to social/economic goals. By making academics and advanced developers in industry a part of the same collaboratory, the same 'intellectual stew,' we can achieve both effects simultaneously and naturally.

Wulf warned that we might never know quantitatively the impact of these combined effects because

> we don't know how to define 'research productivity' quantitatively, but also because we may not know what would have happened without the collaboratory. Moreover, not every researcher will wish to collaborate remotely, nor will any one single technological 'fix' cure the myriad problems faced by the country. (2)

Nevertheless, Wulf proposed, the effects will be profound. He explained that just one of the impacts outlined, the speed of technology transfer from research idea to product, had already been shortened from the usual 15-20 years to less than four years.

So, Wulf asked, "What needs to be done?"

> For the most part we do not need to begin whole new areas of research. Rather, we need to coordinate and expand research already underway, to deploy the enabling infrastructure...to guide the establishment of national projects (such as the human genome and global-change databases) along paths that will permit them to interoperate, and, eventually, to set standards for both commercially-produced and one-of-a-kind instrumentation to be usable remotely. (2)

The first step, coordinating and expanding research underway, was to be undertaken at the Rockefeller University workshop. Wulf charged the workshop with setting the research agenda for the collaboratory, by addressing such questions as

- What are the central problems?
- What is the best mode for attacking each of them?
- How can research be coordinated?
- Who are good candidates for demonstration projects?
- How best can results be used as they emerge? (2)

Wulf concluded his *White Paper* with the recommendations that the NSF play a leadership roll implementing the agenda, but warned that the effort may become, in both size and scope, larger than any one agency can handle and will also require heavy involvement of the private sector (2).

Towards a National Collaboratory (Lederberg and Uncapher 1989)

> The goal is to build no less than a distributed intelligence, fully and seamlessly networked, with fully supported computational assistance designed to increase the pace and quality of discourse, and a broadening of the awareness of discover: in a word, a collaboratory. (Lederberg and Uncapher 1989, 3)

The report of the Invitational Workshop Wulf convened at Rockerfeller University on March 13-15, 1989, *Towards a National Collaboratory*, endorsed the concept of the collaboratory enthusiastically. It recommends a "three-fold agenda that would repeat itself in cycles of design, implementation, and testing" (8). The first cycle concerned systems architecture and integration, and would examine ways to allow people and machines to use the collaboratory's components most effectively. The second cycle would evolve tools and technologies themselves, and the third would develop user-oriented testbeds to validate both technology and organization.

Lederberg and Uncapher's 18-page report has five sections with an Introduction. The sections are:

Science and Support for Collaboration in which the concept of team science is discussed within the framework of Lederberg's "Epicycles of Scientific Discovery" model (Lederberg 1989).

Expected Impact in which the collaboratory's potential amplification of future research is discussed with particular attention paid to the impacts on:

- Global Change research underway in the NSF, NASA, United States Geological Survey (USGS), and Department of Energy (DOE);
- The Human Genome project underway at NSF, The National Institutes of Health (NIH), and DOE; and
- Parallel Processing Research underway at NSF, DARPA, NASA, and DOE.

The Functional Collaboratory – which provides a functional description of, and assumptions about, the collaboratory.

Research Agenda in which details of the three-fold approach are provided.

Conclusions and Recommendations, which details the critical factors and issues to which attention must be paid.

This study examines the Functional Collaboratory, Research Agenda, and Conclusions and Recommendations sections of the Lederberg and Uncapher report in detail.

The Functional Collaboratory

> What is a collaboratory? As we use the term here, it is the combination of technology, tools and infrastructure that allows scientists to work with remote facilities (co-laboratory) and each other (collaborat-ory) as if they were co-located and effectively interfaced. (Lederberg and Uncapher 1989, 6)

First, the authors warn, it is important to remember that scientists have always collaborated. Such collaborations include the processes of publication, co-authoring articles and attending conferences, sharing students, and working on teams at experimental facilities.

> The norm of mutual scientific criticism is an intense form of intellectual collaboration, however antagonistic it may appear. Besides its cognitive utility, criticism is also indispensable to a rational system for the allocation of resources, tenured positions, research funds, and facilities. (6)

As science becomes more multidisciplinary and requires increased access to expensive and rare resources that are impossible to duplicate, the collaboratory will allow access to this remote instrumentation, "greatly expediting such scientific research: The collaboratory will provide seamless access to colleagues, instruments, data, information, and knowledge" (6).

Lederberg and Uncapher's (1989) report provides the intellectual foundation of the collaboratory. It relies on two distinct models: The first model is Lederberg's "Epicycles of Scientific Discovery," which outlines the processes and phases that can and should be supported through the collaboratory. The second model is Mark Stefik's "The Functional Collaboratory", a flowchart that shows how each of Lederberg's research functions might be supported through the technical capabilities in the collaboratory.

For example, one critical function of scientific research, project organization and management, is examined. The functions required from a collaboratory to support coordination of action, joint design, and resource scheduling would include

> email and directories, tools to support structured discussions, a digital library with appropriate search mechanism, user education and training tools, real-time computer supported multi-media teleconferencing, a remote experiment scheduler, and so on. These capabilities are in turn supported by a number of enabling technologies, such as networks, advanced human-machine interfaces, high resolution displays, and video compression techniques. Finally, underlying the collaboratory paradigm must be an understanding of how groups work together as well as offering seamless new technologies to enhance the availability of old knowledge, permit scientists new means of accelerating the pace of discovery and support the amplification of human intellectual capability. (7)

The Research Agenda

The recommendations for a research agenda outlined in Section Four of the Lederberg and Uncapher report are based on the following assumptions:

- The underlying communications network provides a high level of minimum capability (TI communication lines with 1.544 Mbps throughput and sufficient bandwidth [T3 or 45Mbps] to support anticipated load without delay; eventually achieving 1 Gbps throughput);

- Computing systems with relatively high capability (workstations with 10 Mips processor speed, 10 Mb memory, and 1000x1000 pixel color display connected to high performance computing with processor power of gigaflops and beyond;
- Infrastructure described above is made available to users/scientists. (7)

The research agenda focuses "on developing and demonstrating the technologies required to make the National Collaboratory a reality (8). The agenda recommends a three-fold approach:

1. Systems architecture and integration aimed at the system issues that allow people and machines to effectively use various technologies that are the components of the collaboratory;
2. Evolution of the underlying technologies and tools themselves; and
3. User-oriented testbeds coupled with better theories about the process of collaboration that are required to validate both the technical approaches and the overall system components allowing understanding of the requirements on such a system and the role that the various technological components play in the overall design.

The three-fold approach is envisioned as "an iterative cycle of design, implementation, and testing" (8).

Systems Architecture

The report admits that most of the research that needs to be done to actualize the collaboratory is in the area of system architecture and integration, but it echoes Wulf that the collaboratory is more than a set of tools.

> It is a functional capability to improve scientific effectiveness by taking advantage of a broad set of resources, including but not limited to remote facilities and other scientists. Understanding the appropriate system architecture, where such architecture includes not only the underlying tools but also the people that are to use those tools, requires a dedicated effort. (8)

Available Technologies

Lederberg and Uncapher point out that there were already tools available, both from the research community and the commercial sector, on which to begin design research on the systems architecture outlined above. These tools (and their limits, and suggested areas for research) include:

Electronic Mail (which needs interoperability, graphics capability, privacy, and user support);

Electronic File Transfer, which was already well proven;

Remote Access and Control, including remote logon (in need of enhancements to assure access control and authentication for safety and security);

Shared Files (which allows the sharing of ASCII files themselves, but with limited ability to share information though such files, and in need of a higher level of functionality and standardization to include graphics and data research representations);

Database Access (ability to store and retrieve data from shared databases needs standardization);

Access Control and Authentication (security mechanisms need to be adopted and refined);

Multimedia Mail (integration of graphics, sounds, spread sheets, scanned images into text requires powerful mechanism for interoperability);

Structured Interaction Support (migration of multi-media teleconferencing, structured conversations, and information sharing from proprietary platforms to open architecture);

Simulation of Instruments (prototyping instruments through computer simulations via totally compatible hardware and software with remote debugging capabilities; after which, the distribution of simulated instruments to large number of scientists for conduct of large, simulated distributed experiments).

The recommended research agenda would investigate the integration of these tools and the development of user interfaces in a context of user feedback (with the following objectives):

Integrating Technologies

Digital Instrumentation (dedicated to theories and technologies for development of real-time control and feedback from instruments, and real-time communication concerned with remote and multi-user instrumentation, experiments with communication and control technologies, development of interfaces to address delays and scheduling, and use of human and machine agents);

Multi-media Meetings (experiments on collaboration in meetings, distributed education; economic means for providing very high-bandwidth transmissions; social experiments to study the effects of technology on interpersonal argumentation at a distance);

Digital Mail (develop ability to send a verified and trustable electronic check, linking value-added services, better addressing mechanisms, comprehensive yellow-page services, technical extensions and social issues surrounding the use of electronic mail);

Scientific Reference Service (service to provide expertise and network to answer tough questions, a "Who Knows...?" service using literature access and intelligent agents, but drawing first on the human, then on artificial intelligence);

Digital Journals and Peer Review (services for logging documents, logging comments on documents, and offering digital document retrieval; support for collaborative writing, experimentation with different modes for commentary, editing, and document exchange; social experiments to determine salient effects on the perceived qualities of number of reviews, and effects on peer group size);

Digital Library (many variations including software, video, and other "unusual forms" in a distributed electronic database; collaboration and electronic publishing; integration of services over distributed libraries; social experiments with policies, citation mechanisms, pricing, collection and distribution of royalties);

The digital library was given added attention in the report's section on integration of technologies. Of particular interest was development of techniques for discovery through digital search, including technologies for scanning and comparing strings of digital data; document storage; and content recognition capabilities through large-scale linguistic analysis or comparison. Social questions about the digital library include analysis of the ways that automated searching enable collaboration or discovery. "The digital library is likely to be the key to valuable old knowledge, and new knowledge so vital to the scientific process" (12).

Advanced Technologies

Developing the integrated capabilities outlined above, the report says, will require developing tools that did not yet exist. These underlying technologies are described as:

Hypermedia Conversion Support such as hypermedia databases to track design decisions, operational problems and corrections, and research approaches.

Intelligent Agents such as distributed processes that would act on behalf of users. The report visualized each entity in the collaboratory (scientists, instruments, databases, computer resources) having an intelligent agent between it and the network. These intelligent agents would act on behalf of the entity, negotiating with other agents, conducting searches, scheduling, etc.

Interoperable Data Description that would describe data from multiple disciplines using a common format to allow interoperable data analysis and manipulation.

Information Fusion that would allow integration of information from heterogeneous sources.

Smart Agents for the Design of Experiments to facilitate the use of multi-sensor experiments by multiple investigators.

Smart Data Gathering incorporating intelligence into the instrument that would allow "self-directed" data gathering (13).

Technology Utilization

How the emergent technology is used, and "the relationship between technologies and the way scientists do and will conduct their research" (14) is identified as a critical issue needing investigation in order to make the collaboratory a reality. Lederberg and Uncapher recommend that appropriate testbeds to understand the impact of technology be coupled with a research program into the underlying mechanisms of the collaboratory itself.

User Testbeds

Historically, many new technologies have been left dangling at the end of the research cycle waiting to be adopted by some user community or integrated into commercial projects (14). Lederberg and Uncapher suggest setting up user-oriented rapid-prototyping testbeds as partnerships between users and developers, and identified several critical attributes such testbeds must have:

- Represent a partnership between users who see the potential for the collaboratory improving their scientific research and technologists who are interested in working with such a community.
- Be of a size that is sufficient to explore the impact of the collaboratory on scientific research (which means a team of geographically dispersed users working with laboratory facilities) but small enough to be manageable as a rapid prototyping environment.
- Provisioned with adequate infrastructure (networking, workstations) so that the prototype does in fact represent future potential.

The report notes that it is important that those who are working on developing technologies be provisioned at any stage with the next stage of infrastructure so as to act as a leading edge for the technology.

Collaboration Mechanism

In order to develop tools for supporting scientific collaboration, the Lederberg and Uncapher report insists it is critical to understand the process of collaboration itself. Achieving this understanding is a multidisciplinary enterprise and will draw on a variety of existing disciplines. Some of the work will be observational (field studies, surveys, archival analysis), some will be experimental. The testbeds will be one environment for conducting this research.

It is also crucial to synthesize previous work into new theories about how collaboration and coordination occur and how technology can help (15).

Examples of Research Questions

The Lederberg and Uncapher report provides some of the questions that needed to be addressed by the National Collaboratory research agenda. Those questions include:

What are the basic processes involved in coordination?

What structures are possible for carrying out these processes?

How is collaboration among scientists different from other kinds of collaboration?

How might use of collaboration technologies affect incentive structures for the conduct of science?

Is the social science structure of science affected by intensive use of communication technology for remote collaboration and resource sharing?

To what degree is it possible to substitute capital (electronics) for scientific labor?

The Report's Conclusions and Recommendations

A number of factors and issues addressed in the conclusion of the Lederberg and Uncapher report bring firm focus to the critical elements necessary for developing the National Collaboratory:

- Importance of integration and user testbedding
- Careful selection of user testbed communities
- Community workshop to bring users and developers together
- Targeted integrated system that all works together
- Drawing on experience of other agencies/organizations

Conclusion

The foundation of the collaboratory is provided by three key documents. The first two of those documents were never published nor widely distributed, although they are widely cited, and are examined in detail in this chapter. The first document, William Wulf's *White Paper* (1988) puts forth the concept of the collaboratory, sets its philosophical foundation, and identifies the disciplines and focus of research needed to actualize the National Collaboratory. Wulf projected that the collaboratory would be an interdisciplinary endeavor requiring a relatively equal contribution from a variety of disciplines.

The second key document, Lederberg and Uncapher's (1989) *Towards a National Collaboratory*, sets the intellectual foundation of the collaboratory, outlines the National Science Foundation's National Collaboratory research agenda, and identifies the topics and approaches of research needed. Lederberg and Uncapher reflect Wulf's suggestion that the collaboratory be constructed as an interdisciplinary environment from relatively equal contribution from multiple disciplines.

Chapters Three and Four of this study constructs taxonomies, or categorical classification schemes, based on the Wulf and the Lederberg and Uncapher documents. Chapter Three also constructs a taxonomy based on Haddow's (1997) types of publication. These three taxonomies are used to guide exploration of the collaboratory literature, to conduct taxono-bibliometric analysis of the literature to determine the extent to which the assumptions of relative equality of contribution to and interdisciplinarity of the collaboratory environment are reflected in the subsequently published work of collaboratory research, and to arrive at an objective reality of the collaboratory. The third key document, the National Research Council's *National Collaboratories: Applying Information Technology for Scientific Research* (1993) is examined in Phase Two of this study.

CHAPTER THREE

DISCIPLINE, FOCUS, AND TYPE OF PUBLICATIONS

Wulf invented the word "collaboratory" "to combine the words collaboration and laboratory," (2) and to define a

> 'center without walls,' in which the nation's researchers can perform their research without regard to geographic location—interacting with colleagues, accessing instrumentation, sharing data and computational resources, accessing information in digital libraries.(1)

Wulf's (1988) *White Paper* identifies the disciplines that needed to participate in collaboratory research, and the focus that research needed to take. Chapter Three constructs a taxonomy based on Wulf's disciplines and focus, and tests if the library literature reflects the relative equality of contribution to, and interdisciplinarity of, the collaboratory environment he assumed.

The Document Retrieval Set

Eighty-seven documents containing the word "collaboratory" were retrieved during an exhaustive search of the library resources available to students and faculty through the Mary Evelyn Blagg-Huey Library at Texas Woman's University. Texas Woman's University is a Carnegie I Comprehensive Land

Grant State University. In addition to extensive book and serial holdings, the Blagg-Huey Library provides access to over a hundred proprietary electronic databases, and on-site CD-ROMs. Many of the articles retrieved were represented in several resources.

The search was difficult because there are no established journals, print or electronic, nor are there documentary portals to the collaboratory literature; therefore every resource had to be searched individually in order to achieve a comprehensive retrieval set. The search was further complicated because the word "collaboratory" is not included in any database thesaurus, nor is it a subject heading in indices. Collaboratory is not a Library of Congress Subject Heading.

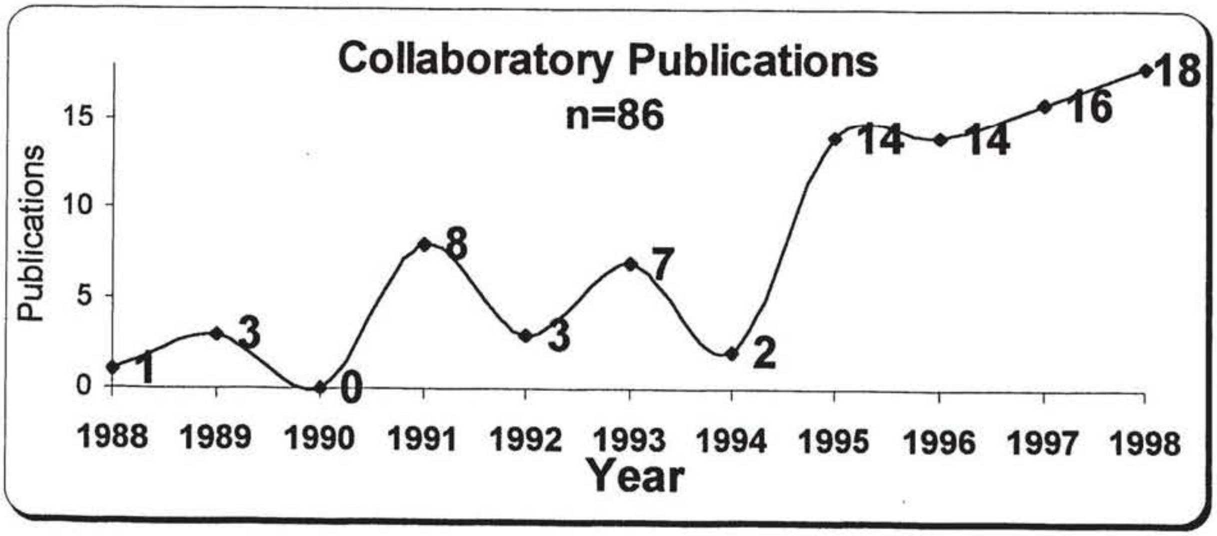
In the case of bibliographic searches, the cataloger or abstracter would have had to use the word specifically, or it would have had to appear in the title of the work in order for a record to be retrieved. In the case of fulltext search, the word could also have appeared in the body of the document. Because "collaboratory" was coined by Wulf in 1988, all the documents contained in the retrieval set were published, cataloged, and entered into the library holdings between January 1, 1988 and December 31, 1998, and thus represent the documentary evidence of the first ten years of the collaboratory. The two key documents explored in Chapter Two never appeared in the retrieval set.

The third key document, NRC's (1993) *National Collaboratories* (which is discussed in Phase Two of this study) was removed from the retrieval set for use along with Wulf, and Lederberg and Uncapher, during analysis of the remaining eighty-six documents. The eighty-six documents were indexed and abstracted into a Microsoft Access97® database. Admittedly, the document set by count forbids analysis using statistical inference. However, the retrieval set is important as it is comprehensive, and thus highly representative of the documentary evidence of the first decade of the collaboratory. The library documents are the only publicly preserved record of the collaboratory, and thus their compilation here has historical value in addition to their value to this study. The eighty-six documents are cited and annotated in Appendix A.

The proprietary databases searched included, but were not limited to, FirstSearch™, Dialog™, Ebsco™, UMI™, ERIC™, GaleNet™, Academic Abstracts™, Articles1st™, General Science Abstracts™, Dissertation Abstracts™, Social Science Abstracts™, OCLC™, and Library of Congress Catalog. The search and retrieval activity took place during weekly in-library and frequent extra-library sessions between August 1998 and December 1998, and consumed well over 100 person hours. The search and retrieval frequently relied on the advice and assistance of professional librarians, particularly for retrieval of many of the documents via Interlibrary Loan.

The retrieval set represents a document base that any serious and library-savvy researcher conducting traditional "library research" and exploiting the full capability of the library, could achieve. The retrieval set does not assume that every relevant or pertinent document was located and retrieved, but it does presume to be highly representative of the available literature and therefore a proper foundation on which to build an objective reality of the collaboratory. Figure 1 shows the number of documents by publication year of the eighty-six documents.

Figure 1. Publications by Year



Taxonomy Construction

A taxonomy is an analysis tool that facilitates identification, naming, and classification of objects. For this study, three taxonomies are constructed. Each taxonomy has two main categories. Each main category has subcategories. The taxonomies are constructed using Microsoft Excel97® spreadsheet software, with the main categories placed along the X- and Y-axes. The subcategories are placed in columns along the X-axis and rows along the Y-axis, as shown in Table 1.

		X Axis		
		X Subcategory	X Subcategory	X Subcategory
Y	Y Subcategory	Cell 1	Cell 4	Cell 7
Axis	Y Subcategory	Cell 2	Cell 5	Cell 8
	Y Subcategory	Cell 3	Cell 6	Cell 9

Table 1. Basic Taxonomy

The intersection of each column and row is a cell in the taxonomy. Each cell is assigned a distinct number. Documents are evaluated and assigned to cells according to their best fit in the X and Y categories and subcategories. Cell numbers are then used to analyze the document set. The categories and subcategories for each taxonomy are discussed in detail in the following sections.

The eighty-six documents in the retrieval set were examined individually as they were retrieved and entered into the database, then analyzed as a body three separate times, once for each taxonomy. Each document is categorized by assigning the number from the most representative cell in each taxonomy. The cell numbers were entered into corresponding fields created in the Microsoft Access97® document database. The database fields were imported into Microsoft Excel97® for statistical analysis.

The Wulf Taxonomy and Analysis

Wulf's (1989) *White Paper* identifies three discipline classes that needed to contribute to research about the collaboratory:

- Computer Science (CS)
- Computer/Communication Engineering (CCE)
- Social, Behavioral, Economics (SBE)

and three areas that needed research focus:

- Instrumentation
- Colleagues
- Data

A 3x3 taxonomy based on Wulf's disciplines and focus was drafted, and an analysis of the document retrieval set undertaken. For multiple-author publications, the discipline of the lead author was used. The discipline of the lead author was determined by information provided with the article, usually an affiliation in the byline, author biographical note, or email address. In the event the primary affiliation of the author was not determinable, the article was placed in the most logical category based on the journal of publication or topic of research.

It became quickly apparent it would be impossible to maintain precise distinction between the first two of Wulf's discipline categories, so the Computer Science and Computer/Communications Engineering categories were collapsed into a single category, CS/CCE. Two additional categories emerged during document analysis and coding, and were created. The first new category, Library Information Science (LIS) was added because of researcher preference and curiosity. The second new category, Other, was added because many of the disciplines did not fit the Wulf categories neatly. Library Information Science includes authors whose primary affiliation is either a library or information agency, library school, or an information school or department. Disciplines assigned to the Other category includes authors from government, journalism, medicine, education, chemistry, botany, physics, biology, and chemistry, among others. Abbreviations for the revised discipline categories are provided in Table 2. The eighty-six documents were categorized into the reconstructed 4x3 Wulf taxonomy without problem, and a second coding was performed to assure consistency.

CS/CCE	Computer Science, Computer Communication Engineering
SBE	Social, Behavioral, Economics
LIS	Library Information Science
Other	Government, Journalism, Physics, Medicine, and others

Table 2. Taxonomy of Disciplines

Several articles had multiple foci. The primary focus of each article was used. Articles concerned with hardware, software development, or infrastructure were placed in the "Instrumentation" category. Articles with a primary focus on humans or human groups were placed in the "Colleagues" category. Articles with a primary focus on data (acquisition, manipulation, data sharing, standards, etc.) or information (storage and retrieval, search algorithms, metalanguages) were placed in the "Data" category.

To clarify how specific articles might be categorized, a library-accessible document that reports research performed by a computer communications engineer about the development of a routing protocol that allows multiple simultaneous occupants of a singal documentary space over computer networks, and retrieved using the search string "collaboratory, " would be placed in the CS/CCE x Instrumentation cell. The cell was assigned an address of one, so that document, and all others fitting that category, would be assigned a taxonomic code of one. A paper published by a sociologist addressing the impact of that interface on successful conduct of international business communications within the collaboratory would be placed in the SBE x Colleagues cell, which is assigned the taxonomic code six.

Each document's taxonomic code was entered in the document database, then imported to a spreadsheet. Counts and subtotals were calculated. Table 3 shows the number of documents assigned to each of the cells within the discipline by focus taxonomy.

	Focus of Research			
Disciplines	Instrumentation	Colleagues	Data	Totals
CS/CCE	30	2	2	34
SBE	14	4	0	18
LIS	5	2	1	8
OTHER	18	6	2	28
Totals	67	14	5	86

Table 3. Publications by Discipline and Focus

Computer Science/Computer Communication Engineering produced thirty of the sixty-seven Instrumentation publications, the largest category. CS/CEE also produced two of the fourteen Colleagues publications, and two of the five publications concerned with Data, for a total of thirty-four publications.

Social, Behavioral, or Economics (SBE) produced eighteen publications; Library Information Science (LIS) produced eight, and Other disciplines produced twenty-eight. Figure 2 shows the percentage of publications, by discipline, and Figure 3 shows distribution within the full discipline by focus taxonomy.

Figure 2. Percentage of Publications by Discipline

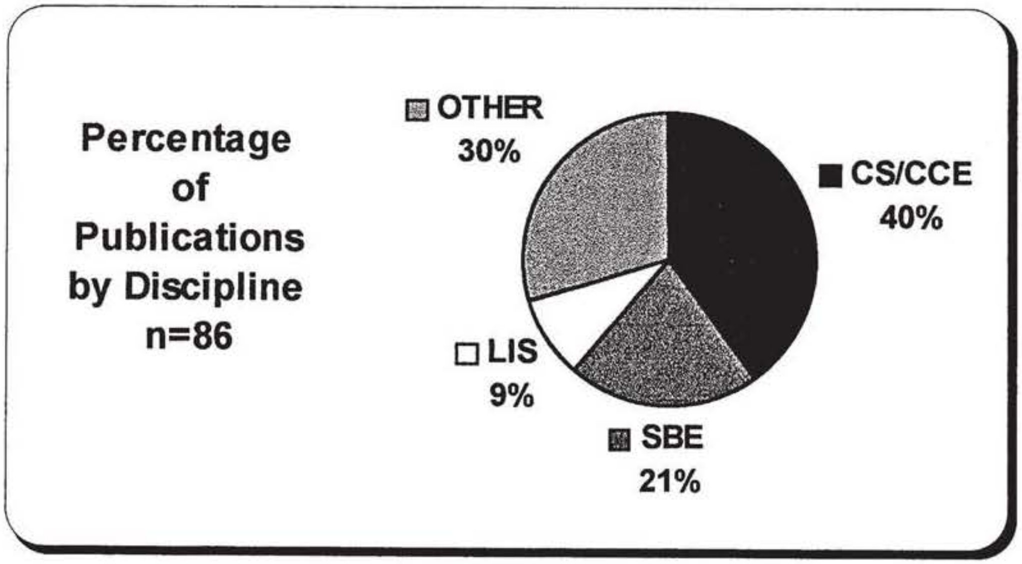
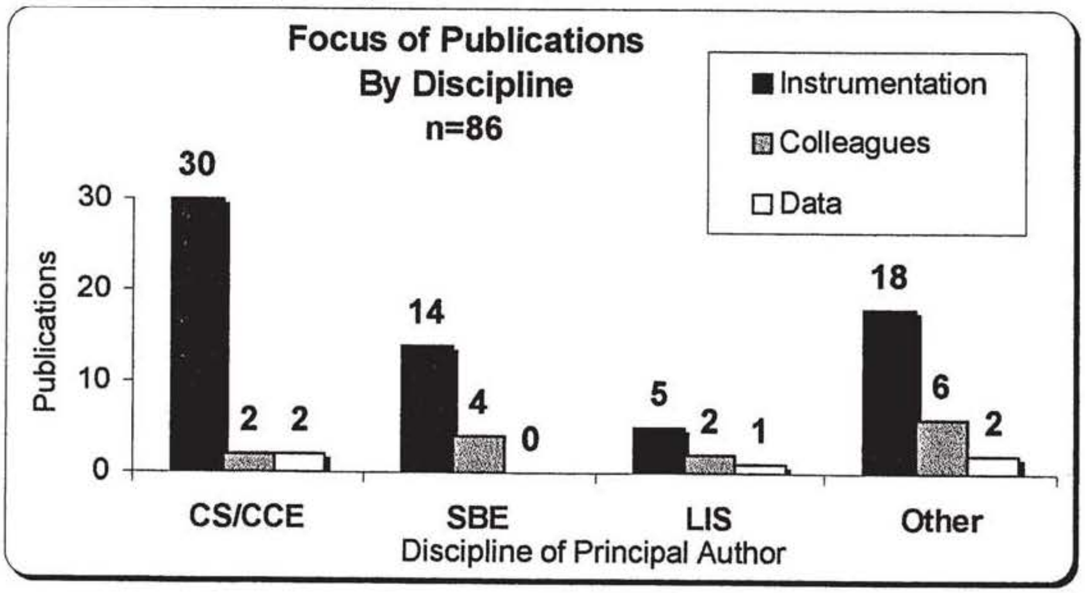


Figure 3. Publications by Discipline and Focus



The "Other" category of disciplines produced 30%, or twenty-six of the eighty-six documents, including eighteen Instrumentation documents, six Colleague documents, and two Data documents. The number and percentage of Other disciplines confirms Wulf's assumption that the collaboratory would be an inherently interdisciplinary environment constructed by multiple disciplines. Because the Other category was added during data analysis and contains a significant number of articles, a second taxonomy based on Haddow's (1997) types of publications is constructed.

The Haddow Taxonomy and Analysis

Many of the documents in the eighty-six document retrieval set were not research articles in the traditional sense. Haddow's (1997) review of the nature of journals of librarianship offers a second taxonomy into which the collaboratory articles are placed for a more exact contextual analysis.

Haddow relied on Price, and Windsor and Windsor's definition of 'scholarly' literature as hinging on the number of citations an article includes, with those publications having citations classified as scholarly, and those without citations not scholarly. She recalls Beal's description of library publications as either "glad tidings, testimony, or research," type articles, and Saracevic and Perk's further classification of "news-type articles."

For this analysis, several of Haddow's (1997) classifications were combined. Articles concerned with visions, speculations, and success stories, and which contained no or minimal citations, are placed in the "Glad Tidings and Testimony" category. Articles with substantial citations, published in scholarly journals, that develop theory or hypothesis or provide detailed analysis, development, or implementation details are placed in the "Research" category. Articles concerning announcements of funding, partnership formations, commercial implementations or software or hardware rollouts and the like, are placed in the "News-type" category. Table 4 illustrates the placement of the articles in the retrieval set within the article type taxonomy.

Type of Article	**Number of Articles**
Glad Tidings and Testimony	14
Research	22
News-Type	50
Total	86

Table 4. Publications by Type

Fifty of the articles, or 58% of the total, were placed in the News-Type category. Fourteen articles, or 16% of the total, were placed in the Glad Tidings and Testimonies category. Together, the News-Type and Glad Tidings and

Testimony categories represent 74% of the retrieval set. Figure 4 shows the number publications by type of article. Twenty-two of the eighty-six publications, or 26% of the collaboratory literature, are classified as Research. The publication types are plotted by publication year in Figure 5.

Figure 4. Article Type

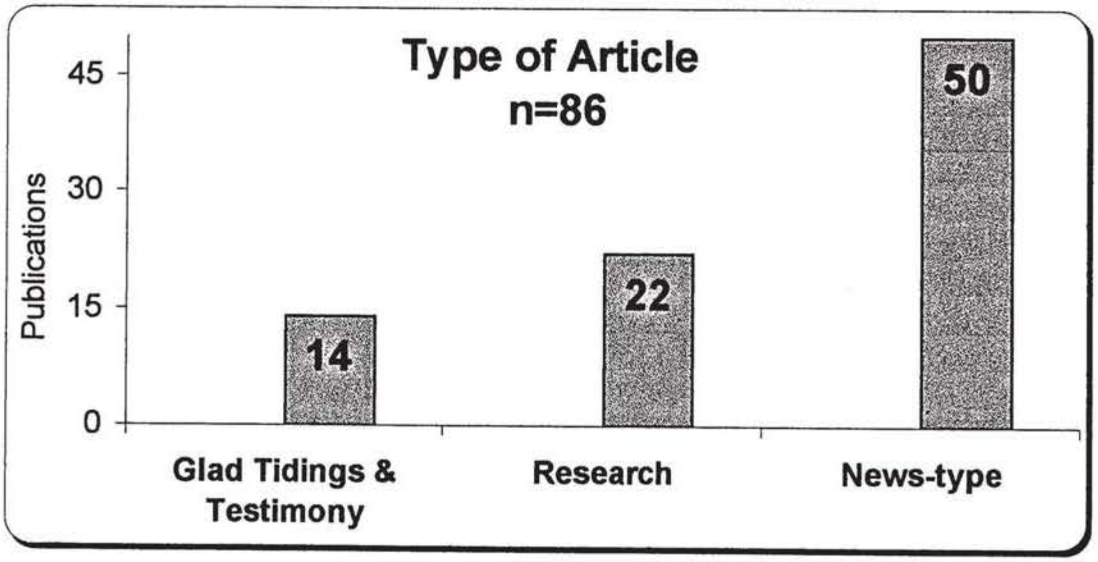
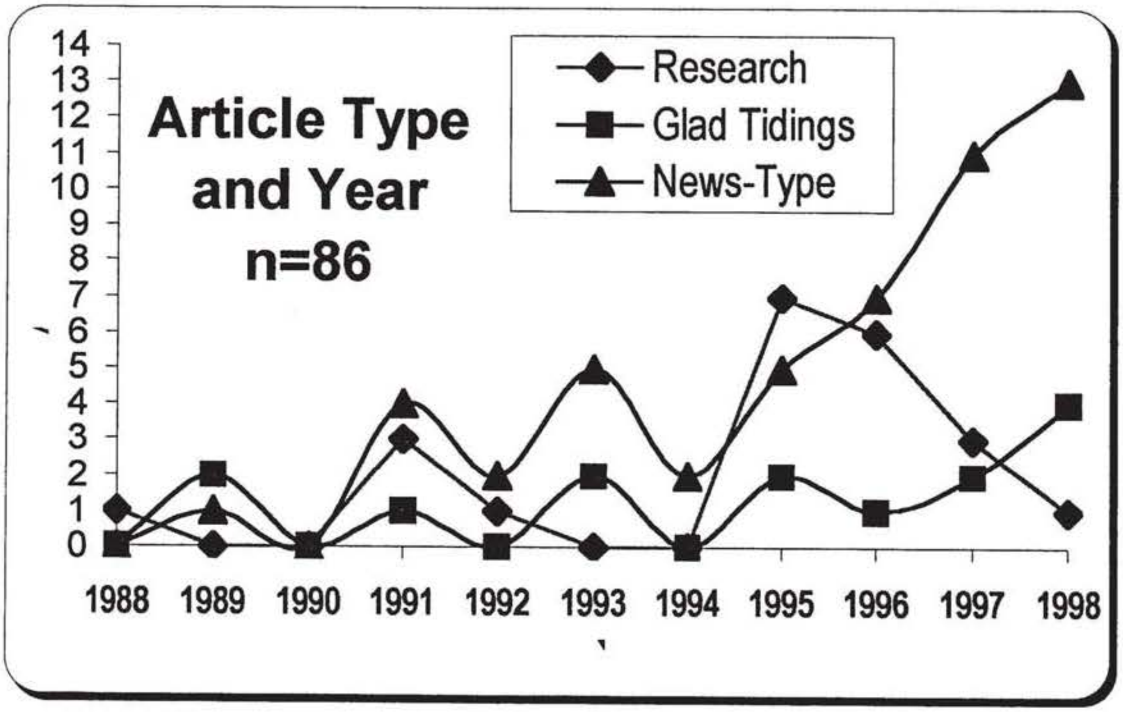


Figure 5. Article Type and Year



Two Glad Tidings articles and the collaboratory's first Research article were published in 1989, the year Wulf's *White Paper* was presented at the Rockefeller Workshop. There were no publications in 1990. The first official collaboratory-specific federal research funding was announced in 1990, and a surge of News-Type articles followed. News-Type publications dominate the collaboratory literature for the next four years, until 1995, when, for the first and only time in the ten year history of the collaboratory, more Research articles were published than any other type.

News-Type publications began four consecutive years of increased frequency in 1994, reaching a high of thirteen News-Type articles in 1998, a year that also saw the most number of Glad Tidings and Testimony articles. Quantitatively speaking, the seven research articles published in 1995 mark the research high-point of the decade. The year 1995 also marks the beginning of an overall upswing in the total number of publications, with a peak 20 articles published in 1998, the last year included in this study.

Figure 5 draws attention to three two-year "waves" in publications: 1988-1990, 1990-1992, and 1992-1994. These waves roughly correlate with announcements of funding for collaboratory research. These early indicators of trends, waves, and possible correlation in the types of articles indicates a potential research agenda interested in analyzing media effects, or publication affects in relation to federal funding, or by other aspects of mass media, mass communication, or political science theories.

Wulf noted in his *White Paper* that the research leading to the collaboratory is uncoordinated. So are the federal government's funding documents related to collaboratory research. Full fiscal documents could not be retrieved during the five-month data gathering period of this study because, like the research documents, they are buried here and there in the volumes of data, and use an uncoordinated vocabulary with undeveloped access portals. For example, of the forty-one NSF projects funded in the 1998 Knowledge and Distributed Intelligence Initiative (KDI), a $350 million, seven-year research program intended to specifically advance research about the collaboratory, only one funded proposal uses the word "collaboratory" in its title.[2] A fulltext fielded search of the abstracts of the NSF funded research database for keyword "collaboratory" produces seventeen funded projects, dating from 1990, including the one described above.[3]

Descriptive Statistical Analysis

Figure 6 shows a moderately strong positive linear trend ($R^2 = 0.7533$) in the number of collaboratory publications over time. Granted, the dataset is too small for rigorous inference. Nevertheless, it is clear that the concept of the collaboratory, as reflected by a decade of representative literature, has sustained positive interest.

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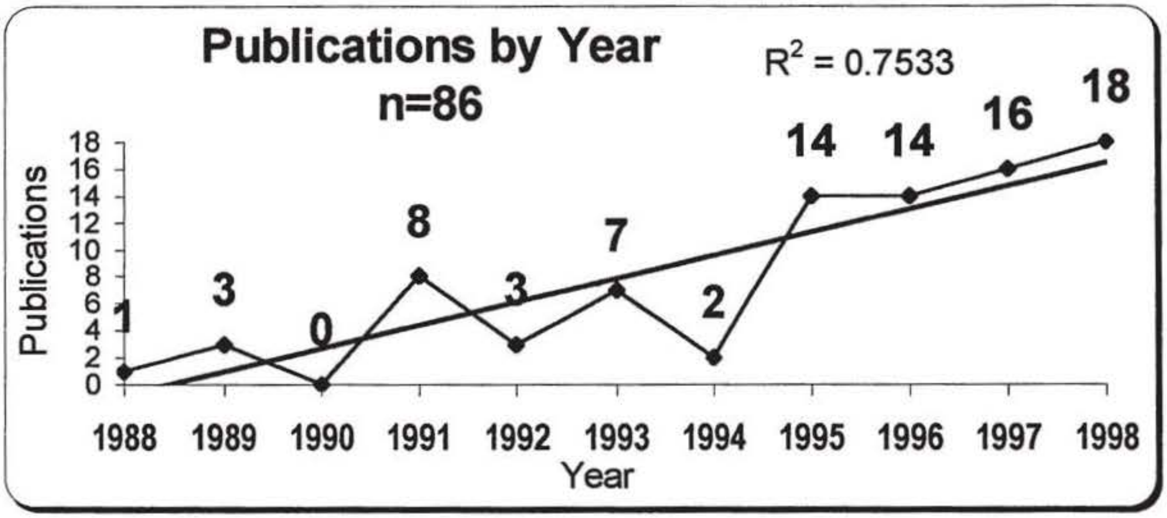
[2] See an html-ized version of the NSF Comma-separated-value (CSV) concantenated dataset of 1999 KDI awards at www.intertwining.org/collaboratory/1998_Awards.htm .

[3] The search page for NSF-funded research projects is at http://www.nsf.gov/verity/srchawdf.htm . The NSF's KDI webpage is at http://www.ehr.nsf.gov/kdi/

Figure 6. Trends Analysis, Publications over Time



Many of the fifty News-Type publications identified by the Articles Type taxonomy were written by or about individual collaboratory participants who are actively engaged in scholarly or scientific research, and most are clearly attempts to foster popular understanding and garner popular support for the notion of the collaboratory. Simultaneous with the rise in News-Type publications in the last half of the decade, there was a rise in Glad Tidings and Testimony publications but a decrease in the number of Research articles. An average of one Glad Tidings and Testimony article was published each year. Many of these Glad Tidings and Testimony articles were also written by or about a core group of researchers or projects, indicating a concerted public relations effort. Future analysis might include publication production by author or project, and citation and co-citation analysis to reveal the "personalities" of the collaboratory.

Discipline x Focus x Article Type Co-analysis

This section analyzes the twenty-two research-type articles identified by the Haddow Taxonomy by the disciplines and focus of the Wulf Taxonomy. Figure 7 shows the subset of research-type articles by research focus. Fifteen of the twenty-two research-type articles focus on Implementation, six focus on Colleagues, and one is about Data.

Figure 7. Focus of Research Articles

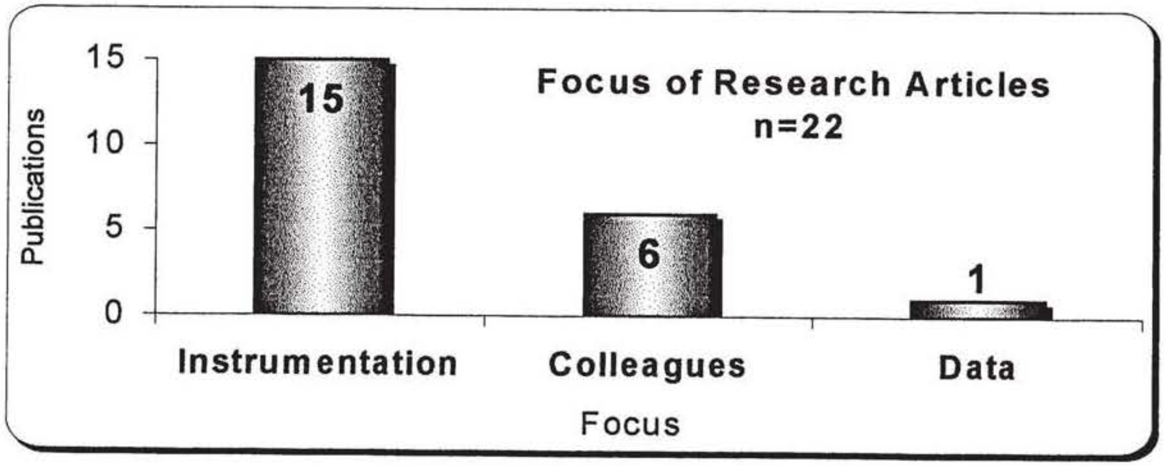
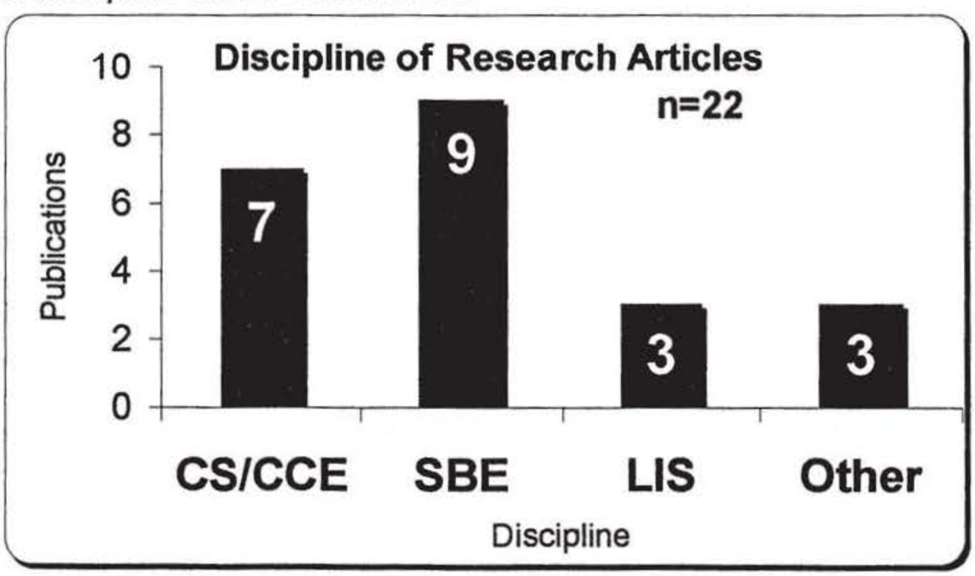


Figure 8 shows the twenty-two research-type articles by discipline of primary author. Seven of the articles, or 32%, originate from Computer Science/Computer Communication Engineering (CS/CCE). Nine of the research-type articles, the largest portion, are published by the Social, Behavioral, and Economics disciplines (SBE). Library Information Science (LIS) produced three of the twenty-two research-type articles, and Other disciplines produced three research-type articles. It is likely that at least some of the articles were co-authored by scholars from different disciplines.

Figure 8. Discipline of Research Articles



Co-author citation and co-citation analysis would add another dimension to understanding the dataset as it reflects collaboratory research between the disciplines, but, that, too, is outside the focus of this Study. Figure 9, Discipline of Research Articles, also shows that half of the eighteen articles produced by the Social, Behavioral, and Economics disciplines (revealed in Figure 3) are research-type articles and represent 41% of the total research-type publications.

Table 5 provides a numbers and percentages overview of total publications, research-type publications, and research publications as percent of total publications, by discipline. SBE produced the highest percentage (41%) of the total research publications in the collaboratory literature, but produced relatively few of the total overall publications, while CS/CCE produced the highest number (34) of overall publications but a significantly lower percentage (21%) of them are research.

Discipline	Publications	Percent of Total Publications	Research Articles	Percent of Articles that are Research	Percent of Total Research Articles	Research as Percent of Total Publications
CS/CCE	34	40%	7	21%	32%	8%
SBE	18	21%	9	50%	41%	10%
LIS	8	9%	3	38%	14%	3%
Other	26	30%	3	12%	14%	3%
Totals	**86**		**22**			

Table 5. Frequencies and Percentages of Articles by Discipline

Returning again to Figure 3, Computer Science/Computer Communications Engineering disciplines produced 40% of the total documents, thirty of which focus on Implementation, and two each on Colleagues and Data. Coanalysis with the Article Type shows that seven, or 21% of CS/CCE's articles are Research, and that they represent 32% of the total Research articles and 8% of the total collaboratory literature.

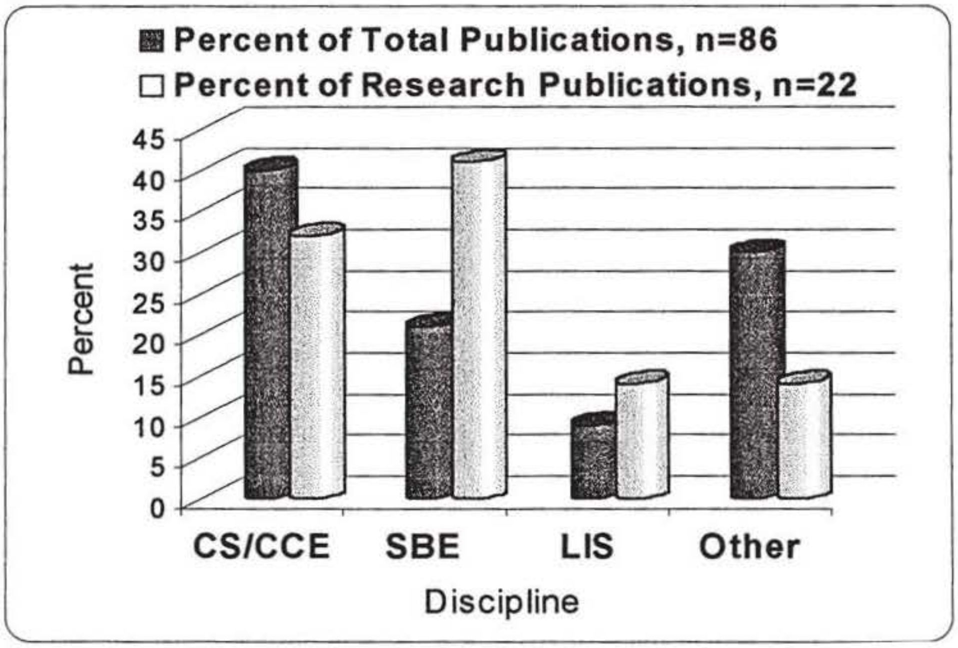
The Discipline x Focus Taxonomy revealed that "Other" disciplines produced twenty-six of the eighty-six documents in the collaboratory literature, and that eighteen of those articles are about Implementation, six are about Colleagues, and two are about Data. Coanalysis using the Article Type Taxonomy shows that three, or 12% of the "Other" disciplines' publications are Research publications, and that they represent 14% of the Research. Other disciplines contribute 3% to the total Research literature of the collaboratory.

The Discipline x Focus Taxonomy reveals that Library Information Science produced eight of the sixty-eight documents in the collaboratory literature, five of those eight publications are about Implementation, two are about Colleagues, and one is about Data. Coanalysis with the Article Type Taxonomy reveals three of LIS's eight articles, or 38%, are research-type articles and that LIS Research contributes 14% to the total research literature, and 3% to the total collaboratory literature.

This wearisome deconstruction of the collaboratory Literature exceeds Miller's (1956) "Magical Number Seven, Plus or Minus Two" limit of human information processing capacity, and forbids elegant graphing, so an alternative reconstruction is undertaken.

Figure 9 compares percent of disciplinary contributions to total publications (n=86) and percent of disciplinary contribution to research-type publications (n=22). LIS and SBE each produce proportionally higher percentages of research-type articles in their total publications than do the CS/CCE and Other disciplines.

Figure 9. Percent of Total and Research Publications by Discipline



When LIS and SBE are collapsed into the larger category of "Social Sciences," and CS/CCE and Other are collapsed into the larger category of "Hard Sciences" as in Figure 10, an inverse relation between percent of total and percent of research-type publications is more dramatically revealed.[4] The social

[4] Although the "Other" Category contains several contributions from discipliens perhaps better classified as "Social Science" than "Hard Science," such as journalism and economics, the contributions of these disciplines was minimal....only one article each. Thus, further reclassification is not deemed necessary.

sciences produced more research articles as a percentage of their total publications than did the hard sciences. However, if the percentages are converted to numbers, as in Figure 11, the data show that the hard sciences produced more overall publications than did the social sciences, but the social sciences produced a relatively equal number of articles that are research.

Figure 10. Percentage of Total and Research-Type Articles, by Discipline

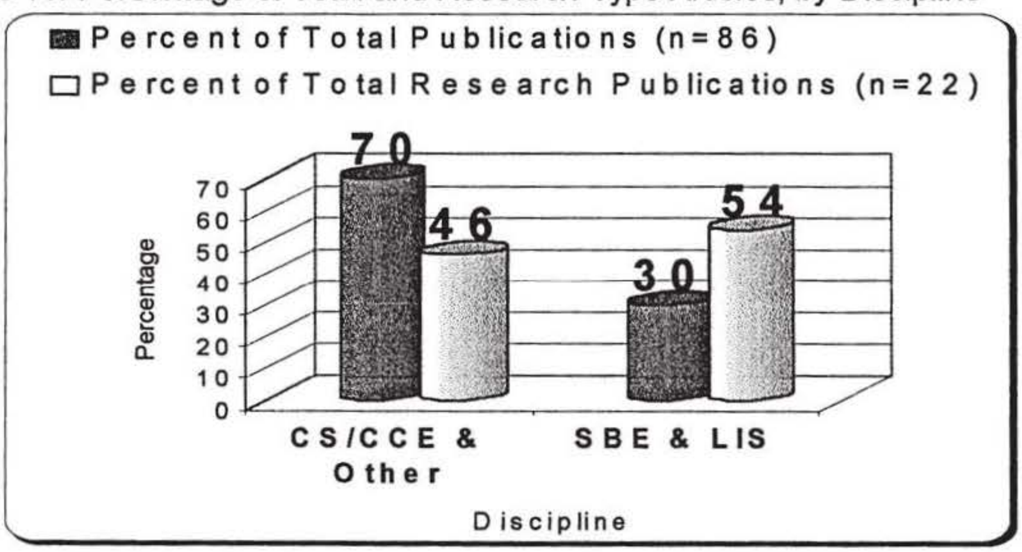
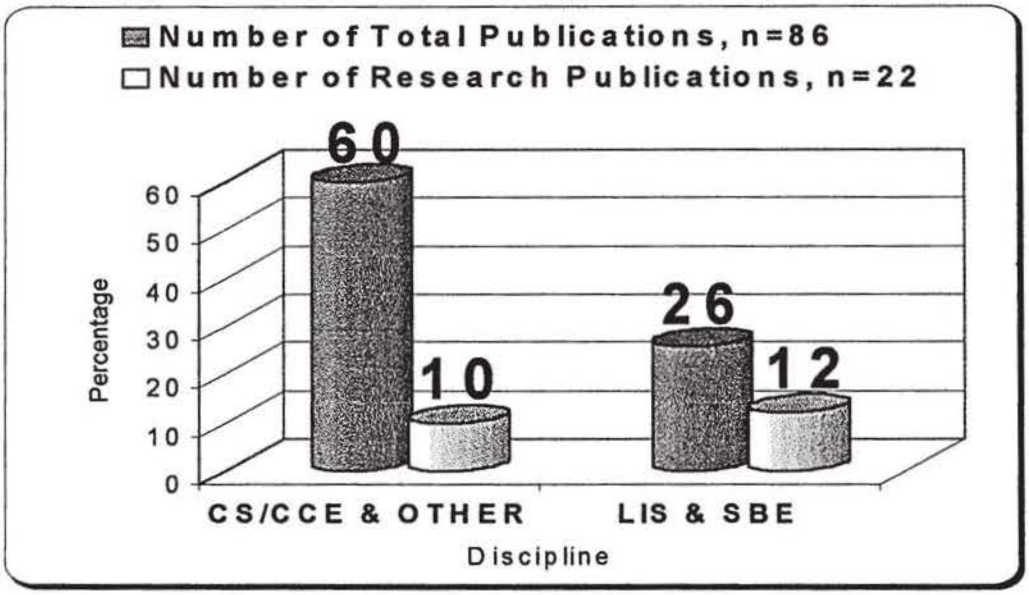


Figure 11. Number of Total and Research-Type Articles, by Discipline



Conclusion

Wulf (1988) stressed the importance of disciplinarily-balanced research and relative equality of contribution to research aimed at developing the collaboratory, and assumed that research leading to the collaboratory would reflect this balance and equality of contribution. This chapter constructed taxonomies from Wulf's *White Paper* (1988) and Haddow's (1997) document types to analyze the collaboratory literature for disciplinary contribution, research focus, and article types, and to test those assumptions.

The hard sciences and the social sciences made relatively equal, though significantly different contributions to the literature representing the first decade of the collaboratory. The hard sciences produced a higher overall number of publications, but most of them are Glad Tidings and Testimony and News-Type articles rather than Research-type. The social sciences produced significantly fewer overall publications but a greater percentage of them are Research-type publications. The number of Research-type articles produced by the hard sciences and the social sciences is relatively equal.

This relative equality in number of publications indicates that the scientific community, as a whole, has responded positively to Wulf's interdisciplinary assumption about the environment of the collaboratory. The balance between discipline, focus, and type of publications within the collaboratory literature supports the assumption of relative equality of contribution to, and interdisciplinarity of the collaboratory environment. [5]

In Chapter Four of this study, a taxonomy of research type and topic based on the Lederberg and Uncapher (1989) report is developed, and the collaboratory literature is reanalyzed and coanalyzed from a triangulated taxono-

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[5] An examination of the words interdisciplinary and multidisciplinary is warranted. In this study interdisciplinary is in reference to the environment of the collaboratory, not to the individual or collective articles used to analyze the environment.. Many, if not most, of the articles are disciplinary, in that they reflect the knowledge base and epistemology of discipline-based scholars. Together, the articles are multidisciplinary, in that they reflect contributions from many individual discplines. The environment the articles constitute, however, is interdisciplinary, in that it includes the intellectual space "between the disciplines." See Klien (1990) for a full explication of the concept of interdisciplinarity.

bibliometric perspective to further test the assumption of relative equality of contribution to, and interdisciplinarity of, the collaboratory environment. Chapter Five undertakes a qualitative, synoptic analysis of a subset of Theory-Type Research articles (n=22) to lay a foundation for development of an environmental theory of the collaboratory.

CHAPTER FOUR

TOPIC AND APPROACH OF PUBLICATIONS

In Chapter Two, William Wulf's (1988) *White Paper*, which sets the philosophical foundation of the collaboratory, and Lederberg and Uncapher's (1989) report, which sets the intellectual foundation of the collaboratory, were presented in detail. In Chapter Three, the collaboratory literature (n=86) is described and analyzed using constructed taxonomies based on Wulf's disciplines needing to contribute to, and the needed focus of research leading toward development of the collaboratory, and on Haddow's (1997) article types. Analysis of the research-type publications (n=22) by discipline and focus revealed that the social sciences and the hard sciences have made relatively equal contributions to the collaboratory's literature. This supports Wulf's assumption of relatively equal contribution to and inherent interdisciplinary of the collaboratory environment.

Chapter Four continues taxonomic analysis of the collaboratory literature by turning to Lederberg and Uncapher's (1989) *Toward a National Collaboratory: Report of an Invitational Workshop*. Lederberg and Uncapher's report identifies three research topics and three approaches of research required for development of a national collaboratory. A taxonomy based on Lederberg and Uncapher topic and approach is developed, and the collaboratory literature is reanalyzed. A triangulated analysis using the Discipline x Focus, Article Type, and Topic x Approach taxonomies explores a subset of Theory-Type Research publications (n=22). Qualitative synoptic analysis of the content of the Theory-Type Research publications is undertaken to balance the triangulated, quantitative, taxono-bibliometric analysis and explore for an emergent environmental theory of the collaboratory.

The Lederberg and Uncapher Taxonomy

The Lederberg and Uncapher's report identifies three topics that need to be researched for the collaboratory to be realized:

- Systems Architecture
- Tools and Technologies
- Uses and Testbeds

These topics correspond loosely with Wulf's foci on instrumentation, colleagues, and data. However, Lederberg and Uncapher's topics do not address data as a separate area, and Systems Architecture (networks and networking) and Tools and Technologies (computers and software) are separated into two categories while they are combined in Wulf's Instrumentation category. Also, the emerging environment of the collaboratory, the testbed, is coupled with uses and user studies, as they might be logically but are not specifically in Wulf's Colleagues category. These slight but significant differences warrant a third taxonomy for analysis of the collaboratory literature and provides an opportunity to validate the findings of relative equality of contribution and interdisciplinarity.

The Lederberg and Uncapher report also identifies three functional approaches of research that needed to be done:

- Design
- Implementation
- Testing

The philosophical approach of Wulf's *White Paper* does not address the need to research the processes of building the collaboratory, as does the Lederberg and Uncapher report with its approaches of research. The attention to more practical matters in the Lederberg and Uncapher report begins building the intellectual foundation for the collaboratory.

A 3x3 taxonomy is constructed based on Lederberg and Uncapher's research topics and approaches, and a third coding of the eighty-six-document retrieval set is performed. During analysis, the literature quickly revealed that a fourth and very distinctive approach to collaboratory research was being taken: theory research. These theory type articles did not fit comfortably into any of the

Lederberg and Uncapher research approaches. Accordingly, a new category, Theory, was added to the taxonomy and is used for classification of publications concerned with construction of general intellectual models or the development of theory intended to support Implementation, Design, and Testing work. Again, documents might logically belong in multiple categories, but each was logged only once, based on its primary topic and approach.

The leftmost column in Table 6 represents Lederberg and Uncapher's topics of research: Systems Architectures, Tools and Technologies, and Uses and Testbeds. The remaining columns represent the three approaches identified as necessary for development of the National Collaboratory: Design, Implementation, and Testing, with the fourth category, Theory, which emerged from the data, added.

As an example of coding decisions, a published document representing the development of a multimedia email interface for use in the collaboratory is categorized in the Tools and Technologies/Design cell, while a paper concerned with interpersonal communication theory in the electronic environment of the collaboratory is placed in Uses and Testbeds/Theory cell. Again, each cell was assigned a number, and the number ascribed to each document was transferred to a created field in the study database. The database records were imported into a spreadsheet for analysis and graphing.

	Approach				
Topic	DESIGN	IMPLEMENTATION	TESTING	THEORY	TOTAL
System Architecture	9	8	0	9	26
Tools and Technologies	8	11	3	4	26
Uses and Testbeds	5	12	6	11	34
TOTAL	22	31	9	24	86

Table 6. Topic and Approach of Articles

There is little difference in the number of publications within each of the topics. Number of publications by topic is graphed in Figure 12. Uses and Testbeds includes thirty-four articles, and Systems Architecture, and Tools and Technologies each include twenty-six.

Figure 13 shows that among the eighty-six documents, Implementation-type publications dominate with thirty-one articles, and the added category, Theory, contains the second largest number, twenty-four of the total. The Design-type category includes twenty-two articles, and the Testing-type includes nine. Figure 14 shows the full Topic x Approach taxonomy and reveals a relative equality in dispersion among the categories.

Figure 12. Topic of Articles

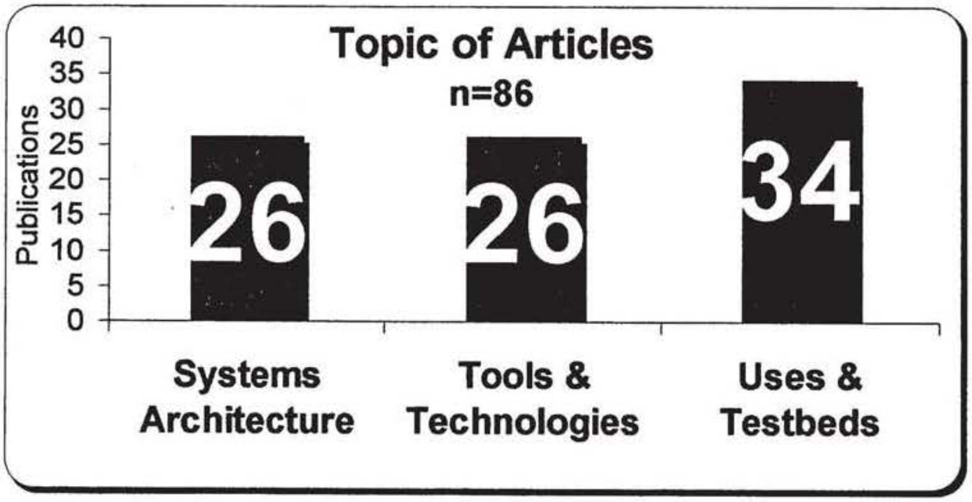


Figure 13. Approach of Articles

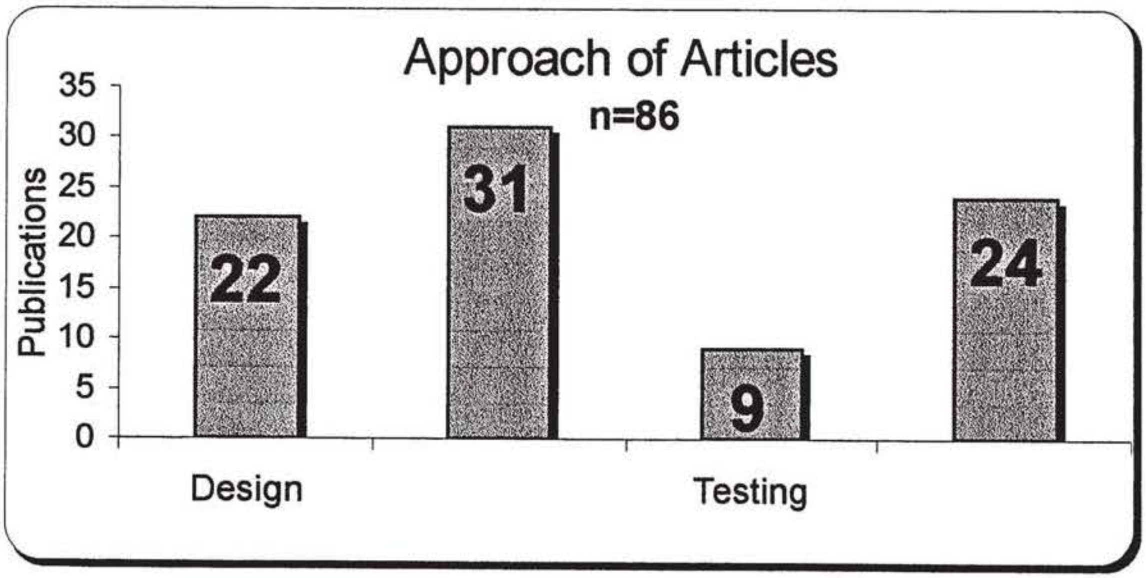
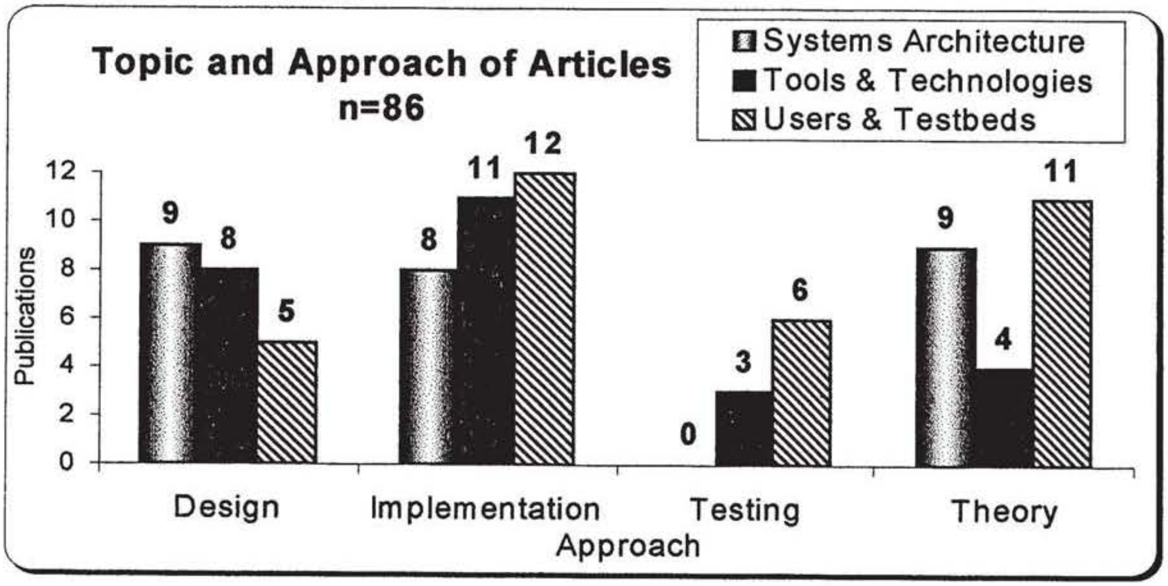


Figure 14. Topic and Approach of Articles



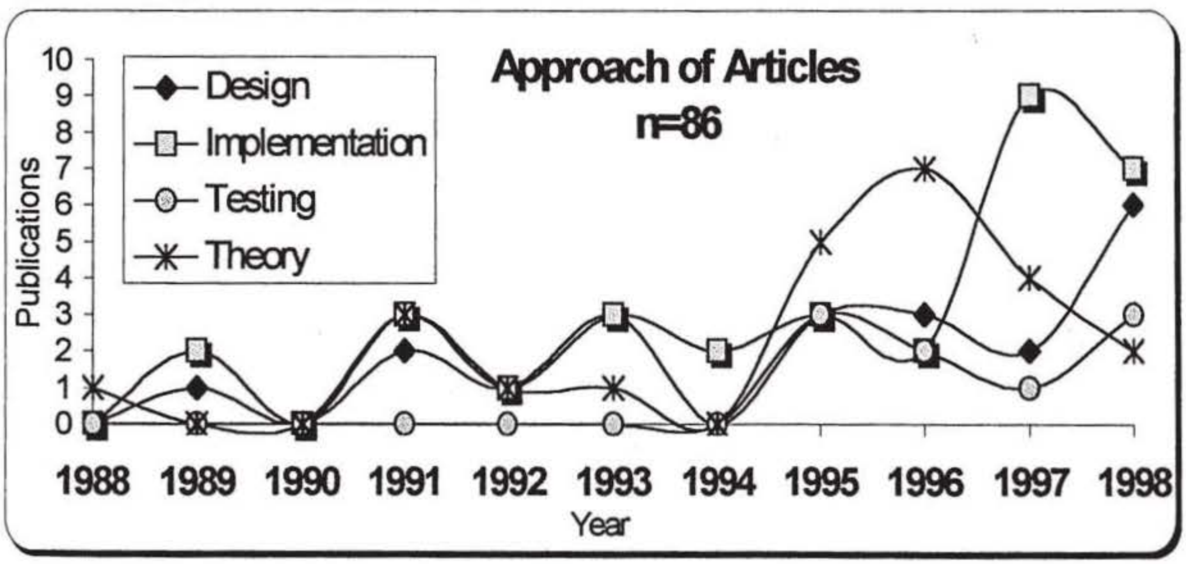
Lederberg and Uncapher's "Cycles"

The Lederberg and Uncapher report suggests that collaboratory research will take a three-fold approach (8), and that the three approaches will repeat themselves in cycles of design, implementation, and testing. To test this, the collaboratory literature was plotted using the Topic x Approach taxonomy, over time.

In Figure 15, each line represents one approach of publications plotted annually. Classic time-series data analysis requires a minimum of fifty datapoints for confidence, so the dataset does not allow the luxury of statistical inference, but early analysis hints that publication by approach does appear to be cyclical.

The widest possible view shows a slight cyclical irregularly beginning in 1994, when theory and then implementation publications make positive surges. Continued monitoring from this perspective would allow inference to such areas as predicting fruitful focus for short and mid-term research agendas, and cyclical research funding needs. Because the theory category was added during coding of the dataset, and because of the relatively high number of publications placed into it, the theory category was selected for closer analysis.

Figure 15. Approach of Articles Annually



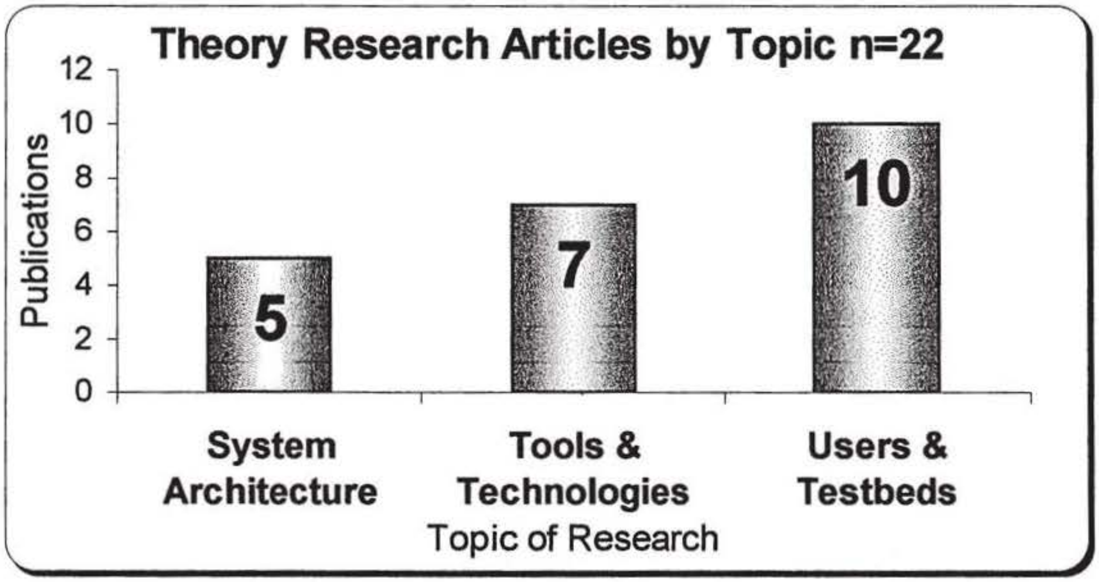
Theory-type Research Publications

The twenty-four publications identified in the Topic x Approach taxonomy's Theory category were coanalyzed with the twenty-two documents classified as Research in the Article Type taxonomy developed in the previous chapter. The Article Type taxonomy classes publications as either Glad Tidings and Testimony, Research, or News-Type. The resulting subset is Theory-Type Research publications.

One of the Theory documents not included in both sets is classed as a Glad Tidings and Testimony article because it did not develop or exercise theory, merely speculated about it, and the other is classed as a News-Type article *about* collaboratory research generally. Both are removed from the document set, which is reduced to twenty-two publications.

The subset of Theory-Type Research articles is further classified by topics of research and graphed in Figure 16. Ten of the theory-type research publications are classed in the Users and Testbeds topic category. Seven are classed in Tools and Technologies, and five are classed as System Architecture.

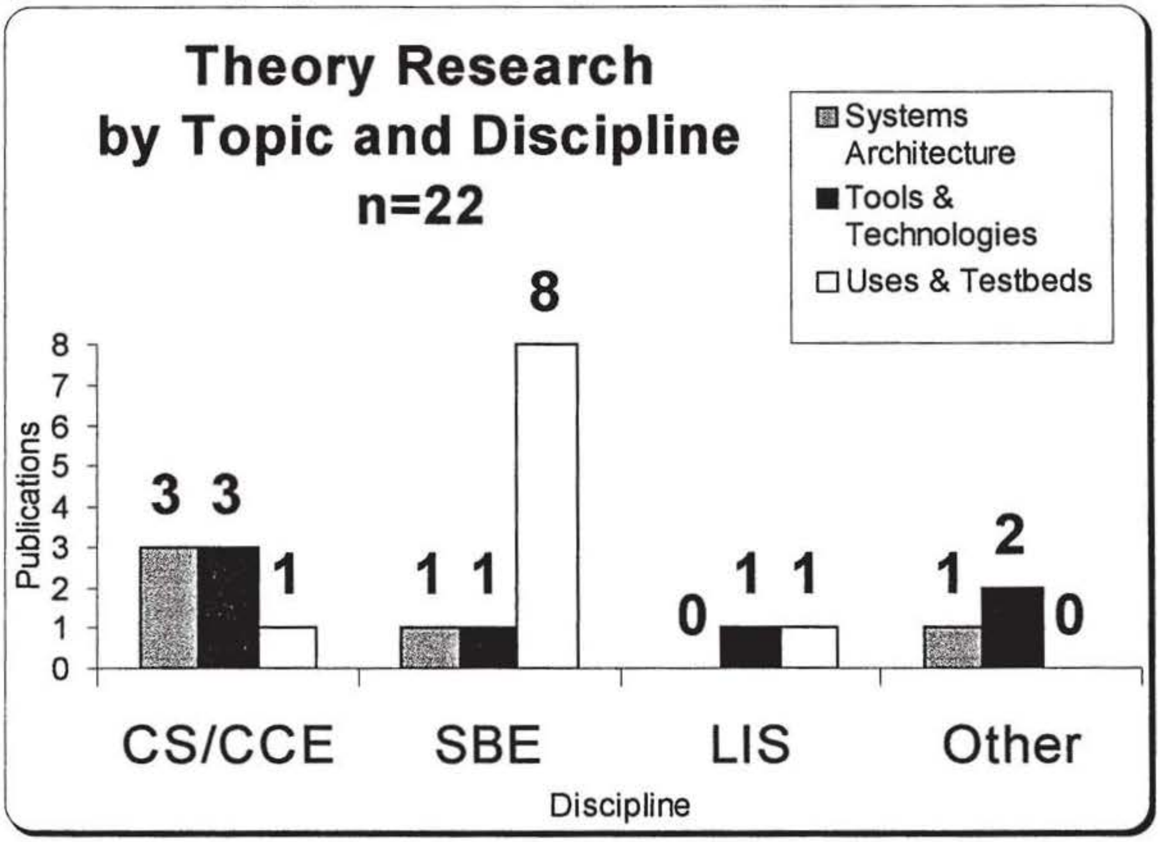
Figure 16. Theory-Type Research Articles by Topic



Theory-type Research Articles by Discipline

When the twenty-two Theory-Type Research articles are classed by discipline and plotted in Figure 17, we see that the Social, Behavioral, Economics (SBE) disciplines contribute the greater overall number as well as the greater percentage of Theory-Type Research articles, and that the Uses and Testbeds Topic produced the greatest number of Theory-Type Research articles.

Figure 17. Theory -Type Research by Topic and Discipline



Social, Behavioral, and Economics disciplines (SBE) contribute ten Theory-Type Research articles: eight about Uses and Testbeds, and one each about Systems Architecture, and Tools and Technologies. Computer Science/Computer Communications Engineering (CS/CCE) contributes seven Theory-Type Research articles: three each in Systems Architecture, and Tools and Technologies, and one in Uses and Testbeds. Library Information Science (LIS) contributes two Theory-Type Research articles: one each in Uses and

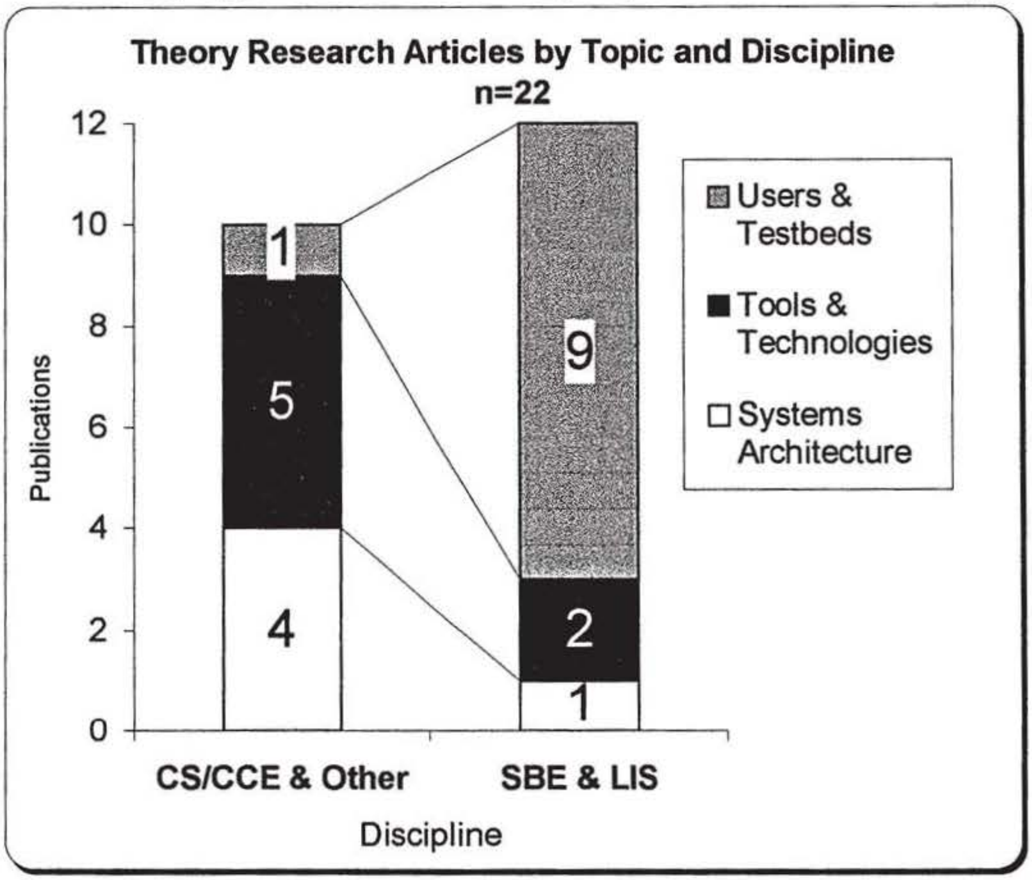
Testbeds, and Tools and Technologies, but none in Systems Architecture. Other disciplines (including physics, biology, botany, chemistry, medicine, journalism and others) contribute three Theory-Type Research articles: one in Systems Architecture, two in Tools and Technologies, and none in Users and Testbeds.

Following the precedent set in Chapter Three, reconstructing the disciplines by collapsing CS/CCE and Other into "Hard Sciences" and SBE and LIS into "Social Sciences," another subtle balance in the contributions to the collaboratory literature is revealed, and is graphed in Figure 18. While the hard sciences contribute ten and the social sciences contribute twelve Theory-Type Research articles, the topic of research reveals a complementary balance between the disciplines: between Use and Testbed, or human-oriented research, by the Social Sciences, and Systems Architecture and Tools and Technologies, or technology-oriented research by the Hard Sciences.

The hard sciences, or CS/CCE and Other, produced a greater number of Theory-Type Research articles dealing with Systems Architecture and Tools and Technologies while the social sciences, or SBE/LIS, produced an inversely proportional number of Theory-Type Research publications dealing with User and Testbeds. This finding further confirms as practiced the assumptions of relative equality of contribution to, and interdisciplinarity of, the collaboratory environment as put forth by Wulf, and Lederberg and Uncapher in their foundation documents. It also provides the foundation for a statement of an objective reality of the collaboratory: that the environment of the collaboratory, as represented by the published literature, reflects a relatively equal contribution from the disciplines (the body of articles is multidisciplinary), and that the environment of the collaboratory they constitute is inherently interdisciplinary when analyzed by one if not all of Klein's (1990) four strategies for definition of interdisciplinarity:

1. *by example*, to designate what form it assumes;
2. *by motivation*, to explain why it takes place;
3. *by principles of interaction*, to demonstrate the process of how disciplines interact; and
4. *by terminological hierarchy*, to distinguish levels of integration by using specific labels (55).

Figure 18. Theory-Type Research Articles by Topic and Combined Disciplines



Conclusion

Chapter Four examines the collaboratory literature (n=86) and the subset Theory-Type Research publications (n=22) using a taxonomy constructed from the topics and approach of research suggested by Lederberg and Uncapher (1989). Triangulated analysis with the Discipline x Focus taxonomy constructed from Wulf's *White Paper,* and the Articles Type Taxonomy constructed from Haddow's (1997) publications types in Chapter Three, confirms the relatively equal contribution in number of collaboratory research articles from the hard and soft sciences. A subtle complementarity between approach by discipline within the relative equality of total number of publications, is also revealed, with the soft sciences contributing more in the human-centered areas of research (user testbeds) and the hard sciences contributing more in the technology-centered areas of research (tools and technologies, systems architecture). Chapter Five examines the twenty-two Theory-Type Research articles qualitatively, and seeks an emergent theory of the environment of the collaboratory.

CHAPTER FIVE

TOWARD A THEORY OF THE COLLABORATORY

Chapter Two identifies the philosophical and intellectual assumptions of the relative equality of disciplinary contribution to, and interdisciplinary of, the environment of the developing collaboratory as put forth in Wulf (1988), and Lederberg and Uncapher (1989). Chapter Three verifies these assumptions as practiced, and Chapter Four confirms these practices as principles reflected in collaboratory specific publications. These findings provide the first statement of an objective reality of the collaboratory: that the collaboratory, as an information environment, is constructed from a relatively equal contribution from the disciplines, as an inherently interdisciplinary environment.

This study now turns to qualitative techniques for a deeper understanding and to explore for an emergent theory of the environment of the collaboratory. The content of the twenty-two Theory-Type Research publications identified in the previous Chapter (and cited with asterisks in Appendix A) are analyzed using constant comparative techniques in the original spirit of Grounded Theory (Glaser and Strauss 1967).

The twenty-two Theory-Type Research publications represent 26% (n=22) of the total collaboratory literature (n=86). These twenty-two articles are Theory-Type Research articles, as distinct from topic-specific but non-theoretical research articles about Systems Architecture, Tools and Technologies, or Uses and Testbeds. The Theory-Type Research articles are further distinct from the two non-research theory-type articles eliminated earlier, and from the Glad Tidings and Testimony and News-Type articles analyzed in Chapter Two.

Systems Architecture Theory-Type Research

Five of the twenty-two Theory-Type Research articles address the topic of Systems Architecture (Wilson 1991, Jaffay et al. 1992, Haga 1996, Huang 1996, Rugelj and Svigelj 1997). Multiple disciplines contribute to this class of articles (Computer Science, Knowledge Engineering, Medicine, and Psychiatry), and the articles also have an international flavor both in author and journal of publication (United States, Slovenia, Japan, United Kingdom).

Wilson (1991) takes an historical approach to explain that the collaboratory relies on two factors: underlying technologies and group process issues, but contends that these two must be considered together. Jaffay, et. al. (1992) present a conceptual construct of the process of collaboration as one of inclusion into a consistent, coherent, correct whole that is equally viable in the collective synchronous and individual asynchronous modes. Huang (1996) develops a four layer collaboration model, but contends that the collaboratory can only be grasped in its whole, that changes in one layer reverberate through all levels, and that the ability to adapt and change are of paramount importance. Haga (1996) develops a four layer generic model of collaboration based on participants' activities and (their functions within and commitment to) information flows, and maintains that individual participants and flows have a nonsymbiotic existence within the whole. Rugelj and Svigelu (1997) present a model of the collaboratory based on a medical implementation, and contend that effective communication is the key function, and the selection of instruments should be based on need of the users. The common theme among these System Architecture Theory-Type Research articles is inter- and intra-systems communication, integration, adaptability, and independence supported by individual participation within an indivisible and cohesive whole.

Tools and Technology Theory-Type Research

Seven of the twenty-two Theory-Type Research publications are about Tools and Technologies (Schooler 1991, Rice, More and D'Ambra 1995, Harper and Sellen 1995, Fox and Furmanski 1995, Karamuftuoglu 1997, Citera 1998, Ashton and Levy 1998). Schooler (1991) reviews the history and development of video teleconferencing and predicts that multimedia teleconferencing has come of age. Rice, More, and D'Ambra (1995) explore Media Richness Theory and identify choice based on situational context as a deciding criteria for the suitability of new media use. Harper and Sellen (1995) explore Media Richness in organizations, and use the cultural inertia argument to explain the lingering preference for paper, concluding that information that requires judgment in its production is less easily shared than information that does not require judgment; and that social interaction is not as crucial to the sharing of objective information as it is to sharing of interpreted information. Fox and Furmanski (1995) explore the future of the Web and conclude that the vision of the Web can only be achieved with truly open and pervasive technologies. Karmanuftuoglu (1997) argues for the semiotic approach to information storage and retrieval, and uses choice as a foundation on which to resolve the conflicting acts of detonation (description) and prescriptions (performatives) as forms of computer language for development of information systems. Citera (1998) looks at the impact of communication media on influence and decision quality, concluding that dominant personality types maintain levels of influence across media, while less dominant types gain influence when using technology for communication. Ashton and Levey (1998) explore the impact of network learner support and the new roles for service and staff with responsibility for promoting skilled use of electronic information resources, concluding that new roles based on the sharing principle are developing. The overarching concept of these seven Tools and Technologies Theory-Type Research articles is equalization in communication via media richness empowered by choice, power, openness, and sharing.

Uses and Testbed Theory-Type Research

The ten articles in the Uses and Testbeds Theory-Type Research retrieval set (Kydd and Ferry 1991, Mantovani 1995, Barua et. al. 1995, 1996-1997, Robbin 1995, Travica 1995, Mitchell and Singh 1996, Andersson and Roonnberg 1996, Glasner 1996, Swanson et. al. 1997) include all eight of the articles produced by the Social, Behavioral, and Economic (SBE) disciplines. Kydd and Ferry (1991) provide an integration of the literature of Computer Supported Cooperative Work and Media Richness Theory. They use behavioral theory to argue that information processing occurs during group work for two reasons: to reduce uncertainty, and to reduce equivocality; they contend that matching the situation with the appropriate tool is a critical implementation decision.

Mantovani (1995) explores virtual reality from the social psychology perspective as being a communication environment involving consensual hallucination, fiction and possible selves, and integrates a theoretical framework centered on self identity processes. Barua, Chellappa, and Whinston provide two of the publications (1995, 1997). The 1995 document recounts the experience of creating a collaboratory for the business environment and explores complementarity theory as a way to evaluate the value that users derive from the system. The 1997 publication recounts the design and development of an Internet and intranet-based collaboratory, analyzes the needs of three geographically dispersed electronic communities, and concludes that a shift of technology platforms from proprietary to open environments is necessary. Robbin (1995) recounts the construction of a collaboratory based on delivery of the federal government's massive *Survey of Income and Program Participation* (SIPP) database. She explores the use of distributed database software for delivery of partial information from a large dataset using internetworked technologies, and analyzes the success of the project based on the NRC (1993) *Report* (both Robbin and NRC are discussed further in Chapter Six). She concludes that focus on communication flows, the data-to-information-to-knowledge process, and alleviating administrative bottlenecks are necessary for progress. Travica (1995) explores the accounting industry for the culture of collaboration, concluding that traditional cultural propositions largely hold online, and that it is possible to create a profile of the typical collaborating professional.

Mitchell and Singh (1996) explore the survival of businesses that use collaborative relationships, and conclude that those that collaborate are less likely to shut down than businesses that follow independent approaches when the environment changes gradually, but that businesses using collaborative relationships are susceptible to takeover. They also find that businesses that collaborate and suffer sudden environmental shock in the area of the collaboration are more likely to shut down than collaborating businesses that suffer sudden environmental shock outside the area of collaboration, concluding that inter-firm collaboration is usually beneficial.

Andersson and Ronnberg (1996) find a difference among individuals who collaborate during two types of memory tasks (semantic memory tasks and episodic memory tasks). Friends as opposed to non-friends reduce the negative impact of collaboration and the "free-ride" or "hide-in-a-crowd" phenomenon frequently associated with collaboration has no impact on the success of collaborators in either type memory tasks. Glasner (1996) uses social theory based on Merton's view of science to investigate the changing culture of science based on the collaboratory, and finds that the collaboratory model has no real impact on accepted views of the culture of science. Swanson, Bailey, and Miller (1997) investigate how entropy as a measure of system disorganization occurs and is measured in physical, biological, and social systems from the perspective of exchange of money-information markers. The underlying theoretical theme among these ten articles is fair exchange, sharing, and commonality, with maintenance of strong individuality within the collective collaboratory environment.

Theory Development

Synoptic statements from the abstracted content of the twenty-two Theory-Type Research articles are:

- Integration and adaptability is necessary and good.
- Change, choice, and personal power are requisite.
- Consensus, sharing, and exchange are positive and practiced.
- Individuality and collectivity are distinctly and respectfully maintained.

Taken as a whole, these qualitative findings point first to the remarkable absence of even the most subtle trace of masculine (hierarchical or patriarchal) social behaviors, among them individualism, dominance, competition, confrontation, mastery, aggression, advantage, etc. (Crimshaw 1986). Second, they resonate with an underlying harmony antithetical to traditional scientific and technological practices.

Without mentioning gender, Wulf (1988) and Lederberg and Uncapher (1989) project that the collaboratory would be antithetical to the traditional practice of (male dominated) science. They expected competition to be replaced with cooperation. They expected individual work to be replaced by group work. They expected individual rewards to be replaced by group rewards. They expected traditional administration and control mechanism and notions of ownership to be supplanted by new, decentralized systems based on sharing. They also projected it would be difficult to convince practicing scientists to accept these new notions about how science might be done.

McLuhan (1963) warned that the "medium is the message," and that we are entering a tribally-oriented "global village," in which electric technology is an "extensions of the self," leading toward a "world soul" or universal human nervous system. Teilhard de Chardin (1975) observed that incorporation of technology is part of the natural, uninterrupted human evolution leading toward an etherized human consciousness and a unification of the nervous system. If technology is about the process of knowledge, about *how* we know, rather than the product of knowledge, or *what* we know, as it was in the mechanical age (Castells 1996), the early ideals, philosophies, and theories of the technologically-determined collaboratory suggest that these fundamental intellectual changes have been incorporated in the theoretical design of the emerging collaboratory environment.

Dorman (1998) finds that girls and boys interact with technology differently. Boys view technology as a way to extend their power and play games based on competition and contest, finding the workings of technology itself as enthralling as the uses of technology, whereas girls use technology as a way to connect with people and solve real life problems. In light of the fact that technology and science are male dominated professions (NSF 1999, Raber 1998, Clegg 1999, Weinman 1999), and the collaboratory is a male construct, this raises the question of feminism.

It is dangerous to draw dichotomous generalities about gender, and equally difficult to describe a fundamental feminism (Crimshaw 1986). Nevertheless, collaboration is a social practice at which women, generally, excel over men (Clinchy 1985, Roschelle 1992) and the collaboratory is an environment purposively constructed to foster collaboration. Certainly, engendering female attributes does not make the collaboratory feminist; that would be a sort of "this is not a duck" definition of a goose. It does, however, suggest a purposively ungendered masculine environment, which in many circles is remarkably feminist (Haraway 1985).

The qualitative statements distilled in this chapter are admittedly synoptic and preliminary, but nevertheless suggest that the collaboratory is at once protective of the individual, yet highly conducive to the collective. This reflects feminism's concern with the relationship between autonomy and dependence; between responsibilities to others and needs for self-realization or self-affirmation (Crimshaw 1986, 260). But, pending substantive ecological or sociological studies of the people, practices, and values of humans working in the functioning collaboratory, we are limited here to considering that part of the environment which is determined by technology, and specifically, how that environment is reflected in the library literature.

Perhaps the collaboratory, which is built of traditionally male tools but purposively designed to accommodate predominantly female behaviors, is a large step toward the unification of the human nervous system. Perhaps American scientists have built an ideologically utopian (Mannheim 1936) feminist environment, a sort of intellectually equalized opportunity to make new realities that reflect a holistic human way of knowing. Unlike the public Internet, which is open to all who would connect, the collaboratory is a closed environment of highly trained and educated intellectuals and visionaries, and so in many ways is protected by protocol from the overt and covert sexual exploitation and gender objectification behaviors that proliferate online. Perhaps the American scientist, by accommodating women's ways of knowing (Goldberger 1996), has in the process set himself intellectually free from the self-imposed limits of men's ways of knowing. It is too early to draw such broad conclusions, which is not the point of this study anyway. It is not, however, too early to consider the ungendered, harmonious nature of the collaboratory as informing the sociological and ecological studies that are required to sustain and advance the collaboratory.

Joining Haraway, feminist scholars Herring (1994) and Mallon (1998), among others, find fertile ground in technologically-enabled internetworked environments for the propagation of women's ways of knowing. They see great potential, but also the need for constant vigilance lest old constructs propagate unchecked in these new environments. Kelley (1963, 161) identified three conditions favorable to the formation of new constructs, including use of fresh elements (specifically setting), experimentation, and availability of validating data, all of which are available in the collaboratory. Wilson (1999) calls for a consilience or unity of knowledge between the hard and social sciences; and McLuhan projects that technological media will require replacing the traditional human classification imperative with pattern recognition behaviors. Castells (1996, 32) sees technological uptake as an evolutionary process moving from the accumulation of knowledge to the application of knowledge. Clearly, we are in the midst of great change.

As a connective, problem-solving scientific environment, the collaboratory seems remarkably hospitable to female ways of using technology. Certainly, nothing in this study so far finds the collaboratory inherently antagonistic to feminism. The collaboratory emerges from the male-dominated worlds of technology and science as an ideologically ungendered, harmonious environment built from relatively equal contributions from the disciplines, as an inherently interdisciplinary, intellectual environment. Since the "nucleus of the scientific method is the rejection of certain propositions in favor of others in strict conformity to fact-based logic" (Wilson 1999, 264), the theory that the collaboratory is a relatively equal, interdisciplinary, ungendered information environment is put forth, and this study proceeds seeking rejection of that proposition.

As the evolution of the collaboratory passes from the implementation, and tools and technologies stages, and begins to concentrate on productive human uses and designs, focus shifts to the actual (vis theoretical) environment, and to the population, or the inhabitants of the new environment, and eventually to the intersubjective "rules of the road" for the collaboratory and the skills collaboratory pioneers value in prospective participants. These last two issues are considered in Phase Three of this study. But first, a subjective, experiential understanding of the functioning collaboratory is necessary. The subjective reality presented in the Phase Two of this study is achieved through prolonged immersion in the online environment of the collaboratory. It serves not only as a synoptic introduction for prospective participants, but tests experientially the validity of the objective ideals, philosophies, and theories the library literature provides. For Phase Two of this study, the collaboratory is not only an object for the conduct of science, but an environment subject to scholarly investigation: the collaboratory becomes the scientific sample.

Conclusions

Quantitative analysis of the collaboratory literature using taxonomies constructed from Wulf (1988), Haddow (1997), and Lederberg and Uncapher (1989) confirms as practiced principles the assumptions of relative equality of contribution to, and inherent interdisciplinarity of the information environment of the collaboratory. The hard sciences and the social sciences have made relatively equal contributions to the collaboratory literature, and publication patterns as they constitute a single information environment, are inherently interdisciplinary (Klein 1990, 55). The differences in the contributions of the disciplines in topic, type, and approach of publication equalize within the numbers and percentages of total publications.

Synoptic description of twenty-two Theory-Type Research articles reveals four theoretical themes: that integration and adaptability are necessary; that change, choice, and personal power are requisite; that consensus, sharing and exchange are positive, and that individuality and commonality are maintained within the collaboratory. The overarching commonality among these four distilled theoretical themes: equality, choice, sharing, and consensus, are, by virtue of the absence of traditional male scientific philosophies, ungendered, and by their very nature, harmonious. An emergent theory of the collaboratory as a harmonious, ungendered, intellectual, information environment is put forth.

CONCLUSION OF PHASE ONE

Phase One of this study, comprised of Chapters Two through Five, constructs an objective reality of the collaboratory based on the holdings of the library. Published collaboratory research reflects the relative equality of contribution to, and inherent interdisciplinarity of, the collaboratory environment. Chapter Two explores two of the collaboratory's three key documents, neither of which was published or widely distributed, but both of which are frequently cited. Wulf's (1988) *White Paper* provides the philosophical foundation of the collaboratory and identifies the disciplines that need to participate in and the focus of needed research for the collaboratory to develop. Lederberg and Uncapher's (1989) report provides the intellectual foundation for the collaboratory and identifies the topics and approaches of research needed. The collaboratory literature (n=86) is defined as those publications made available through the intermediation of the library, retrieved using the search term "collaboratory," and accessed during skilled library research. The collaboratory literature represents only those documents highly pertinent to the collaboratory, is recognized to exclude a substantial relevant literature, and does not represent the total literature of either criterion. The literature spans the first ten years of the collaboratory (1988-1998), and is recognized of insufficient number to support rigorous statistical analysis. Therefore, taxonomic classifications and descriptive statistical techniques using counts, frequencies, trend analysis, and various coanalyses are used for taxono-bibliometric analysis of the literature.

In Chapter Three, two taxonomies are constructed and analysis of the documentary evidence of the collaboratory is undertaken. The first taxonomy is based on Wulf's (1988) research disciplines and focus, and the second on Haddow's (1997) article types. Chapter Three identifies and confirms Wulf's assumption of relative equality of contribution to, and interdisciplinarity of the collaboratory environment.

In Chapter Four, a taxonomy based on Lederberg and Uncapher's research topics and approaches is constructed and used individually, in tandem, and in triangulation with the Wulf and the Haddow taxonomies to reanalyze the collaboratory literature. Chapter Four confirms as practiced principles the assumptions of relative equality of contribution to, and inherent interdisciplinarity of, the collaboratory environment, and identifies twenty-two Theory-Type Research articles for closer analysis.

Chapter Five relies on synoptic description to probe the twenty-two Theory-Type Research articles for an emergent theory of the collaboratory environment. Common themes of interdependence, sharing, fair and equal exchange, openness, and preservation of the individual within the collaboratory environment are identified, and a theory that the collaboratory is an harmonious, ungendered, intellectual information environment is put forth.

Phase Two of this study creates a subjective reality of the collaboratory during prolonged immersion in the online environment, develops criteria for inclusion as a collaboratory, and presents four descriptive studies. Phase Three creates an intersubjective reality of the collaboratory via a Delphi among collaboratory pioneers to determine the "rules of the road" for the collaboratory and identify skills collaboratory pioneers value in prospective participants. The study concludes with a philosophical intertwining of the objective, subjective, and intersubjective realities of the collaboratory and suggests areas of additional research.

Phase Two

Toward A Subjective Reality Of The Collaboratory

CHAPTER SIX

CRITERIA FOR INCLUSION AS COLLABORATORY

Phase One of this study constructs an objective reality of the collaboratory based on a taxono-bibliometric analysis publications made available through the world's libraries. The assumptions of relative equality of contribution to, and inherent interdisciplinarity of, the collaboratory environment are proved as practiced principles, and an emergent theory of the collaboratory as an harmonious, ungendered, intellectual information environment is put forth. Practically speaking, the collaboratory is represented as a technologically-enabled shared "mind space" (Schrage 1995) where people, ideas, instruments, and information come together to make "new ways" of knowledge. Objectively, the collaboratory *seems* to exist. But, the practical question remains: does the collaboratory exist outside the publications of its researchers, and is it as the library represents?

A distinct boundary between objective reality and subjective reality has never been successfully resolved. Haraway (1991) prefers a hybrid object/subject construct, maintaining that the two cannot be considered separately, while Wilson (1999) contends that all things, including human subjectivity, are ultimately reducible to objective physics.

Objective reality is generally understood as having an embodiment outside the mind in objects or actions that can be "seen" and therefore epistemologically proved by empirical investigation, with negation the motivation in the quest for absolute truth. Subjective reality is based on the feelings, emotions, experiences, assumptions, and considerations internal to the human mind. Subjectivity cannot be disproved, even when it is factually wrong. Objective reality is connected to things external to self, while subjectivity is internal and separate from things outside of self (Goldberger 1996).

Phase Two of this study seeks a subjective reality of the collaboratory based on immersion in the online environment. Chapter Six introduces and examines the third foundation document of the collaboratory literature, the National Research Council's (1993) *National Collaboratories: Applying Information Technologies for Scientific Research,* which sets the instrumental foundation for the collaboratory. NRC (1993) is synthesized with Robbin's (1995) evaluative criteria for collaboratory implementation, and the **CIRAL** matrix of necessary but not sufficient criteria for inclusion as a collaboratory is developed. Chapter Seven presents the collaboratory testsite experience. Chapter Eight presents three additional descriptive studies developed during immersion in the larger collaboratory environment.

National Collaboratories (NRC 1993)

On the philosophical foundation of Wulf's (1988) *White Paper,* and the intellectual foundation of the Lederberg and Uncapher (1989) report, the National Science Foundation, in December 1991, convened the Committee on a National Collaboratory and charged it with establishing a user-developer partnership to actualize the collaboratory. The Committee's task was to study and report on the need for and potential of information technology to support collaboration in the conduct of scientific research (vii). The yearlong effort included frequent face-to-face meetings and three two-day disciplinary workshops (molecular biology and specifically genome research, oceanography, and space physics). As the NRC study evolved,

> the idea of developing a single national collaboratory was replaced by the idea of developing multiple scientific collaboratories which would share network and computing resources, software, and infrastructure but would have unique features dictated by the needs of particular scientific disciplines. (viii)

The committee's motivation was to inspire tool development and leverage the efforts of computer scientists. Its goal was to "develop a more explicit partnership between scientists in general and computer scientists in particular" (1). It was recognized that science's traditional culture of competition and individuality, and the traditional system of rewards and recognition among scientists, were major impediments to achieving effective collaboration. Bottom-up motivation was recognized as an essential success factor (2). Education and research were given equal priority (3). A resolution of the perception of technology and tools development as being somehow "less than" research needed to be reached (4) in order to achieve

> an environment in which a scientist's instruments and information are virtually local, regardless of their actual locations... [and the] ...virtual presence of an individual in someone else's laboratory [can be achieved]. (2)

The 105-page *National Collaboratories* includes an Executive Summary, six sections, and four appendixes. Three of the sections focus on specific requirements for building collaboratories for genome research, oceanography, and space physics. Together, these criteria provide the generic model for the collaboratory. The final section of *National Collaboratories* focuses on the logistics for implementation of a national program.

"Building and Using Collaboratories"

Section Five of *National Collaboratories,* "Building and Using Collaboratories" distills the discipline-specific needs identified in its preceding chapters. It enumerates the basic capabilities a generic collaboratory should support, and analyzes the social, organizational, technical, and practical considerations for individuals and institutions.

There are four general classes of information-related problems and specific needs within those areas that the collaboratory must address technically for large-scale functionality to achieved:

1. Data Sharing

- Electronic libraries combining databases, literature, and software
- Easily accessible data archives
- A comprehensive system supporting retrieval of data from any and all sources, regardless of origin or location, and the ability to record logical associations between items in this federated data

2. Software Sharing

- Between on-site data and off-site software
- Between off-site data and on-site software
- Network-accessible storage of results

3. Controlling Remote Instruments

- Reliable networking with sufficient speed to support interactive responses
- Method for capturing and transmitting output
- Standardized telemetry protocols

4. Communicating with remote colleagues

- Including voice, video, text, data, images
- Synchronous and asynchronous modes. (56)

Functions between and among these information problems must be transparent (62), i.e. they must use a single set of commands. Knowledge Robots, or intelligent agents, might be developed to achieve this transparency.

Social and Institutional Factors

National Collaboratories identifies social and institutional factors relevant to the individual scientist that must be tackled:

- Motivation for participation
- Confidence and security in data
- Rewards and recognition for contributions
- Resolution between the perceived value of tools and technology construction, and research (64).

The NRC workgroup recognized that a sense of community was necessary in order to establish and sustain collaborative communication among scientists, and recommended starting with scientific communities predisposed to communication while research developed. The workgroup recognized that the costs of using computer-based collaboration technology for individual scientists include:

- Incompatibility/critical mass of tasks and people (having to switch between media)
- Economic costs
- Dependence on network and vulnerability (of data and functionality)
- Need for ongoing education and training
- Development of effective, equilateral partnerships (65).

Issues for institutions supporting collaborating scientists include:

- Providing local infrastructure support (including new administrative, control, and accountability models, and increased support for technicians and support personnel)
- Managing the results of increased interaction, including increased travel and managing shared results (68).

Structural Issues

Structural issues were the major funding concern for the collaboratory. Since no one agency is charged with infrastructure development, it is generally perceived that allocating funds implies taking money away from individual or domain-specific research grants (70). Fear of funding diversion coupled with the problems that many scientists have in collaborating in any circumstances led the NRC to recommend that collaboratory projects be selected from the bottom up,

> that is, they will be launched in response to inquiries and efforts by groups of scientists who recognize a need to collaborate and who manifest an interest in applying more and better information technology. (70)

Technological Base

The technological base for the generic model of the collaboratory includes five criteria:

- Interoperability
- Transparency
- Customizability
- Integrity
- Extensibility (28-29)

The Generic Model of the Collaboratory

Robbin (1995, 40) synthesized the collaboratory environment described in *National Collaboratories,* and constructed a generic evaluative model of the collaboratory for evaluation of her collaboratory project. The NRC-Robbins generic model includes:

- A distributed computer system
- Networked laboratory instruments and data-gathering platforms
- Tools to enable a variety of collaborative activities

- Financial and human resources for maintaining, evolving, coordinating and assisting in the use of computer-based facilities
- Digital archives and libraries that include tools for organizing, describing and managing data, including images, to enable large-scale sharing of data
- Digital libraries which include tools for organizing, describing, and managing the information derived from analysis of the data.

The CIRAL Matrix

Phase Two of this study seeks a subjective reality of the collaboratory based on immersion in the online environment. The subjective reality seeks to determine whether, and to what extent, the collaboratory actually exists, and whether the subjective experience corresponds with the objective reality determined in Phase One. To establish preliminary criteria for evaluating the existence of the collaboratory, Robbin's NRC-based generic model for evaluating the collaboratory is synthesized and reconstructed. The fundamental components of the NRC-Robbins model are: distributed **C**omputing, networked **I**nstruments and tools, support **R**esources, data **A**rchives, and digital **L**ibraries, or **CIRAL**.

The **CIRAL** matrix (rendered as Appendix B) considers the needs of expansive research into the other key constituents of the information ecology (people, practices, and values), as well as the need to explore issues and factors at both the individual and institutional levels as identified in *National Collaboratories.* But, to serve the scope of this study, that is, a synoptic exploration of the environment, the **CIRAL** matrix is used in modified form to concentrate on the presence of the five criteria for inclusion, and to answer the fundamental question: Does the collaboratory exist?

Discussion of Criteria for Inclusion

For a collaboratory to exist, the presence of computerized networks, and by necessity the resources to support them, are a given. Without computerized networks and the resources to support them, no collaboratory *could* be online and so none would exist. Several articles from the collaboratory literature offer online addresses for collaboratories. Finholt's (1997) general article in *Psychological Science* 8(1), provides a compilation of thirteen "existing collaboratories" (31), and includes most of the collaboratories that are given individual attention in or are otherwise mentioned by the remaining literature. Simple searches for the single word "collaboratory" on major World Wide Web search sites (Alta Vista, Hotbot, Excite, Yahoo, etc.) produce thousands of links to sites that call themselves "collaboratory." These preliminary results advance the assumption that computerized networks and the resources to support them exist, and that there is some manifestation of the collaboratory online.

Data archives must also exist if the **CIRAL** criteria for inclusion are met. Data archives may simply be the collection of computer files and programs that facilitate USE of the computerized networks for the collaboratory, and so are also a given if indeed an online collaboratory exists. But, data archives may be much more than a collection of enabling software, and, indeed, the archives may be of an entirely new sort of data. They may include archives of data created by collaboratory participants or instruments during the course of collaboratory activity, such as with virtual "notebook" systems that allow the logging of text, images, messages, and other digital information in central or decentralized systems available to collaboratory participants. The question of data archives raises the question of digital libraries, and the difference between them, which will be discussed later. But first, the question of remote instrumentation needs attention.

It is clear from Wulf (1988), Lederberg and Uncapher (1989) and NRC (1993) that the intended definition of remote instrumentation is a mechanical device or contrivance which serves as a tool for specific types of work, is rare or not widely held, and which may be manipulated by someone remotely located using computerized networks. It may be argued that the computer network is itself a collaboratory instrument. Thus, interactive online environments that rely on the instrument of the network (as with virtual reality systems or interactive web sites), or those that rely on the human mind (as with MUDS and MOOS, which construct text and object-based interactive online environments), may be included as collaboratories. While it is easy to imagine and exciting to argue that these online environments are at least of the same family as the collaboratory, for this study the stricter definition is adopted. Accordingly, any computerized network supported by resources that has data archives and digital library resources, but which does not include access to and the ability to manipulate remotely located instrumentation, is excluded as a collaboratory.

Likewise, any site that does not include access to and support of the digital library must be excluded. The obvious distinction between data archives and digital library is the application of librarianship, a professional activity (Abbott 1988) concerned with the intellectual work of collecting and disseminating information resources to support specific human activities or goals. Whether this service is digital, as with a webpage of relevant links, or is an intelligent agent, (a computer program that searches for, harvests, formats, and delivers relevant data), or is provided in real time by a human being, is irrelevant to this study. An exact and rigid definition of "digital library" is also not necessary since the concept is still very much in its own early evolutionary stage (Spink 1999). For the purposes of this study, however, digital library is defined as a specifically built and purposively managed collection of relevant and pertinent internal and external data and information intended to support the knowledge activities of collaboratory participants. As such, digital library resources are distinct from, but may include, data archives, which are defined as files that support the collaboratory's technological functions and/or record its activities.

Certainly, one collaboratory's data archives may be another collaboratory's digital library, so further distinction must be made. For the purpose of this study, data archives are defined as the accumulated and saved records that support the collaboratory's functional existence, and digital library resources are defined as value-added data, or information saved, accumulated, and made accessible in service to collaboratory participants.

Conclusion

Phase One's objective reality uses the library literature to prove as practiced principles Wulf's assumptions of relative equality of contribution to, and inherent interdisciplinary of, the collaboratory environment, and theorizes that the collaboratory is an harmonious, ungendered, intellectual information environment. Chapter Six begins Phase Two's subjective reality with an investigation of the collaboratory's third foundation document (NRC 1993), which sets the instrumental foundation for the collaboratory and from which an evaluative instrument, the **CIRAL** matrix for inclusion as a collaboratory, is derived (Appendix B). The necessary but not sufficient criteria for inclusion as a collaboratory are identified and discussed. Chapter Seven reports the collaboratory testsite experience, and Chapter Eight presents three descriptive studies as empirical evidence of the study's immersive phase.

CHAPTER SEVEN

INTO THE COLLABORATORY

Phase Two of this study seeks a subjective, experiential reality of the collaboratory based on a prolonged immersion in the online environment. Chapter Six discusses criteria for inclusion as a collaboratory and derives an evaluative instrument, the **CIRAL** matrix of criteria for inclusion as a collaboratory. Chapter Seven relates the experience of a prolonged immersion in a collaboratory testsite, and tests the usefulness of the **CIRAL** Matrix for guiding exploration of the larger collaboratory environment. Chapter Eight presents a series of descriptive studies and examines the media, modes, and architectures of the collaboratory.

Phase Two's immersion began in October 1998 and continued on a not-less-than-weekly basis through July 1999. In February 1998, a web search using the term "collaboratory" on the Alta Vista® search engine and index at http://www.altavista.digital.com produced 489 hits. The same search conducted in February 1999, one year later, produced 4687 hits, an almost ten-fold increase. The same search of the indices at http://www.hotbot.com, http://www.excite.com, and http://www.yahoo.com produced similar results.

The increase and differences in results can be attributed to any number of factors (including index age, search algorithm configuration, index effectiveness, index growth, or increase in sites using the word). The results are taken here only as sufficient reason to assume a collaboratory exists and that it is publicly accessible.

Five Collaboratories are referred to frequently in the library literature, and are also represented in the web search results herein described. These five Collaboratories were selected for first contact because their longevity and institutional affiliation make them likely to be fully functioning. They are:

- The Materials MicroCharacterization (MMC or M2C) Collaboratory of the U.S. National Laboratories;
- The Upper Atmospheric Research Collaboratory (UARC) at the University of Michigan;
- The Collaboratory for Research on Electronic Work (CREW), also at the University of Michigan;
- The Management Information Science (MIS) Collaboratory at the University of Texas; and
- The U.S. Department of Energy's Diesel Combustion Collaboratory (DCC).

A simple web search for the full name of each collaboratory quickly produced web portals and the email address of the most logical gatekeeper (usually the project coordinator or Principle Investigator). An email message requesting consent to enter the collaboratory for environmental dissertation research was sent to each gatekeeper. An interactive consent form was made available on the web at http://www.intertwining.org/dissertation/consent/p2consen.htm (Appendix C). M2C returned first consent so was selected as the testsite for this study. Following is the account of the researcher's immersive experience in the M2C Collaboratory.

M2C, The Materials MicroCharacterization Collaboratory

> Dire chimera's conquest was enjoined;
> The mingled monster, of no mortal kind;
> Behind a dragon's firey tail was spread;
> A goat's rough body bore a lion's head;
> Her pinchy nostrils flaky flames expire;
> Her gaping throat emits infernal fire.
>
> --Homer, Iliad

It is difficult to tell the head from the tail of the Materials MicroCharacterization (M2C) Collaboratory, if in fact it has either or only one of each. But, if extent of media coverage and saturation of online search indices revealed to this point of the study are a true indicator, there can be no doubt M2C is the both the loudest and proudest collaboratory in the world.

M2C is the virtual co-location of five individual TelePresence Microscopy (TPM) Collaboratories, a sort of mega-collaboratory or collaboratory of collaboratories. The M2C Collaboratory includes three US government laboratories: Argonne National Laboratory (ANL) in Illinois, Lawrence Berkeley National Laboratory (LBNL) in California, and the Oak Ridge National Laboratory (ORNL) in Tennessee. Also included are the National Advanced Materials Testbed (NAMT) of the National Institute of Technology and Standards (NIST) in Maryland, and the University of Illinois' (U of I) Center for Microanalysis of Materials (CMM). The M2C Collaboratory is supported, in part, by the U.S. Department of Energy's DOE2000 Initiative, and by DOE's prior initiative, the "Distributed Computing Electronic Environment" or DCEE.

All five labs are concerned with microscopy: they look at very small things closely; and with materials science: the interconnections of materials at their point of contact. Materials Science is a

> blend of a multitude of disciplines ranging from basic science to applied engineering, from physics and chemistry through metallurgy and ceramics...which rely on techniques employing electrons, ions, photons, x-rays, neutrons, and mechanical and/or electromagnetic radiation to elucidate the microstructure of matter. (http://tpm.amc.anl.gov/MMC/HomePage.html)

Each of the M2C's TPM sites sends and receives web-based video and provides web access to and remote manipulation of unique microscopy instruments. Each maintains a unique online address with a distinct Uniform Resource Locator, or URL. Each has its own set of webpages.

While several of the TPM sites look alike, some use distinctly different webpage designs. Movement between the look-alike sites is virtually seamless and, unless close attention is paid to the URL on the browser status bar, it is easy to move from one site to another without knowing. But, each TPM site also uses a different primary name for their larger online presence, making it difficult during preliminary searching to determine that while they are, at the larger level, disconnected and distinct, they are at the functional level, very interconnected and interdependent. The concept is caught elegantly in the M2C's animated online logo (Figure 19), which slowly highlights one acronym at a time in a sort of peacefully rotating disconnected connection.

Figure 19. M2C Collaboratory Logo

ANL — LBNL

U. of I. M^2C NIST

ORNL

At least seven Industrial Partners participate technologically and financially in the M2C Collaboratory. Industrial Partners include Gatan Inc., R.J.Lee Group, EMiSPEC Systems Inc., Philips Electronic Instruments, Hitachi Scientific

Instruments, Inc., JEOL USA Inc., and Graham Technology Solutions. None of these partners have a strong graphical or informational presence on the M2C Collaboratory's five TPM sites.

Together, the M2C Collaboratory's five TPM sites have $50 million in rare and expensive microscopy instruments, with key pieces hardwired to the network, and hundreds of highly trained scientists and technicians with tens of thousands of hours of specialized scientific experience at each others' disposal. None of the labs do exactly the same thing, and each has specialized and unique instruments that, when brought together as M2C, do the larger job at each individual lab.

The "hand" of the M2C Collaboratory seems to be at the Argonne National Laboratory, http://tpm.amc.anl.gov (Zaluzec 1999), from where the coordinated web video telepresence and an aggressive public relations program originates, and the M2C's most public personality, Nestor Zaluzec, is located. The unofficial "head" is at Oak Ridge National Laboratory (Wright 1999) where the information science aspect of the project is centered.

Zaluzec arranged for two video cassettes (Argonne 1998, Dept. of Commerce 1998a), and a CD-ROM (Dept. of Commerce 1998b) about M2C and DOE 2000 to be sent to the researcher as soon as consent to enter the Argonne TPM site was granted. The researcher was also advised of a recently published "hot" article about the M2C Collaboratory (Kling 1998), which provides a nice introduction to the project, but which was not discovered during Phase One's library research. The multimedia materials are intended for educational use, are distributed freely to the public, and are available by request to the U.S. Department of Commerce NIST Public & Business Affairs Office in Gaithersberg, MD.

The professionally produced CD-ROM and video cassettes present the story of an exciting collaboration between scientists at NIST, Argonne, and Texas Instruments (TI) during which a microscopic problem that developed during silicon chip production at the TI manufacturing plant in Texas is resolved online during a M2C Collaboratory session. The TI scientist prepared and sent the problem chip to Argonne. Argonne positioned the chip in one of its microscopes, and opened a collaboratory session with TI. The TI scientist could see through the eyes of and manipulate the microscope, and collaborated with the Argonne microscopist to identify the problem, and joined by the NIST microscopist, devise the solution.

But, full color, multimedia glitz and promising public relations aside, the actual experience of M2C Collaboratory's virtual facility is a hard-on-the-brain cacophony of overcrowded information presented on a battleship gray webpage awash in a sea of acronyms. Each Argonne TPM web page is chunked into five or more scrollable frames, all crowded onto one computer screen. One quick click on the wrong acronym switches the participant, without fanfare, from one lab to the next, one instrument to another, from one side of the country to the other. This arrangement makes it difficult to achieve and maintain orientation. Nevertheless, the promise that anyone, anywhere in the world, can log on to the public Internet, go to the Argonne TPM web site, and fine focus a million dollar microscope located at any one of five National Laboratories around the country, overshadows complaints about the cacophony of the interface. This potential is a powerful feeling, and provides a taste of what the future may hold for virtual scientists.

Consent to enter the ORNL, U of I, and NIST TPM sites was also received. Consent to enter the LBNL TPM site was denied because the site would be inactive during the term of this research, and the primary contact at LBNL was out of the country. The testsite experience, then, became an exploration of four Collaboratories, as one.

TPM : TelePresence Microscopy

The Argonne TPM site is the control center of the M2C's telepresence. It coordinates constant video feed between and among the five TPM sites using "push" technology. It does not support audio transmission, so the experience is all eyes, no ears. The video transmission rate over a simple dialup connection to the web is three frames per second and begins as soon as the website is accessed. Three frames per second delivers jerky video: more a slow steady series of independent snapshots than a flowing stream. The connection, however, is constant and consistent if the client system is not running superfluous programs, particularly anything from the Microsoft family of software, the AutoSave functions of which consistently cause crashes and session interruptions. Argonne recommends a high speed dedicated connection for full effect, and use of the Netscape Navigator web browser.

Whether through a dedicated connection or by Internet dialup, maintaining a connection to M2C's video feed requires lots of RAM, or Random Access Memory, the client "desktop" space available during any computer session. For ease of this research, a personal computer dedicated exclusively to the collaboratory session was necessary (additional systems configuration and requirements are discussed later in this chapter.)

Argonne's TPM website provides multiple, simultaneous live or recorded video transmissions from itself and any ONE of the other four TPM sites, with as many as six separate video transmissions available on a single webpage. Switching between the video views and between TPM sites is as quick as a click. The web telepresence uses a point-to-point video feed rather than a multi-point videocast, as it would if all five sites were sending and receiving video simultaneously (which TPM facilitates on special occasion using CuSeeMe teleconferencing software). Participants are able to switch between and control the views from the microscopes and the macroscopes (room view video cameras) at any of the sites. Split screen "collaboratory sessions" allow the participant to view microscope and macroscope video transmissions from two cameras at each of two sites simultaneously for a sort of "four-eyed" experience. Everyone accessing the TPM website sees the same video feed, and anyone can change which video is seen. The host-site may override and disable a remote controller and any change in video view changes the view for everyone. A warning is posted that if the view suddenly "changes" it is because someone else who is accessing the site has switched views. No information is provided about who else, or how many others, are accessing the TPM sites, so it feels as if only you, and the people you see on the macroscope view from the lab (if there are any), are present, when in fact thousands of others might be.

To further confound the confusion about who, or how many, are seeing what view from where, the number of possible simultaneous video feeds on a single screen is six, making a sort of six-eyed experience with each eye seeing something different. Getting oriented to what is on the screen is difficult and confusing, and often, as soon as orientation is gained, the "view" suddenly changes.

The Argonne lab is the video "headquarters" of the M2C Collaboratory, and must be included as a partner in any two-lab collaboratory session. The Argonne setup does not allow direct connection between two remote labs, only between itself and one other lab, or any other lab and itself. The same is true of the other sites, which allow a view from themselves and Argonne, or from Argonne and any one other site. Accessing any one of the labs by itself is also possible, either from a connection at Argonne, or by logging on to that TPM's separate URL.

For instance, a collaboratory session between the Oak Ridge Lab and the Berkeley Lab is not supported; however two sessions can be set up simultaneously, as between Argonne and Oak Ridge, and Argonne and Berkeley, and participants can switch between these sessions, requiring orientation to as many as twelve video feeds. Collaboratory sessions are preprogrammed and executable with a one click switch to "collaboratory mode." Remote users may "join" an ongoing collaboratory session, and will receive microscopic and macroscopic video from two labs on a single screen (see "collaboratory mode" later in this chapter). In other words, participants may be visually "in" one of the labs alone, or, in collaboratory mode, be "in" two labs at once. Participants can even be in multiple collaboratory sessions, conceivably four at once.

For a scientist at one of the labs, or for one of the M2C Industrial Partners, or someone from the wider Internet, to conduct an experiment using one of the instruments at any of the five TPM sites, the materials sample has to be prepared and sent to the lab, and a technician or scientist has to receive the sample and load it into the instrument. This setup, then, allows the remote scientists to have their eyes at the remote site, one on the lens of the microscope, and the other viewing the room, with their hands on the remote control buttons for the microscope in a separate frame on the M2C webpage. They can see through and manipulate the microscope, but they cannot move the sample at all, or talk to the remote scientist without a subsidiary telephone connection. A "snapshot" of the microscope's results can be viewed either as real-time online video, or the results can be captured and posted to a collaboratory notebook (the notebook configuration is discussed in detail later in this chapter.)

It is possible and practicable to connect to and enjoy the full function of the M2C Collaboratory and participate in TPM activity with a 14.4kps dialup ISP connection to the Internet from a 486-66 mhz PC with 16 mb RAM and a standard video monitor. It is slow, but possible. A frames-capable version of Netscape Navigator® (2.0 or higher) is required to receive video; otherwise, no special software or unusual configuration is required. Microsoft's Internet Explorer® browser does not support the file type used for video transmission. This research used a 28.8 kps dialup Internet connection from a 200 mhz Pentium II with 128 mg RAM and 2 mb Video RAM, as well as a 166 mhz

Pentium laptop with 16 mb RAM and 1 mb Video Ram connected by dialup via a 56.6 kps modem.

Only one area of each TPM site has restricted access: the "Online Control" of the hardwired instrumentation. Online control of the instruments must be justified and arranged ahead of time. As U.S. National Laboratories, however, each of the TPM sites is required to make their instrumentation available to qualified outside researchers. A form for requesting instrument use is online at each site. However, users may view others' use of the instruments, or read the contents of the public notebooks, (password protected private notebooks are also set up) and may remotely manipulate the site's macroscopes without password access.

Video from and manipulation of the room-view cameras is provided around the clock, whether anyone is in the lab, or not. However, video feed is often not "live" in that it may be a prerecorded transmission intended for demonstration purposes. It is often difficult to distinguish whether the video is live or prerecorded. Of course, macroscope and microscope views that are prerecorded have the remote control options disabled.

Each TPM site hosts shared public and private notebooks. The notebook is a shared, online document space in which participants may post pages containing text or still graphic shots captured from the microscopes. Only one person can have realtime control of any given notebook page; so, chat-like communication is not possible. Private notebooks are password protected and reserved for specific experiments, which may be of a proprietary nature, as with a collaboration with Texas Instruments or one of the Industrial Partners. Public notebooks allow real-time addition of pages via web forms technology. Each notebook page has an email-like header identifying the author, subject, etc. While there is a provision for searching the subject line of notebook pages, there is no provision for full text search, nor for annotating or linking among notebook pages, or among notebooks.

The Argonne TPM site hosts a data archive where programs, software patches, and activity logs are stored and shared via file transfer protocol. The site hosts an "Ask-the-Microscopist" service, and provides information about setting up middle/high school experiments. There is a questionnaire and comments form, and access to join or read the archives of a six-year-old distributed email list. The researcher was granted access for research in the archives of the M2C Collaboratory email list, an opportunity which will provide data for expansive studies of other aspects of the collaboratory ecology, but which was not undertaken in this study.

The site design relies heavily on web frames (dividing the screen into multiple, smaller windows) to organize and present these many options. The interface is cacophonous and confusing. The framed sections quickly become quite small and are packed with options, most of which involve arcane acronyms that may be confusing to the novice user. The confusion is compounded because each of the five laboratories has its own specific set of acronyms along with an individual name and domain, and one click can mean a switch between labs and instruments without noticeable change in layout or design of the web interface. At certain times, the M2C Collaboratory's TPM sites feels as if it is five labs in one, and at other times, five individual labs.

This study monitored the M2C Collaboratory through the Argonne TPM site at odd times and for varying durations and intensities, on at least a weekly basis, for ten months from October 1998 until July 1999, for an estimated twenty hours total observation time. It wasn't until three months into the experience that the "who's on first" feeling of disorientation was relieved, and comfortable orientation to the larger environment was achieved. The final confounding variable is that contact information from each of the sites leads back to Argonne, making the Argonne TPM site appear as if it is the center of the Materials MicroCharacterization Collaboratory. But M2C may also feel "centered" at any of the other TPM sites when primary access is made through that lab's distinct URL. M2C is actually a megacollaboratory encompassing five individual but intertwined collaboratory sites: ANL, LBNL, NIST, ORNL, and U of I.

During the ten months of this study's immersion, the main microscope at TPM Argonne was frequently offline, and two of its seven microscope lenses were under repair. No public collaborative experiments were conducted. Many times a prerecorded video of collaboratory activities was webcast and it looked "as if" there was live lab activity, when in fact it was not real-time activity at all, but prerecorded video.

Because the macroscope controls were accessible even when no one seemed to be in the lab, users are free to "poke around," panning the cameras, and focusing in and out on pieces of equipment and researcher desk space to get a sense of the place. Because the transmission rate is three frames per second, however, and because the views could be changed without notice by some unknown, other visitor, sometimes someone would just "appear" in a chair in the laboratory, and just as quickly "disappear" between frames. It was not immediately possible to tell whether this appearance was real, or recorded, and often from which lab it originated. In fact, it was generally difficult to tell what was "real" and what was recorded, what was live, and what was contrived, during most of the M2C sessions. At no time during the ten month immersion did any collaboratory participants make contact with the researcher while in the collaboratory. No response was posted to the researcher's entry in the public notebook. The M2C Collaboratory's video telepresence provided a sense of, but no real connection to, other humans.

Because of the specialized, scientific focus of the M2C, an understanding of instrument type and function would help with orientation, and for educational purposes an elementary overview of the equipment and the work it is used for would be helpful. Much of the researcher time was spent learning which piece of equipment did what sort of job. Without this specialized knowledge it is virtually impossible to get a comfortable sense of the work that takes place in the M2C.

The Argonne TPM public notebook contains 125 entries, dating from March 1997. Most of the posts are brief messages concerned with startup technicalities and configuration tests for various graphic settings. Again, this was no place for beginners as none of the messages made an attempt to explain either technicalities or acronyms. There are a few series of messages (indicated by the subject line of the notebook entry), which are mostly single frame graphic files that appear to have been produced on a microscope during remote collaboration with a microscopist. None of the notebook pages that containing graphics provided more than a brief, acronym-laded description of the shot; there was no discussion of the contents of the graphic file, nor any sort of formal diagnosis or discussion of the materials problem.

The M2C's digital library (although the word "library" is not used) is a separate collection of internal and external web links maintained by the microscopist/webmaster at Argonne. The link to the digital library (called "General Info about TelePresence Microscopy") is not prominently displayed but, once located, transports the user to a separate web address at http://www.amc.anl.gov, home of the Microscopy and Microanalysis WWW Server. The server offers a collection of project papers, proceedings, and reports aimed at general education about the M2C concept and the science of materials microscopy. None of the documents were for specific project support nor were they about ongoing experiments. They seemed intended for general visitor information rather than to support collaboratory activity. The "General Information" site also points to data archives that include the site's distributed email list archive, and links to related microscopy societies and other external WWW resources. There were no preprint papers, and no peer review postings. It felt as if the M2C Collaboratory's main purpose was the exchange of video and captured shots from the instruments. Very little attention is paid to the intercommunication or inculturation of participants.

With all the **CIRAL** criteria in place and functioning (Table 7), the Argonne TPM site of the M2C Collaboratory proves the collaboratory exists as it was philosophically, intellectually, and instrumentally described by Wulf (1988), Lederberg and Uncapher (1989), and NRC (1993). It is not possible to say M2C was the first or is the only full implementation of the collaboratory, but it is possible to say that the Argonne TPM site of the M2C Collaboratory appears to have been fully functional in March 1997, when its public notebook went online.

CIRAL Criteria for Inclusion as Collaboratory	Criteria Found in Materials MicroCharacterization (M2C) Collaboratory
Computerized Network	✓
Remote **I**nstrumentation	✓
Resources to Support	✓
Data **A**rchives	✓
Digital **L**ibrary	✓

Table 7. M2C Collaboratory Criteria for Inclusion

NIST TelePresence Microscopy Site

At first, there is no apparent difference in the look and feel of the Argonne TPM and the National Institute of Standards and Technology (NIST) TPM site, and for a while the researcher was not aware they are two distinct TPM sites. Even though the online address, or URL, is different, the interface and design are nearly identical, as if the Argonne TPM webpages were mirrored on the NIST site at http://scanner.cme.nist.gov. Only the acronyms seemed to change. But, on closer inspection, the Argonne TPM site showed 41,566 visitors logged on since 1997, while the NIST site logged 1801 visitors. The microscope video feed from each site is different (although this might only be apparent to a microscopist). All other options seemed identical.

Achieving collaboratory mode between the Argonne and NIST TPL sites is a one-click operation that brings both sites together onto a single screen. Micro- and macroscopic video views from each site are framed above other frames that contain video control, comments, and instrument controls, for a total of seven frames on a single webpage. Similar sessions can be configured between Argonne and ORNL, Argonne and U of I, or Argonne and LBNL.

Figure 20 is a screenshot of a TelePresence Microscopy session between Argonne National Laboratory (ANL) and National Institute of Standards and Technology (NIST) on May 16, 1999, as seen from an Internet connection to the website at http://tpm.amc.anl.gov/TPMLVCollabNIST.html.

The upper left frame is a lens shot *from* the Advanced Analytical Electron Microscope (AAEM) at Argonne in Illinois. The upper right frame is a shot *of* the NammMetrology SEM Microscope at NIST in Maryland. The top center shot is a macroscope (room) view of the Argonne lab, and the middle center shot is the macroscope (room) view of the NIST lab. The lower left frame has buttons to change between the instrument or cameras at either site. The lower center frame contains links to switch between collaboratory sessions and to other web-based resources. The lower right frame is the online instrument controls, which, in this shot, are offline.

Figure 20. Screenshot of M2C TelePresence Microscopy Session

Consent from ORNL's TPM gatekeeper suggested the researcher access the M2C from http://tpm.amc.anl.gov/MMC/, yet another portal to the site. This access point provides a thorough overview of the M2C Collaboratory and includes an introduction and background information, goals, tools, status, opportunities for involvement, expansion plans, partners, visions, publications, workshops, and images. It includes a form to request use of resources or information at/from any of the TPM sites, email access to TPM gatekeepers, an overview of research programs, and connection to the project's steering committee. While all this text-based information helps make sense of the science of microscopy, and the notion of the collaboratory generally, it does not aid visual orientation to the TPM experience.

The M2C experience has a sort of "virtual" feeling of being there, somewhere, within and among these five labs, but in eyes only, and with a lingering and somewhat creepy sense that others MAY be around, but are hidden. Because there was no human interaction, either via audio transmission or real-time chat, and because it was difficult to determine whether the video feed was live, or prerecorded, and also difficult to orient to which lab one was connected, the M2C experience was generally disorienting and produced a feeling of disconnected connection, of being alone online with unknown virtual others.

Conclusion

The Materials MicroCharacterization Collaboratory, M2C, meets the **CIRAL** criteria for inclusion as a fully functioning collaboratory as put forth in Wulf

(1988), Lederberg and Uncapher (1989), and NRC (1993). It includes computerized networks, remote instrumentation, resources to support, data archives, and digital library-like resources. The collaboratory exists. Chapter Eight explores other collaboratory environments and presents descriptive studies of four other collaboratory implementations.

CHAPTER EIGHT

DESCRIPTIVE STUDIES

In Chapter Seven the existence of at least one collaboratory that meets all the criteria for inclusion of the **CIRAL** matrix is established. The Department of Energy-funded Materials MicroCharacterization (M2C) Collaboratory, with its five remotely-located TelePresence Microscopy (TPM) sites, uses resource-supported computerized networks to provide access to and manipulation of remote, rare, and expensive instrumentation, and hosts digital archives and digital library resources to support the work of collaborating scientists and researchers. Such a system, a "collaboratory," was first visualized and described by Wulf in 1988, and further developed by Lederberg and Uncapher (1989), and NRC (1993). Chapter Eight seeks to discover whether other full collaboratory implementations are in place, to determine the nature of their environment, and also explore the nature of sites that use the word collaboratory, but do not meet the **CIRAL** criteria for inclusion.

There are virtually thousands of websites that use the word collaboratory but which obviously do not meet the **CIRAL** criteria for inclusion. Most of the thousands of websites clearly miss the definition because they do not incorporate access to and manipulation of remote instrumentation. Many, in fact, are simply personal or institutional websites that incorporate some level of interactivity using web server functions that are now generally and widely available to the public. In fact, a simple website with a link to the Library of Congress and set up to facilitate a Microsoft NetMeeting® session (which allows point-to-point real time audio/video transmission, remote access to and control of the desktop on either end of the connection, file sharing, and whiteboard capabilities), can claim to meet all the criteria for inclusion as a collaboratory *except* for providing access to and manipulation of rare and expensive remote instrumentation.

Online environments that use the word "collaboratory" but that do not meet the **CIRAL** criteria for inclusion are mostly academic or educational websites. Most of the sites incorporate various collaborative or communication functions, including links to email, chat, or forum functions, and provide access to various types of data archives, or links to internal or external digital library facilities. Consequently, access to and manipulation of remote instrumentation is either the determining criteria for proper use of the word "collaboratory," or the definition of the word "collaboratory" needs revision. If redefinition is adopted, however, the word "website" and "collaboratory" become virtually interchangeable, the Internet has become the collaboratory (or vice versa), and the distinct notion of a collaboratory is meaningless.

Derivative "Collaboratories"

Many publicly accessible collaboratories are K-12 oriented web-based information clearinghouses that present some sort of interaction between students and remote scientists, educators, or datasets. For example, the CoVis Collaboratory, which is funded in part by the National Science Foundation, is

> the website of the *Learning Through Collaborative Visualization Project* at Northwestern University, comprising... a community of thousands of students, over one hundred teachers, and dozens of researchers, all working together to find new ways to think about and practice science in the classroom. (http://www.covis.nwu.edu/)

Many collaboratories, such as the University of Michigan's Learning Collaboratory at http://databases.si.umich.edu/LearningCollaboratory/ are intercollegiate university computer labs that can connect to each other using point-to-point or multi-point audio or video transmissions, but do not host access to remote instrumentation. Some collaboratories, such as the nonprofit Research Collaboratory for Structural Bioinformatics (RCSB) at http://rcsb.nist.gov/ are shared data repositories but do not incorporate human-to-human communication functions or provide access to remote instrumentation, and are more library than they are collaboratory.

Some collaboratories, such as the University of Michigan's Collaboratory for Research on Electronic Work (CREW) at http://crew.umich.edu/index.htm, and the MIS Collaboratory at the University of Texas at http://cism.bus.utexas.edu/collab.html, are metacollaboratories, or web sites for university-based centers of research about collaboratories or collaboratory work. These sites offer extensive data archives and digital library functions, but (in the case of CREW) no remote communication function, and in the case of both, no access to remote instrumentation.

Undoubtedly, some government agencies, such as NASA and branches of the U.S. military, have fully operational collaboratories that facilitate manipulation of remote instrumentation such as launch rockets, satellites, and space station instruments. But, these setups are "hidden" from public access and, for security purposes are more likely to co-locate participants in command centers than they are to co-locate instrumentation virtually. Likewise, there are undoubtedly private, proprietary implementations of the collaboratory environment, as in large corporations such as at IBM (1997) and Bellcore (Cooper 1993). Such sites are not pursued by this study.

The sites that are pursued in this study are publicly-accessible and identified and located either from references in the collaboratory literature or by searching the World Wide Web. The following descriptive studies were developed during prolonged immersion at each site. Prolonged immersion involves an exploration and evaluation of the information environments for content, context, design, and delivery, and for other aggregated things, conditions, and influences that constitute an information environment.

SPARC : The Space Physics and Aeronomy Research Collaboratory

The Upper Atmospheric Research Collaboratory (UARC) at the University of Michigan was undergoing major revision during the term of this research, and has been renamed the Space Physics and Aeronomy Research collaboratory (SPARC). SPARC is funded, in part, by the National Science Foundation under the Knowledge and Distributed Intelligence (KDI) initiative as part of NSF's Upper Atmospheric Facilities.[6] SPARC maintains a primary public web interface on the University of Michigan's Collaboratory for Research in Electronic Work (CREW) server at http://www.crew.umich.edu/UARC/. Buried deep in the SPARC site is a form for requesting guest access or a logon account for access to the password-protected "working" portion of the collaboratory. This access point is at http://sparc-1.si.umich.edu/sparc/central/edit/Login/REGISTER. SPARC also maintains a separate K-12 education-oriented web site with games, experiments, and other instructional material at http://www.windows.umich.edu/sparc/. The

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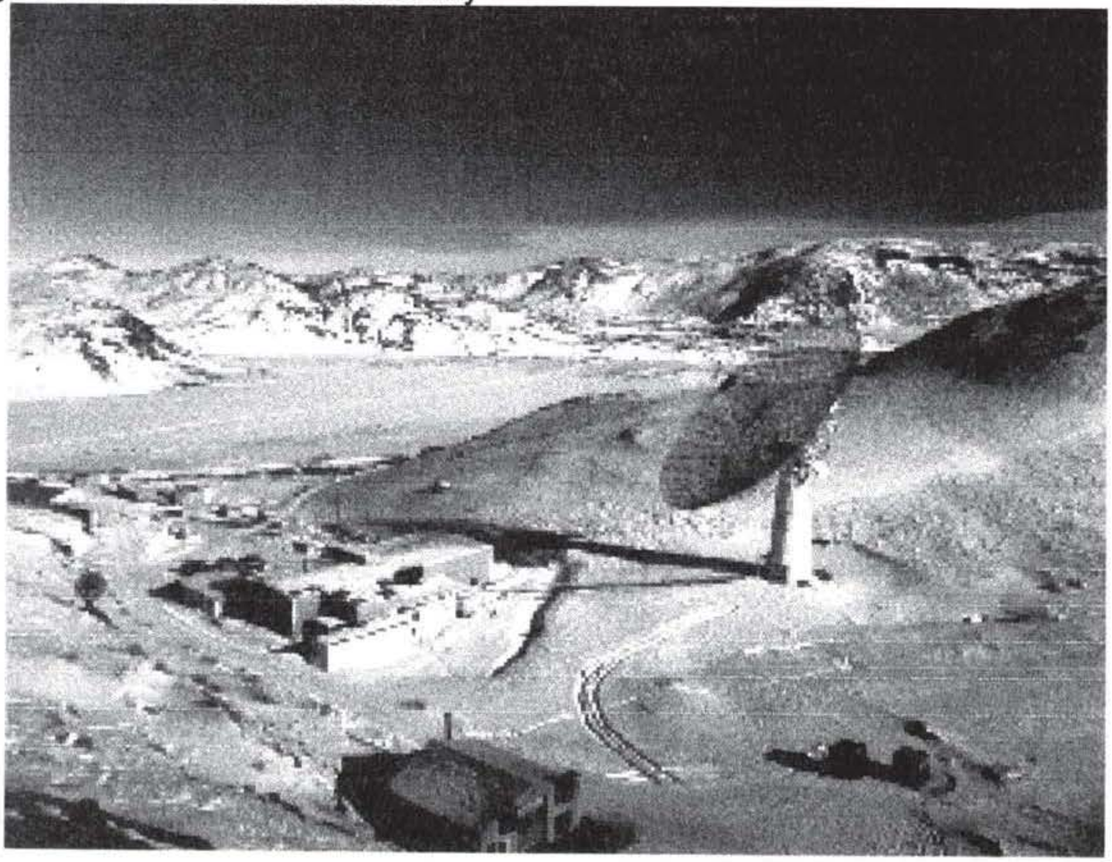
[6] The NSF's Upper Atmospheric Facilities include four large incoherent-scatter radar and optical facilities located along a longitudinal chain from Greenland to Peru. Along with the Sondrenstrom Facility which is accessed via SPARC, they include Millstone Hill Radar near Boston, Massachusetts, Arecibo Observatory in Puerto Rico, and Jicamarca Radio Observatory in Peru (http://www.geo.nsf.gov/atm/uaf.htm#desc).

education site uses Java technology and requires the most recent version of any cookie-enabled graphical web browser software for full functionality.

Upper atmospheric space physics is concerned with the effects of the sun on activities in the Earth's upper atmosphere. SPARC's purpose is to design, develop, deploy, and evaluate Internet-based technology to help space scientists work together in collaborative studies of space and upper atmospheric science. The SPARC team includes an international community of space, computer, and behavioral scientists (http://www.windows.umich.edu/sparc/).

The primary instruments to which SPARC provides access are located at the Sondrestrom Facility, part of a global network of incoherent scatter radars. The Sondrestrom Facility is located north of the Arctic Circle in western Greenland. Figure 21 is an aerial photo of the Sondrenstrom Facility that shows the transmitter and instrument building, power plant, and crew housing. SRI International, one of the world's largest not-for-profit independent research enterprises (http://explorer.csc.com/C3TEI/sri.html), operates Sondrestrom for a variety of universities and government labs.

Figure 21. The Sondrestrom Facility

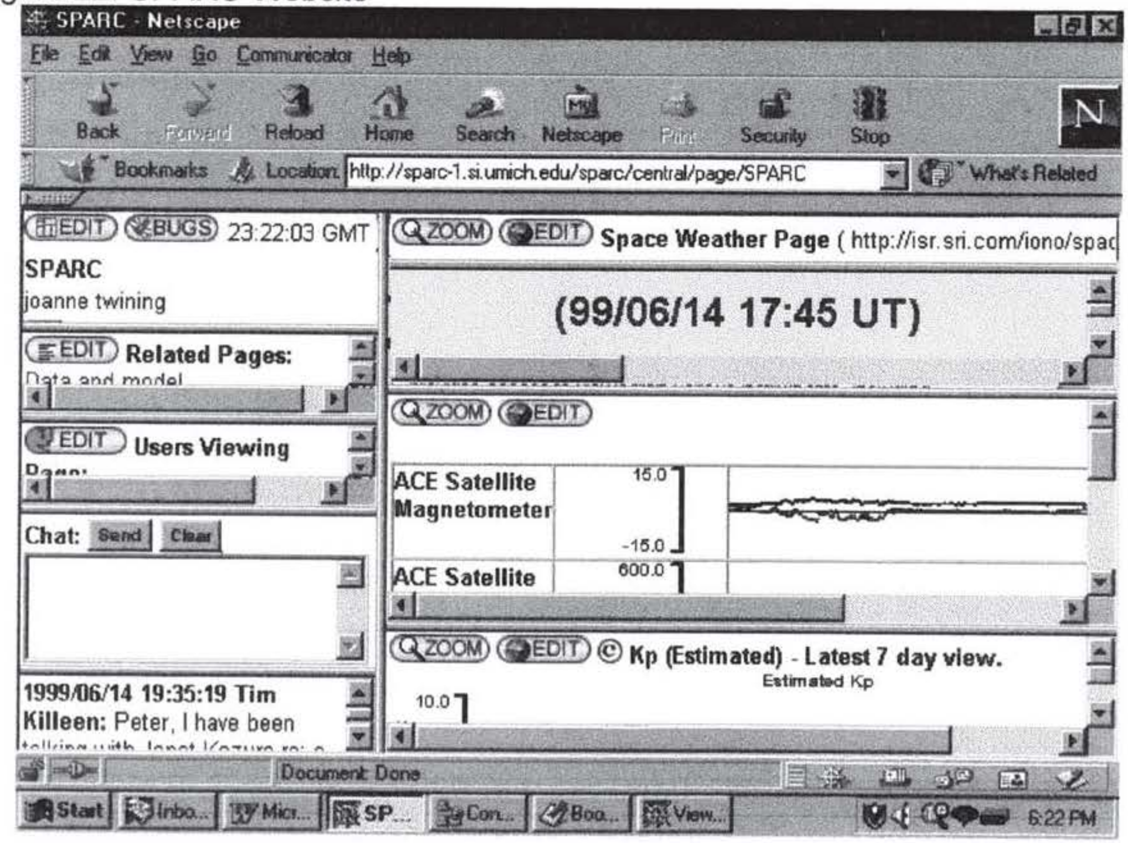


The Sondrestrom Facility's incoherent scatter radar has a fully steerable 32-meter parabolic antenna to which a wide range of optical and radiowave instruments are attached. Prior to UARC/SPARC, scientists had to travel to the site to use the instruments (http://128.18.44.75/iono/issfsond.html).

While SPARC provides access to various archived and live datafeeds from the various Sondrestrom instruments, manipulation of the remote instrumentation is available only through specially configured workstations at five locations. Real-time manipulation of the instruments is not available via public Internet, and SPARC gatekeepers did not respond to the researcher's request to remotely access instrument controls.

As with the M2C Collaboratory's TPM web interfaces, the SPARC web interface is a sea of frames, a technique for dividing a web page into multiple, scrollable sections. The SPARC's main web page (Figure 22) includes nine frames, each with different options, and each less than an inch deep, making it necessary to scroll through the individual frames one line at a time, or open each frames in a new window. Even though the SPARC site does not transmit video, it does have a RAM-hogging refresh default, and quickly maximizes the desktop. Like the M2C Collaboratory's TPM web design, the site is awash in a cacophony of acronym-laden choices that may be difficult for users without a background in space physics to understand. Unlike the M2C interface, SPARC offers a chat window and a list of others who are online, providing a real sense of co-presence that is absent from the M2C. A SPARC session feels more like reading a book than it does like seeing a video, as with the M2C experience.

Figure 22. SPARC Website



DOE2000

The U.S. Department of Energy, though its DOE 2000 initiative, and its prior initiative, the Distributed Computing Experimental Environment, or DCEE,[7] takes the lead in implementation of the collaboratory environment. Besides DOE's M2C

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[7] See http://www-itg.lbl.gov/DCEE/Overview.fm.html for DCEE Program overview and final report.

TPM Collaboratory examined in the previous chapter, and NSF's SPARC as described above, this research found only two other functioning Collaboratories in the public domain that meet all the **CIRAL** criteria for inclusion, and both are funded by DOE.

Successful collaboratory implementation depends on basic and applied research, much of which cannot be easily identified for reasons discussed in Phase One. Any successful implementation rests on the shoulders of this often unrecognized research. Such research and development areas include telecommunications, computer science, multimedia transfer protocols, and hardware and software development, and comes from virtually every quarter of the government as well as from industry and commerce. And, just as there has been no direct tracking of collaboratory-specific research, there has been no direct tracking of federal expenditure on research and development leading to implementation of the collaboratory.[8] Nevertheless, for bringing the research together and establishing a functioning collaboratory environment that is open to the public realm, DOE owns the prize.

Besides the M2C Collaboratory, two other DOE collaboratory environments have been successfully implemented since 1997. The first is the Remote

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[8] For detailed historical tables of federal funding for research and development 1959-1999, see http://www.nsf.gov/sbe/srs/nsf99347/htmstart.htm

Experimental Environment (REE) Collaboratory built around the DIII-D Tokamak fusion reactor at General Atomics Corporation in San Diego, California. The second is the Environmental Molecular Science Collaboratory (EMSL) at the Pacific Northwest National Laboratory (PNNL) in Washington State. In addition to the technical and architectural research they provide, the REE project and EMSL each also includes a sociological research component. The REE social research was contracted to Sara Bly, of Sara Bly Consulting, but results of these studies are intended for internal use and are not published in the scholarly literature. They are, however, available online. This chapter investigates the REE DIII-D Tokamak Collaboratory and the Bly Reports, as well as the ESML Collaboratory, and its sociological and psycho-social studies, and concludes with a general synthesis of the environment of the functioning collaboratory.

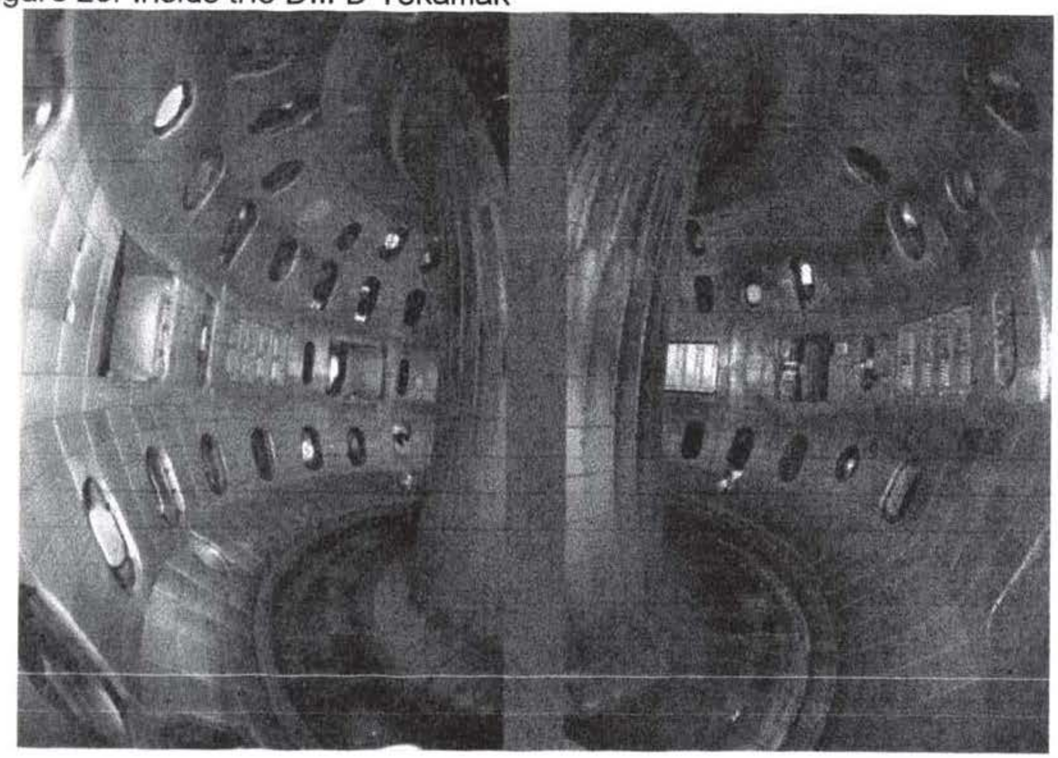
REE Collaboratory Testbed at the DIII-D Tokamak

The Remote Experimental Environment (REE) Collaboratory is a DOE-funded testbed built around the use of the DIII-D Tokamak at General Atomics Corporation. A tokamak is a

> toroidal plasma confinement device invented in the 1950s by the Russians Tamm and Sakharov ... The word "tokamak" is a contraction of the Russian words: "toroidalnaya", "kamera", and "magnitnaya", meaning "toroidal chamber-magnetic.
> (http://fusioned.gat.com/webstuff/Tokamak.html)

More simply, the DIII-D Tokamak is a very large (about three quarters the size of a football field) donut-shaped (toroidal) chamber in which plasma, the fourth most common and the most abundant state of matter on Earth (the others being solid, liquid, and gas) is magnetically suspended at very high temperatures, and into which hydrogen atoms (from water) are introduced, where they fuse, creating energy. Figure 23 shows the inside of the DIII-D Tokamak at General Atomics.

Figure 23. Inside the DIII-D Tokamak



The DIII-D Tokamak is one of serveral tokamaks in operation globally. Hydrogen atoms are injected into the high temperature magnetically-suspended plasma inside the tokamak, where they fuse, or come together, in a controlled thermonuclear reaction. The reaction creates helium energy the same way the sun and stars create energy. Unlike traditional fission nuclear reactors, which split apart heavy atoms such as uranium, and produce troublesome waste and other side effects, tokamak fusion reactors bring two light hydrogen atoms together. Unlike fission, the physics of fusion make it inherently safer: a fusion reactor cannot go through a meltdown. The waste generated by fusion is expected to be less radioactive and to have a much shorter half-life, and is thus easier to dispose of than fission waste. Fusion energy is also much cheaper to produce: 50 cups of sea water contain the same amount of energy as two tons of coal, or a thimble of the element created by the fusion process is equivalent to 20 tons of coal. If advancements continue at the present rate, it is expected that energy break-even with fusion reaction could be accomplished by the year 2010. Commercial power plants could then come on line just as the Earth's oil gauge becomes critically low, about the years 2050-2060.[9]

[9] The preceeding description is synthesized from an introductory slideshow available at http://fusioned.gat.com/Teachers/SlideShow/SlideMenu.html

The DIII-D Tokamak at General Atomics is one of several major fusion programs worldwide. Collaborating organizations include Princeton Plasma Physics Laboratory (PPPL), Lawrence Livermore National Laboratory (LLNL), and Oak Ridge National Laboratory (ORNL), some of the very same labs involved in the M2C TelePresence Microscopy Collaboratory discussed in the previous chapter. As an international resource for plasma physics and fusion energy science research, scientists and researchers from around the world are also involved in REE Collaboratory sessions.

The complexity and cost of firing up a tokamak fusion reactor require a high degree of international collaboration. The energy released by the fusion reaction is abundant, and harvesting multiple very large datasets from multiple, simultaneous, sequential experiments is possible, and usual. There are a variety of instruments attached to the tokamak, and each is used for a different type of experiment, which take place simultaneously at various stations around the tokamak. Instruments can be added to, and removed from the tokamak as needed, like components.

Unlike the TelePresence Microscopy Collaboratory, which involves two or more remotely-located scientists working together at a single microscope with a single sample, DIII-D Tokamak Collaboratory sessions involve hundreds of scientists and researchers. These scientists and researchers are either stationed at various instruments around the tokamak, in other buildings nearby, in labs elsewhere in the United States, or are logged on from positions around the globe. Scientist may be conducting a shared experiment, or may be working on individual experiments, all at the same time, but everyone must nevertheless, and to varying degrees, stay in touch with each other and with the local or remote control team, which coordinates the overall "firing" of the fusion reactor. Unlike the M2C Collaboratory, the tokamak equipment is not accessible to the public via the Internet. Rather, it is wired to an internal network to which password-protected remote logon must be arranged. Unlike the M2C Collaboratory, the REE DIII-D Tokamak Collaboratory is not always online and available; collaboratory sessions are orchestrated special events.

Coordinating communication between and among the hundreds of researchers, scientists, and technicians who are present at or logged on to any given tokamak sessions was the prime concern of the first REE Collaboratory experiments in 1997. Rapid adjustments of instrument settings between the rapid series of shots that make up a tokamak session are often necessary. These fine-tuning adjustments rely on input from any of the people involved (Bly 1997). Communication is achieved via audio/video transmission from the DIII-D control room, and also includes the broadcast of meetings, use of inter-process communication software to post events to the network during a tokamak shot, the creation of a DCE (Distributed Computing Environment) cell for creating a common collaboratory environment, and distributed use of computer cycles, remote data access, and remote display of results (McHarg et. al. 1997).

Not everyone involved in a tokamak session needs to stay in touch with everyone else all the time, however, so communication channels are customized. Any given scientist might need to be communicating on more than one channel, to more than one subgroup of operators or scientists, at any one time during the experiment. Communication involves a very complicated, cacophonous, and continuous connection. Simultaneous communication between and operation of the instrument by as many as fifty scientists around the world is described by one participant as being very much like playing a musical machine:

> ... you're playing it. And you're there all the time. You're doing a dynamic experiment. You're continuously changing the experiment. You're watching the data as it comes out. You're adjusting things, you're measuring things, you're changing the experiment as you go along. (Bly 1997, 3)

In the preliminary report on the ways collaboratory technology was used, and the effects of those technologies on the work of scientists and technologists during the 1997 experiments, Bly et. al. (1997) find that

> Cultural evolution in creating collaboratories may be as critical as computing technology development. The introduction of collaboratory technologies will influence the design and use of the technologies in ways that are different from many groupware situations today. Understanding

> the work activity as well as the technology is critical to the long-term success of these projects. (1)

At the beginning of her study, Bly (1997a) identified six aspects of scientific work common across the laboratories involved in the DCEE initiative:

1. Expensive and hard-to-duplicate equipment for data collection
2. Complex planning and coordination of the experimental design
3. Multiple person, multiple specialties needed for carrying out experiments
4. Rapidly iterating and changing experimental parameters
5. Collaborators who are geographically distributed
6. Shared analysis and results.

At the conclusion of her study, Bly (1997b) identifies seven characteristics of activity that took place during the 1997 DIII-D Tokamak collaboratory session:

1. Nothing is fixed.
2. Everything is interdependent.
3. There are multiple paths to and from multiple sources.
4. Activity is constant and busy, but not frantic.
5. There is strong dependence on recognized, habitual signals and activities.
6. The frustration level varies.
7. The pre-operations meetings are valuable and relatively straight forward.

The REE DIII-D Tokamak Collaboratory experiment was much more a communication- and media-oriented special event than are either the M2C or the SPARC projects, which maintain ever-ready and permanent presence on the Internet. Each REE Collaboratory session is a one-time event involving hundreds of people, and requires special configurations that rely on the coordinated firing of a very large instrument.

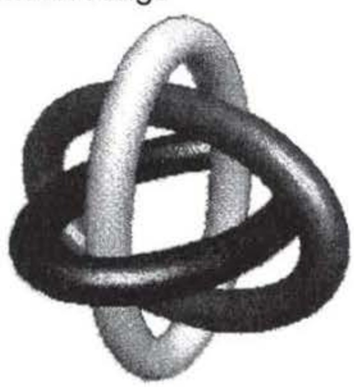
While collaboratory session in M2C and SPARC are also events, they occur within a stream. The M2C instruments are pretty much always available and require minimal preparation and coordination for special use, and the SPARC instruments are always online, supplying a steady stream of data in a one-to-many sort of mode. To continue the musical metaphor, M2C is like a CD player that can be turned on to listen to a specific piece of music. SPARC is like music in the background of a public elevator: it is always on unless something has gone wrong, and you don't get to change the channel. REE is like assembling an international orchestra for a command performance at the White House. Thus, we see, the type of instrument has much to do with the configuration of any given collaboratory, and so must be considered a major influence on the other factors of a collaboratory ecology.

EMSL : The Environmental Molecular Science Collaboratory

The Environmental Molecular Science Collaboratory (EMSL) at http://www.emsl.pnl.gov:2080/docs/collab/ is concerned with the Department of Energy's mission to develop new technologies to clean up the nation's hazardous waste sites. EMSL is specifically but not exclusively concerned with the Hanford Nuclear Reactor site in southeastern Washington State. The Hanford Site has approximately 1.4 cubic kilometers of hazardous and radioactive wastes, 150 square miles of contaminated aquifer, and 60 millions gallons of radioactive wastes (260 MCi) stored in underground storage tanks (of which more than one-third are believed to be leaking). The Hanford Site also has 270 tons of spent fuel, 9 inactive reactors, and 7 major inactive reprocessing plants. The site is the equivalent of nearly 1400 Superfund sites divided into 78 distinct groups sharing common traits and geographies (Kouzes, n.d.).

The William R. Wiley Environmental Molecular Sciences Laboratory hosts EMSL at Pacific Northwest National Laboratory (PNNL) in Richland, Washington. The EMSL "Virtual Scientific Facility" is operated by PNNL for the DOE Office of Biological and Environmental Research (OBER). The EMSL's philosophy of the synergy of the collaboratory is represented by its logo (Figure 24), which is Borromean Rings: three symmetric interwoven loops that cannot be pulled apart although no two rings are interlinked, and removing (breaking) one allows the other two to slide apart.

Figure 24. EMSL Logo: Borromean Rings



EMSL houses many unique facilities for basic scientific research, including the world's first commercial gigahertz Nuclear Magnetic Resonance (NMR) spectrometer, a scanning near field optical microscope, and the most powerful IBM parallel supercomputer yet built. Overall, EMSL is home to some 300 researchers with unique expertise, equipment, and software.

As part of its work, EMSL is developing software tools to support collaboratory operations, specifically CORE, the Collaborative Research Environment, a suite of software tools that provide general collaboration capabilities ranging from distributed file systems to videoconferencing. CORE supports real time computer display sharing, a Web based Electronic Notebook, secure direct acquisition control of the EMSL spectrometers, and the ability to consult with EMSL staff for training, as well as during setup to optimize the experiment, or at any time during analysis or other activities.

EMSL does not provide the public direct web access to any of its instruments, nor to active, ongoing collaboratory sessions. To participate in any of the EMSL activities, the CORE software must be downloaded and configured on the users' computer. CORE software may be downloaded from the EMSL main webpage at http://www.emsl.pnl.gov:2080/docs/collab/. The software was not downloaded for this study.

EMSL Collaboratory sessions are achieved using X-Windows technology, a cross-platform interface which allows remote scientists, regardless of the type of computer they're using, to telnet (or remote logon to the computer in the lab), open a graphical window on their computer, and participate fully in ongoing activities. Collaboratory sessions must be arranged ahead of time by submitting a proposal, negotiating the time for the experiment, acquiring passwords, and arranging for any necessary training. EMSL Collaboratory sessions include both short term, project specific work, and long term ongoing collaborations. An example of an ongoing EMSL Collaboratory project is the one between Kelly Keating at EMSL (who does nothing but collaboratory science) and a scientist at

Lawrence Berkeley Lab. Their ongoing experiment involves investigating the breakdown of DNA after exposure to radioactive waste. (Keating 1999).

Payne and Myers (1996) provide technical specifications for the architecture of the CORE suite. How a typical EMSL Collaboratory session is set up between two remotely located scientists using the CORE suite is described in words and pictures at http://www.emsl.pnl.gov:2080/docs/collab/virtual/VNMRFScenario.html.

The CORE suite of software is designed to support four basic types of collaborations EMSL has identified:

> **Peer-to-peer** collaborations between scientists from the same discipline who share the same vocabulary and focus, who need to share realtime manipulation of the instruments and have access to unanalyzed data, and who may be in competition;
>
> **Student-Mentor** collaborations where there is unequal knowledge, the introduction of new vocabulary, the need for reference materials and lectures, and the need to observe student efforts;
>
> **Interdisciplinary** collaborations between scientists from different fields, (which may be bi-directional student-mentor projects), in which there are shared concepts, goals, and samples, but limited common vocabulary, and where access to analyzed data and data summaries (rather than raw

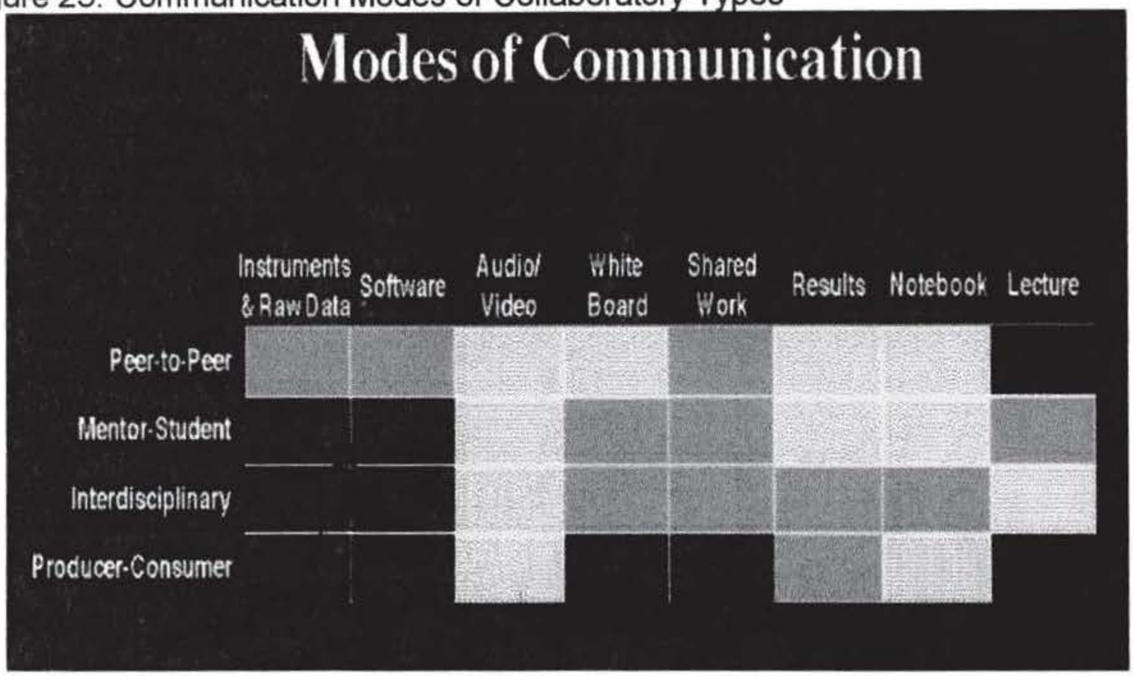
data) is needed, and communication about the meaning of results is necessary; and

Producer-Consumer collaborations where resident scientists perform experiments and interpret the data on behalf of others who prepare and send samples to the lab, and in which there is no competition, few shared concepts, and limited common vocabulary (http://www.emsl.pnl.gov:2080/docs/collab/research/CollabSociology.html.

EMSL research maintains that these four types of collaborations are universal and apply to education, medicine, and business environments as well as to the hard sciences, and that when one type of collaboration is undertaken, it often spawns one of the other types (Payne and Myers 1996).

EMSL's sociological research further identifies the communication needs of each of these four types of collaboratory sessions. Figure 25 is an EMSL-produced slide that shows the different modes of communication required for the four types of collaboratory sessions. (http://www.emsl.pnl.gov:2080/docs/collab/presentations/talk3.96/pg11.gif). The darkest squares represent communication modes that are not necessary, the medium gray squares represent modes of communication that are most necessary, and the light gray squares represent modes of communication that are moderately necessary to support collaboratory functions.

Figure 25. Communication Modes of Collaboratory Types



The EMSL Collaboratory includes access to digital library services in the form of collected published and unpublished articles, including preprints, but does not support the peer-review process or allow annotation of papers. Digital archives include scientist and experiment Notebooks (password protected), software files, and system logs. EMSL also has an aggressive program of both public and formal education, and is developing interrelationships with several regional colleges and universities using its CORE technologies in undergraduate science education.

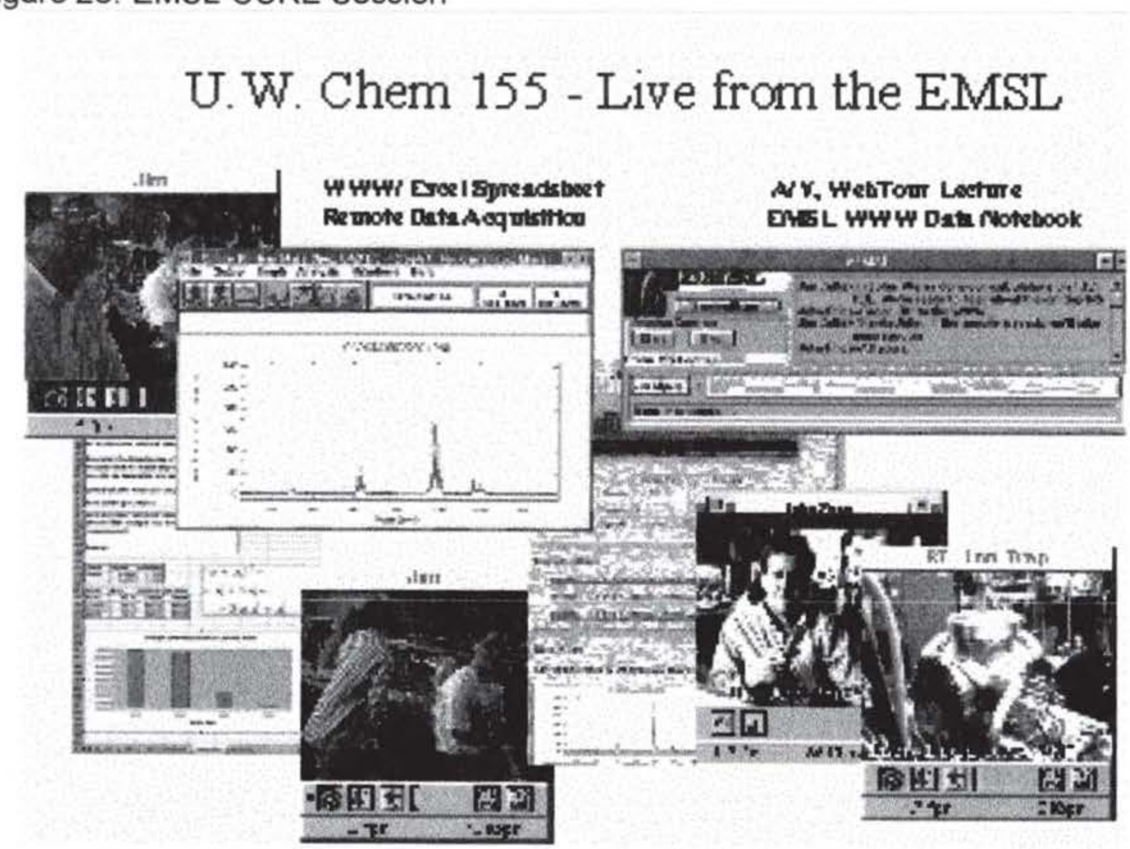
EMSL's Collaboratory for Undergraduate Research Education (CURE) connects regional colleges/universities with each other, and with the lab. Again, downloading and configuring the CORE proprietary software is necessary to participate in the program, as is training, and arranging for access to password-protected portions of the site. Figure 26 is a screenshot of a CURE web session during an introductory chemistry course at University of Washington. The CURE program is dedicated to the proposition that "learning science can be done by doing science: interacting with real data and professional scientists, working and learning collaboratively project oriented and interdisciplinary work" (http://www.emsl.pnl.gov:2080/docs/collab/projects/CURE/index.html).

EMSL's preliminary psycho-social research into the collaboratory is concerned with how the introduction of electronic communications might change and/or enable new types of collaborations, and how the synthetic environment of the collaboratory might be sustained. Findings of this psycho-social research are:

- **A collaboratory is a social system**...nothing less than the village square and campfire juxtaposed to the Information Age

- It relies on **social mechanisms of cooperation** in which collaborators must gain value from a relationship in order for it to be sustained
- It uses **props and controls for social discourse**
- **Either people or work are the focal object**
- It relies on **precedence and ritual** organized by spatial syntax and by ritualized norms of acting
- **A sense of place is essential.** (Wise n.d.)

Figure 26. EMSL CURE Session



Conclusion

Chapter Seven explores the Materials MicroCharacterization (M2C) Collaboratory's five TelePresence Microscopy (TPM) sites, and tests the usefulness of the **CIRAL** matrix of criteria for inclusion as a collaboratory developed in Chapter Six. Chapter Eight briefly explores "derivative collaboratories" that do not meet the **CIRAL** criteria for inclusion, and explores, through prolonged site visits, three additional Collaboratories that do meet the **CIRAL** criteria. Site visits to the Space Physics and Aeronomy Research Collaboratory (SPARC), the Remote Experimental Environment (REE) Collaboratory Experiment at the DIII-D Tokamak, and the Environmental Molecular Science Laboratory (EMSL) Collaboratory are described. Most of the thousands of online environments that use the word "collaboratory" fail to meet the criteria for inclusion because they do not provide access to and manipulation of remote instrumentation. There are undoubtedly other functioning collaboratories operated by business or the government which are outside the reach of this research because of privacy or security reasons.

Each of the four collaboratories explored in Phase Two is a unique information environment. The instrumentation to which each provides access is a major determining factor in the nature of those environments. Each of the four

Collaboratories serves a different scientific purpose, and each deploys a different combination of communication modes.

Comparison of Collaboratory Architectures

In preliminary sociological studies, EMSL identified four types of collaboratory: peer-to-peer, student-mentor, interdisciplinary, and producer-consumer, and the communication modes required for each. The M2C Collaboratory focuses on the simultaneous transmission of microscope and macroscope video views to and from solo or small groups of scientists working online with one or more of the five TPM sites. Participants have access to and can manipulate remote instrumentation, are supplied raw data in the form of microscope lens views, or lens view still shots captured in collaboratory notebooks. Digital archives, and limited digital library resources are available. There is no need for special software. M2C does not support audio, whiteboard, chat, or forum functions. M2C functions as each type of collaboratory, but does not provide the full range of communication functions described by ESML.

The SPARC Collaboratory is centered on the delivery of text and chart-type data that is constantly transmitted from remote instruments, and text-based communication among unlimited participants logged on via the Internet using publicly-available software. Participants have access to the data flow from but cannot control the remote instrumentation. Control of the instrumentation is limited to five specific sites that use specialized workstations. SPARC does not offer collaboratory notebook, whiteboard, audio, or shared work space functions, nor does it support lectures. SPARC functions as all but the Producer-Consumer type of collaboratory, and does not provide all the communication modes identified by EMSL.

The REE DIII-D Tokamak Collaboratory is centered around the audio and video intercommunication among hundreds of scientists, researchers, and technicians who either have their hands directly on some aspect of a very large piece of equipment, or are logged on remotely to participate in experiments or control the tokamak. REE DIII-D Tokamak Collaboratory sessions are events that require considerable preparation and coordination. Special software is required to participate, and all the communication modes identified by EMSL are supported. The REE DIII-D Tokamak Collaboratory functions as all four types of collaboratory.

The EMSL Collaboratory is focused on facilitating shared, project-oriented experiments in either one-time mode or on a continuing basis. Special software is required to participate. EMSL does not make its instruments available via public access to its website. EMSL functions as all types of collaboratory, and facilitates all the communication modes identified.

Comparison of Collaboratory Data Types

Table 8 summarizes the data types generated by each of the four collaboratories explored in this phase of the study. The primary data produced by the M2C Collaboratory are video taken from a microscope and macroscope cameras, with subsidiary data being the record of the video transmission from the labs, the archives of the site's distributed email list, and the content of researcher notebooks. The primary data produced by SPARC are multiple, continuous dataflows of chart and graph-type information, and the logs of the text-based chat sessions. The primary data produced by the REE DIII-D Tokamak Collaboratory are multiple, large data sets created by multiple instruments attached to the tokamak, and the audio, video, and text records of the intercommunication between experiment participants both before and during the event. The primary data produced by EMSL are raw data from the instruments, and the contents of collaboratory notebooks. All the collaboratories also have data generated as session logs.

Collaboratory	Type of Data Generated
Materials MicroCharacterization (M2C) Collaboratory's TelePresence Microscopy (TPM) Sites	Microscope lens still shots Record of video transmissions Archives of distributed email list Researcher notebooks Session (server) logs
Space Physics and Aeronomy Research Collaboratory (SPARC)	Continuous Dataflows as charts and graphs Chat Logs Session (server) logs
REE DIII-D Tokamak Collaboratory	Large, multiple experiment-specific datasets Audio, Video Text of experimenter intercommunications Session (server) logs
Environmental Molecular Science Laboratory (EMSL) Collaboratory	Raw instrument data Researcher notebooks Session (server) logs

Table 8. Comparison of Collaboratory Data Types

CONCLUSION OF PHASE TWO

Phase Two of this study explores four functioning collaboratories and finds that the collaboratory has many manifestations within the CIRAL matrix for inclusion. The common elements of these information environments are computerized networks and the humans who participate in collaboratory activities. The primary differentiating factor is the type of instrument to which each collaboratory provides access. Instrument type and uses, in turn, determine the level and sophistication of communication modes built into each collaboratory.

With implementation achieved, collaboratory research has turned to sociological and cultural aspects of the environment, specifically communication needs of collaboratory participants and the nature and culture of collaboratory work activity. Preliminary sociological studies are underway. From DOE's DCEE program, Bly (1997) identified six characteristics of collaboratory activity and six aspects of collaboratory work. EMSL researchers classify the collaboratory as a social environment and identified six psycho-social conditions of the collaboratory. This study confirms that the social environment of the collaboratory is instrumentally-determined, that is, the instrument to which access is provided determines the media and communication requirements of any particular collaboratory configuration. Media and communication modes, in turn, determine the social and cultural aspects of the environment. Whether and how the synthetic environment of the collaboratory is sustained will be determined by improvements in communication and media modes specific to each environment.

Bly believes the answers to the problem of collaboratory communication will be revealed by understanding the cultural evolution of the collaboratory. It is clear that future collaboratory research must include the social and cultural aspects of the environment, and that Nardi and O'Day's (1999) key constituents of information ecologies offer a guide to that research. It is also clear there is no one "formula" for collaboratory configuration. Each collaboratory is a unique environment determined by its instrumentation, and so also is a unique information ecology.

This study now turns to the people, practices and values of the collaboratory to probe for clues about the culture of the collaboratory and for skills that might be taught to prospective participants. Phase Three engages collaboratory pioneers identified during Phase One and Two in a permutation of the electronic Delphi to determine the "rules of the road" for the collaboratory and identify the skills Collaboratory Pioneers value in prospective participants.

Phase Three

Toward an Intersubjective Reality of the Collaboratory

CHAPTER NINE

DELPHI AMONG COLLABORATORY PIONEERS

Phase One of this study constructs an objective reality of the collaboratory based on library holdings, and proves as practiced principles Wulf's (1988) and Lederberg and Uncapher's (1989) assumptions that the collaboratory would be built from a relatively equal contribution from the disciplines as an inherently interdisciplinary environment. An emergent theory of the collaboratory as an harmonious, ungendered, intellectual information environment is put forth.

Phase Two of this study constructs a subjective reality of the collaboratory based on prolonged immersion in the online environment, and finds the collaboratory an instrumentally-determined social environment, with each implementation unique, supported by various combinations of communication and media modes, and generating unique combinations of data stores.

Phase Three of this study seeks an intersubjective reality of the collaboratory by engaging Collaboratory Pioneers in an electronic Delphi to determine the "rules of the road" for the collaboratory and identify skills collaboratory pioneers value in prospective participants.

"Rules of the Road"

In the Executive Summary of the 1993 report, *National Collaboratories: Applying Information Technology for Scientific Research*, the National Research Council identifies the need to determine the "rules of the road" for the collaboratory:

> Although articulating the rationale for collaboration may be easy, achieving effective collaboration is not. In part, the situation reflects the basic training of scientists: scientists have been educated to focus on individual activity and achievement. Moreover, scientists have had to compete with each other to attain recognition and resources. Collaboration tends to be easier on a small scale and when it is local: when a small number of individuals collaborate it is generally possible to proceed on the basis of mutual trust, but **'rules of the road'** are needed for larger-scale collaboration. These and other human considerations shape and constrain the collaborations that do take place: in some instances they also inform the design of incentives to promote collaboration. (NRC 1993, 2) (emphasis added)

What NRC meant by "rules of the road" is a matter of conjecture, but the expected differentiation of rules according to collaboratory size is clear. Nautically speaking, "rules of the road" are

> regulations concerned with safe handling of vessels under way with respect to one another, imposed by governments on ships in its own waters, or upon its own ships on the high seas. (Webster's 1989)

So defined, "rules of the road" for the collaboratory are inter- or intra-collaboratory protocols. While the functioning collaboratories identified in Phase

Two of this study are, on some levels, interrelated (by common funding source, because some sites hosts several collaboratories, and because the population of Collaboratory Pioneers is very small), they have not yet evolved to inter-collaboratory sophistication. An example of intercollaboratory work might be an investigation of the properties of plasma between the DEE DIII-D Tokamak and the SPARC collaboratories. Nevertheless, as the focus of collaboratory research shifts from technological implementation to sociological and cultural aspects of the work, generic "rules of the road" that apply to all collaboratories, and perhaps between collaboratories, now seem discoverable.

"Rules of the road" may also be organizational and/or cultural. Culture is an overarching part of Nardi and O'Day's (1999) information ecology (comprising people, practices, values, and technology). Anthropology defines organizational culture as

> patterns of shared values and beliefs that over time produce behavioral norms adopted in solving problems. Similarly, culture is a body of solutions to problems that have worked consistently and are taught to new members as the correct way to perceive, think about, and feel in relation to those problems. The sum of these shared philosophies, assumptions, values, expectations, attitudes, and norms bind the organization together. Organizational culture, therefore, may be thought of as the manner in which an organization solves problems to achieve its specific goals and to maintain itself over time. Moreover, it is holistic, historically determined, socially constructed and difficult to change. (Heck 1996)

To mine for the definition and attempt to discover the "rules of the road" for the collaboratory, and simultaneously identify skills collaboratory pioneers value in prospective participants, PhaseThree of this study turns to the Delphi Method.

The Delphi Method

Delphi is a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with complex problems (Linstone and Turoff 1975). It consists of a series of interrogations of a group of individuals whose opinions are of interest, with interrogations continuing in "'rounds" where the anonymous responses of participants are submitted to the group whole for comment until consensus, divergence, or stasis of opinion is reached. Delphi is also an interdisciplinary, intersubjective, futures research technique that allows translation of qualitative data for quantitative analysis, and is particularly useful when the field of interest is too new to have adequate historical data for the use of other methods (Lang n.d.).

The Delphi Method was developed by Kaplan, Skogstad, and Cirshick (1949) and refined by Helmer and Dalkey of the RAND Corporation in 1953 to answer the U.S. Air Force's question about the likely outcome of a Soviet nuclear attack on the United States (Linstone and Turoff 1975). Since then, the Delphi has been used many times, by most disciplines, for a variety of reasons, and under many permutations.

There are no hard and fast rules for Delphi implementation (Turoff and Hiltz, in press). Nevertheless, all Delphi Studies follow a broad procedural outline (Lang n.d.) In brief, the steps for a Delphi are:

1. The problem is identified
2. An expert panel is developed
3. The panel is presented the problem and asked to respond
4. Responses are synthesized into a series of statements
5. The synthesized statements are submitted to the panel
6. The panel responds
7. The process continues until convergence, divergence, or stasis is identified.

Delphi Studies share three distinctive features and common characteristics: anonymity of response, feedback of individual response to the group, and statistical analysis using median and dispersion. Statistical analysis is achieved by synthesizing individual participant responses and presenting them to the group in rounds as statements for individual Likert Scale (sliding scale) responses. In most Delphi Studies, participants are kept anonymous and never meet face-to-face. In all Delphi Studies, however, anonymity of responses is maintained to avert dominance of the group by influential or powerful participants, to avoid specious persuasion, and to avert unwillingness to abandon publicly expressed opinions and other social-psycho affects of face-to-face group decision situations (Welty 1971, Rosenbaum 1991, Turoff and Hiltz, in press).

There are seven basic types of Delphi: the conventional, numeric, policy, and historic Delphi (Strauss and Zeigler 1975), the derivative (when used with other methods), the pedagogical (Rosenbaum 1991), and the conference Delphi. The pedagogical and conference Delphi are executed in face-to-face situations with anonymity of responses (Rosenbaum 1991).

The Delphi Method has been used for futures forecasting, for prioritizing (Cline 1997), for community needs assessment and gathering initial or new information (Carter and Beauleiu 1992). It has been used for soliciting interpretations, predictions, or recommendations (Strauss and Zeigler 1975), for environmental scanning (Lang n.d.), for personnel and budget allocations (Kao 1997), and for participant education (Strauss and Zeigler 1975). The Delphi has been used for both normative (target oriented) and exploratory purposes (Acolyte 1995).

> Delphi operates on the principle that several heads are better than one in making subjective conjectures about the future... and that experts will make conjectures based upon rational judgement rather than merely guessing (Weaver 1971 in Ludwig 1997).

The Delphi's group consensus principle rests on a 1936 study (Loye 1978) by Douglas MacGregor that formulated what came to be known as the "MacGregor Effect, " which refers to his findings that predictions made by a group of people are more likely to be right than predictions made by the same individuals working alone.

The pitfalls of the Delphi Method are well-documented (Linstone 1975, Fisher 1978, Cook 1987), and include concerns that the Delphi does not adhere to traditional tests for statistical significance, sampling errors, and randomness. Delphi has been criticized for its tendency to encourage researcher urges to discount the future, make unwarranted predictions, and oversimplify. Major pitfalls also include the illusion of expertise among the panelists, and sloppy execution (poor panel selection, superficial analysis of responses, and designer's lack of imagination.) It has been faulted for its optimism-pessimism bias, which lures the researcher to project selectively and build on experiential data overlooking entirely new approaches, and for its tendency to researcher overselling or overuse, demonstrated by assuming the Delphi is methodologically appropriate. Further faults include using too many panelists, and methodological mismatch with the goal of the research. The Delphi has been characterized as an elitist rather than democratic process and faulted because participants structure the questionnaire, and finally, because of the possibility of deception.

Delphic deception is often illustrated by reference to the Greek myth of Ino, wife of King Athamus of Orchomenus. In the story, when the king dispatched a messenger to the Oracle at Delphi, and the King's wife, Ino, bribed the messenger to return with a falsified story, in the second round of consultation at Delphi, the Oracle based her pronouncement on the false version of her first utterances.

Criticism notwithstanding, studies comparing the Delphi's results with other methods (Ulschack 1983) confirm the effectiveness of the method related to generating ideas and use of participants' time (Ludwig 1997). There is renewed interest in the Delphi Method in light of the recent evolution of Computer Mediated Conferencing Systems and the personal computer's ability to immediately scale qualitative responses and calculate and represent quantitative group responses in real time. So used, the Delphi has been put forth as an appropriate platform on which to develop long-term knowledge systems, or "Collaborative Expert Systems" (Turoff and Hiltz, in press) in which statistical scaling techniques convert data from nominal to ordinal or ratio format (making them useful for inferential analysis), and allow dynamic contributions to an evolving, and queriable real-time knowledge system. Several web-based Delphi software programs are being developed and tested (Chen, Chiu and Beiber

1998, Mortensen et al 1997), although there are no reports of implementation or execution.

Turoff and Hiltz (in press) contend that the most important design criteria for the electronic Delphi is participant choice. The effectively designed electronic Delphi would allow participants to choose the sequence in which to examine and contribute to the problem-solving process and to exercise personal judgement about what part of the problem to deal with at any time in the process. Work is only just beginning on the design of the ideal computerized Delphi: one that would allow such sequential, parallel, or asynchronous activity by participants, and there is a need for a model which integrates the individual problem solving process with the group process (Turoff and Hiltz, in press). But, when developed, the electronic Delphi holds great promise as an analytical tool for application to existing and evolving collaboratory archives such as those discussed in this study's Phase Two, as well as for expansive research into the collaboratory's information ecology. This study employs a permutation of the evolving electronic Delphi for the purpose of identifying new information and to probe the emerging collaboratory environment for evolving cultural practices, and, while doing so, to identify skills that might be incorporated in collaboratory training and education programs.

Collaboratory Pioneers

The careful selection of participants and participant group size is critical to the successful Delphi. Delphi participants must be purposively (rather than randomly) selected (Ludwig 1997) based on individual qualifications and characteristics. While Delphi Studies have been successfully conducted with hundreds of participants, the median group size is 15-20 participants (Ludwig 1997). Debecq, Van de Ven and Gustafson (1975) suggest using the minimally sufficient number of respondents. Successful Delphi Studies have been executed with as few as five (Telecat 1998) or six participants (Strauss and Zeigler 1975). Since the Delphi is characterized as more of a "search for public wisdom than it is a search for individual knowledge or deliberative judgment" (Lang n.d.), the careful selection of individual experts who have knowledge of the subject and a participatory temperament is more important than rigid group size requirements.

Participants solicited for this study's Delphi meet the following criteria:

1. Participant must be associated with a functioning collaboratory that meets the **CIRAL** criteria for inclusion developed in Phase Two.
2. Participant must have a "big picture" position in the collaboratory (i.e. not be simply an occasional collaboratory participant or involved with a single, isolated aspect or portion of the collaboratory such as software development or infrastructure maintenance).

3. Participant must be a practicing scientist who has actively participated in collaboratory experiments and activities for at least one year (i.e. not just be an administrator or manager, or new to the environment).

These criteria reduce considerably the already small number of available Collaboratory scientists. Extensive and broad involvement in, and affiliation with a collaboratory that meets the **CIRAL** criteria was deemed important so that responses would not reflect either a singular experience or a predominately theoretical or administrative perspective. Seven candidates were identified during Phase One and Two of this study and were invited via email to participate in the Delphi. The email invitation included a brief description of the dissertation, with focus on the subject and execution of the Phase Three Delphi. Each invitee was asked to complete the online consent form at http://www.intertwining.org/dissertation/consent/p3consen.htm (Appendix D). A positive consent generated an invitation to nominate others who might also be appropriate participants. Six of the seven invitees agreed to participate. None nominated other participants. The participants were given several months to consider the subject of the Delphi before the Delphi was actually executed, and asked not to discuss the study with anyone during the interim.

All of the participants are involved with the functioning collaboratories explored in Phase Two of this study. All are practicing scientists who hold top-level positions in their respective collaboratories. All have national reputations; several have international reputations. Four of the participants are male; two are female. The researcher did not know any of the participants before the study was executed. Several participants contacted the researcher, as invited, by return email or telephone to ask questions or discuss the technicalities of the Delphi. There was no discussion of the Delphi topic prior to execution of the study, however.

Round One

The six participants were sent the Round One questionnaire (Appendix E) as an email message and asked to respond within two weeks. The questionnaire gave a brief description of the Delphi technique along with the short excerpt from the "rules of the road" paragraph from NRC (1993, 3) cited earlier in this chapter. Participants were asked to respond to two questions: "What are the 'rules of the road' for the Collaboratory?" and "What skills do you value in prospective participants?" "Rules of the road" was not defined so that researcher bias could be avoided and because it was expected that the emergent definition would be an important finding of the study. Participants were not identified to each other.

Four of the six participants responded to the Round One questionnaire. In many Delphi Studies the unresponsive participants are sent gentle reminders and urged to complete and return the questionnaire. However, keeping with Turoff and Hiltz's (in press) criteria of protecting and preserving choice in level and sequence of participation in the Delphi process, this study did not follow that practice. It was assumed that unresponsive participants would contribute in later rounds and as they deemed appropriate. One of the participants expressed reluctance to respond to the Round One questionnaire because the questions were sociological rather than physical, and were outside the scope and discipline of expertise, but that person responded briefly nevertheless, expressing the expectation to participate more extensively as the study progressed.

Round One responses ranged from brief sentence fragments to fully developed paragraphs. Each participant's response was read and digested as a body with attention to clues about the respondent's interpretation of "rules of the road." The four responses were distinctly different. Two respondents took a philosophical route, one exploring and interpreting the need for "rules of the road" and the NRC's alleged difference between small and large collaboratories. The other focused on the underlying issue of trust-building in relation to size of collaboratory. Two participants took a more practical approach to the questions, identifying "dos and don'ts" and other functional, behavioral, and cultural matters, one taking a very instrumental approach, the other taking a more sociological approach.

After the general evaluation of individual approaches to the questions, the individual responses to the "rules" and the "skills" questions were chunked into thirty-two freestanding thoughts. Each individual thought was transcribed onto a 5x7" card. The cards were shuffled to achieve random order and transcribed to an interactive web page (the text of which is included as Appendix F). For the "rules" section, respondents were asked to respond to each thought by completing a five point Likert Scale representing their level of agreement with each thought. Possible responses were agree, somewhat agree, no comment, somewhat disagree, disagree. A comment box was provided after each thought to allow respondents to expand, explain, or develop any of the thoughts. An additional comments box invited participants to add new items to the Round One responses and also allowed participants who did not respond to Round One to add afterthoughts which could be incorporated into subsequent rounds.

Eight of the thoughts in the "skills" section was assigned a one-to-ten ranking scale (one being an unnecessary skill and ten being a mandatory skill). The last eight thoughts on the Round Two instrument were the quantitative and qualitative findings of Phase One of this study. Participants were asked to agree, disagree, make no comment, or indicate that the thought did not apply. A total of forty-one "thoughts" were submitted to the group as Round Two.

Round Two

The Delphi participants were emailed the URL, or online address, of the Round Two instrument and asked to respond within one week. The url is http://www.intertwining.org/dissertation/round2.htm. The email message also included the name, collaboratory affiliation, and email address of all the participants, along with a reminder not to communicate with each other about the study. Responses to the web page form were programmed to feed a concatenated hypertext file and a concatenated, comma delimited text file, and also generated an email message to the researcher with comma-delimited responses enclosed. The qualitative options on the instrument were automatically converted to quantitative data for analysis purposes. Responses were fed into a Microsoft Excel97® spreadsheet designed to allow side-by-side viewing of the Round One thoughts and the Round Two responses and comments of all the participants, as well as the statistical interpretation of the responses.

One of the participants who did not respond to the Round One questionnaire replied to the Round Two email message with concern about the number and inclusiveness of the participant pool, and their representation of the group "Collaboratory Pioneers." This respondent offered to "round up" more participants for the study. The researcher replied to the message, encouraging nominations of qualified participants and providing details about participant criteria. The participant did not nominate additional participants, however, nor respond to the Round Two instrument.

The Round Two email message sent to the other participant who did not respond to the Round One instrument generated a system email message indicating that the person's disk quota was exceeded and that the message could not be immediately delivered, but indicated that attempts to deliver would continue for five days. The system did not generate a final undeliverable message, but the participant did not respond to the Round Two instrument. The four participants who responded in Round One responded to Round Two. None of the respondents added additional comments or items to the Round One responses.

Round Two responses are insufficient in number for the Delphi's traditional interquartile range analysis in which respondents whose answers fall outside the center-most 50% are asked to justify or explain the deviant answer or response. Alternatively, a means-based analysis was executed in which the average answer for each question was calculated and qualitative cross-thought analysis for themes was undertaken.

Seven of Round Two's forty one thoughts generated unanimous agreement; two of the unanimous thoughts were from the "rules of the road" section of the study, three were from the "skills" section, and two were from the section testing the eight qualitative and quantitative findings from Phases Two of this study. Only one thought (from the testing section) generated unanimous disagreement among participants. One of the testing thoughts generated a different response from each of the four participants. Detailed analysis of each section of the Round Two responses follows.

"Rules of the Road" -- Discussion

All but one of the twenty "thoughts" about the "rules of the road" for the collaboratory were agreed to or somewhat agreed to by a majority of the respondents. While several of the thoughts generated individual disagreement, only one thought generated majority disagreement. The five point scale for possible responses was agree, somewhat agree, no comment, somewhat disagree, disagree. Respondents provided comments on seventeen of the twenty thoughts, for a total of thirty-two comments.

The two thoughts about "rules of the road" that generated unanimous agreement (with respondent comments) are:

1. Be direct. If you have an idea, complaint, or any comment, say it. If you need something, you must ask. Don't expect anyone to read your mind.

   This is important -- the lack of body language, feedback, etc. makes it very hard to pick up subtle expressions of frustrations, etc.

2. You must get involved and get someone in the collaboratory interested in working with you on a problem.

   > Collaboratories should not be approached as a technology push -- deployment should be fueled by the needs of the scientists.
   >
   > If you don't, it will slow down the pace of the research project!
   >
   > One can only spend a limited amount of time playing with collaboration toys. Eventually you have to work on a real problem.

The only "rules of the road" thought that received majority disagreement concerned publications production. The original thought was:

> When researchers visit a collaboratory facility it is probably to complete an experiment resulting in publications: if a researcher pops into a virtual room/session and discusses ideas with colleagues, there may be no direct publishable artifacts.

Three respondents somewhat disagreed with this thought, and two offered comments:

> Publications do not always come out of each experiment. My experience is that a group of experiments conducted over several sessions will usually get a publication.
>
> Maybe true but this is "apples and oranges." While on a site visit, a researcher will have hallway conversations that do not result in a publication.

Although there was no strong overall disagreement with any of the remaining statements, communication issues related to a balance between "hallway conversations" (unscheduled, spontaneous meetings) and formal communications, and planned collaboratory meetings, and between experiment flexibility and rigid experiment planning. Both issues have an undercurrent about trust, and generated the strongest dialog among the remaining "thoughts." While planned, regular collaboratory sessions are considered important for stimulating frequent communication, they are seen as the equivalent of coffee breaks, and do not substitute for planned, scheduled project meetings:

> 'down the hall" (type meetings) imply spontaneity. Frequent communication is very important and scheduled meetings help do that.
>
> It depends on the nature of the collaboratory. You cannot always structure the collaboration. It needs to adapt to the types of work. Some require regular participation, others don't.
>
> One frustration I foresee with planned, regular sessions--as with in-person meetings--(is that) participants may not show up, whether due to conflicts or declining interest. To me, it seems the frustration associated with this would be greater for remote colleagues than for colleagues physically down the hall.
>
> That's what coffee break style meetings, or environmental (always on) video are for.

Two of the participants somewhat agree that establishing at the onset who will do which part of the experiment and follow up analysis is important. The other two somewhat disagree, one commenting that such planning is no different than on a normal (non-collaboratory) project, and the other warning that maintaining flexibility and willingness to change is necessary since some experiments cannot be planned accurately.

It was generally agreed, and to one participant very important, that collaborators commit to making frequent deposits of data, notes, etc. to a shared electronic notebook or database so all collaborators can stay up to date and so the progress of the research can be as efficient as stopping by a colleague's office down the hall to take a look at data. Another participant commented that this takes work. The respondent who somewhat disagreed with this thought explained that while it is helpful, collaboratory technology should be able to automate these processes:

> instruments sending data directly to notebooks or things like the Crosspad - you write on paper and an electronic copy is made that can automatically go to an electronic notebook.

It was agreed that electronic interaction shifts work between collaborators: that when a researcher physically goes to a facility to do an experiment they are available to help with instrument maintenance and configuration, to get supplies from the storeroom, etc., while the remote researcher is not. One respondent commented:

> This is critical. I have heard many people express a lack of interest in collaboratories due to issues like this.

The differing communication needs as related to the trust-building process within large and small collaboratories were generally recognized. One respondent disagreed that size is an important consideration, however:

> I don't see why (establishing trust in) large scale (collaboratories) should take any longer. If everyone is communicating electronically everyone is still on the same scale - i.e. everyone is "equal" electronically, there may be more people/groups to interact with, but I believe the trust level would develop at the same rate as a small collaboratory.

Another did not see size as a trust-building issue unique to collaboratories:

> Isn't this just as for local small and large groups? My statement was that the unique aspect of collaboratories versus local interactions was not the size of the group, but the informal, cross-organizational aspect.

It was generally agreed that trust takes time to build and the time constant is much longer when contact is less frequent due to time and/or distance; however, this was seen as "very personality dependent -- 'trust at first sight' does exist in the world!"

The participants agreed that the balance of trade in informal interaction may favor one person/culture/organization over another with one participant pointing out that this is always true.

All participants but one (who disagreed but had no comment) agreed with the statement

> Our inability to measure value of informal interactions is one reason we organize--we get common culture, i.e. people learn to provide similar amounts of informal help to each other; all the benefits of these interactions accrue to the organization; both these lessen the need to measure them.

It was generally agreed that many if not most research projects can be enhanced by using a collaboratory, but that collaborators must embrace that collaboratory work will take extra time to get up to speed and is subject to glitches in technology and the Internet, or collaboration will be slowed down such that it will not compete as an effective alternative to traditional methods.

> Collaboratories can provide real benefits now. However, a user who thinks they will solve all their current collaboration problems without encountering some new (smaller) troubles is due for a reality check. Collaboratory developers/promoters need to make sure they don't oversell current capabilities or we'll have some backlash.

It was generally agreed that "rules of the road" are an attempt to find a balance between differing cultures, but such rules are still ad hoc:

> Often, Collaboratories require that you formalize processes (perhaps by writing the procedure into collaboration software) that are currently informal or that differ between organizations.

All but one respondent (who disagreed), agreed with the statement

> Because collaboratories are still new enough to be subsidized (we fund development of tools and creation of virtual facilities, accept papers on these topics, etc.) buys time to get the rules right. As collaboratories become standard practice, the subsidies decrease, and the need to equalize the benefits will increase.

"Rules of the Road" -- Analysis

Delphi participants represent all sizes and types of Collaboratory identified by early EMSL psychosocial studies as discussed in Phase Two of this study. Size of the collaboratory, and level of involvement in collaboratory activity might explain the subtle but remarkable differences in preference for balance between formal and informal communication, and planned and fluid experiment modes, as the NRC suspected.

Tuck and Earle (1996) explore the communication modes of different group sizes in the corporate environment, relying on classical cultural anthropology studies to conclude that group size is always a determining factor in group communication structures (Johnson and Earle 1987, Earle 1987, Schmookler 1984, Johnson, 1982). While each individual's role and behavior within the group is determined by inherited nature, upbringing, and training, two communication modes: the egalitarian and the hierarchical, and four universal subgroup structures: the working group, the camp, the tribe, and the state, naturally exist whenever people live or work together in groups.

The two communication modes and their size-based substructures are:

Egalitarian, arising from the belief in equality among all, includes

- The **working group**, which is a temporary association of two to six people, each with useful skills, who come together for a specific purpose, work democratically, organize quickly and informally, and disband when the problem is solved. Leadership of working groups arises from within the group by consensus. Members function at the innate behavior level, meaning that no new or dramatically different communication skills or rules are necessary; and

- The **camp,** which is made up of six to thirty people who have little specialization, and whose job is to make decisions. Although the camp itself may deny having a leader, the camp is lead by a facilitator who is respected for knowledge judgments and skills in organizing opinion. The facilitator leads rather than commands the camp by focusing the decision-making process. The camp does not solve problems, merely makes decisions about how and what problems will be solved (once a decision is made about a problem, the camp delegates the work and smaller working groups, which solve the problem.) When the decision making process of the camp is disrupted, camps often split, forming new camps. Individuals are frequently members of both a working group and a camp, as is the case with most small businesses or companies.

Hierarchical, a system of ranks, one above another, including

- The **tribe**, which is made up of fifty to one hundred people and usually encompasses several camp-size groups. The tribe has a clearly defined leader, many strata, and clear lines of authority. It has well defined rules and patterns of behaviors, and is lead by a chief, who makes decisions for and gives orders and edicts to the tribe. Tribes solve the problem of instability in large organizations, but at the cost of personal and group autonomy. The purpose of the camp is bureaucratic: to facilitate relations with other camps (including conducting commerce and war), for conducting religious observations, and to allow occupational specialization.

- The **state,** which is made up of one hundred or more people, and includes multiple tribes, camps, and working groups. Like the tribe, the purpose of the state is bureaucratic. A camp-like council (which, in the corporate structure, is the Board of Directors) leads the state.

The purpose of Tuck and Earle's research is to determine why Chief Executive Officers, or CEOs, fail. They find that CEOs frequently fail when a communication structure appropriate for one scale is used for groups of other sizes, as when, after promotion from the ranks, a CEO continues to use egalitarian communication modes when hierarchical modes are appropriate. They also find that that CEOs fail when they do not shift gracefully between modes, as when they move from communicating with their employees (a hierarchical tribe or state) to communicating with their board of directors (an egalitarian working group).

The universal differences Tuck and Earle find in communication modes attributed to group size might also be reflected in the culture of the Collaboratory, and could explain the slight but remarkable difference in preference for either informal, unstructured communication and flexible experiment planning within a larger, structured environment, or more formal communication modes and well-planned experiments, and within them, informal and adaptive behaviors.

Conceivably, collaboratory participants might function in all four group sizes simultaneously: as a member of a working group (as on a specific experiment); as a member of a camp (in their role as a researcher associated with a specific collaboratory); as a member of a tribe (as in collaboratory management or administration within a larger laboratory environment); and as a member of a state (as in their place with larger U.S. National Laboratories or with government funding agencies.) Conceivably, each collaboratory implementation might need to support all four group sizes. Clearly, a keener understanding and mapping of the different communication modes and group sizes as they relate to the various collaboratory configurations, and on size-crossing participant roles, will shed light on the preference differences uncovered in the "rules of the road" portion of this Delphi. Such studies would also be useful for configuring automated collaboratory expert systems where the answer to a problem might be significantly different depending on which group size originates the problem, and from which size group a solution or opinion is offered. It would also be interesting to discover if having virtual presence as an individual functioning physically in one group size and virtually in another has impact on the way science is conducted, and the impacts of that simultaneity on the scientist.

"Skills Valued in Prospective Participants" - Discussion

In Round One of this Delphi, participants generated thirteen thoughts about skills they value in prospective collaboratory participants. Five of the thirteen thoughts were presented to the group using the same five-point Likert scale used in the "rules of the road" section. Participants were asked to indicate their level of agreement with each thought and were given the opportunity to make further comments and additions. Eight specific skills were also presented so participants could indicate on a scale of one to ten the level of value they had for each skill, with one being an unnecessary skill and ten being a mandatory skill.

Participants agreed unanimously and without further comment with two of the first eight thoughts generated in Round One. Those thoughts are:

1. Anyone who has a real project in mind (something they want to get done that is cumbersome using travel, email, fax) probably has the right mindset to go forward (trading difficulties of real-world interactions for the reduced difficulties of working via collaboratory).
2. Anyone looking for the perfect solution will probably be disappointed.

Three of the thoughts received substantial, although not unanimous agreement (although none of the statements was disagreed with). Those statements, with participant comments, are:

3. Know why the problem is important to study...enough so to get people interested in helping as well as justifying the time spent on the study.
4. Have some basic knowledge of the science. You don't have to be an expert, but you must be able to discuss it and provide appropriate support at your end to do what is necessary on your part.

   > The fact that collaboratories can allow anyone, e.g. grade school students to access the best instruments in the country should not lead to the expectation that they will start winning most of the peer-reviewed time allotments.

5. Be willing to participate/help with other problems of appropriate nature. Don't expect to be helped without returning the favor at some time in the future, for some arbitrary participant.

Eight specific skills identified by participants in Round One were presented for ranking in value on a one-to-ten scale (one being an unnecessary skill, ten being a mandatory skill). One of the eight received a unanimously low ranking. The remaining seven skills, on average, were ranked 5.5 and above. None of the skills were ranked mandatory, and none were ranked unnecessary. Following is the ranking of those skills, in descending order of value, with mean rank on the one-to-ten scale in parentheses:

6. Tolerance for evolving technology and practices (7.5)
7. Good communication skills (7.0)
8. Good to expert scientific knowledge (6.5)
9. Experience in the (scientific) techniques used (6.25)
10. General team skills (6.25)
11. Familiarity with Internet technology and software (not at a programmer level, but someone who uses a desktop PC on a daily basis and is familiar with spreadsheets, data processing software, etc.) (5.75)
12. Good computer skills/computer literacy (5.5)
13. No one is an expert at everything but everyone has some expertise in something. We expect you to offer to share it when the right time comes (1.25).

"Skills Valued in Prospective Participants" - Analysis

Collaboratory Pioneers value a balance of social, technological, and scientific skills in prospective participants over a superior expertise in any one of them. Social skills identified include tolerance for evolving technologies and practices, good communication skills, team skills, adaptability, and willingness to share and contribute equally. Scientific and technological skills valued include good to expert scientific knowledge, familiarity with scientific techniques, and personal computer applications and Internet fluency. In addition, collaboratory pioneers value in prospective participants the ability to identify and articulate the importance of a particular scientific problem, to engender interest and participation in that problem, and to recognize and be able to articulate the value of collaboratory work in excess of the impediments it might present without creating an inflated perception of collaboratory capabilities.

"Testing Perceptions" - Discussion

The final eight thoughts presented in the skills section were statements derived during Phase One of this research, and were not generated by the Delphi participants. These statements were included to test participant perceptions of these findings. Participants were asked to indicate whether they agree with, disagree with, have no comment on, or to indicate that the statement did not apply to the collaboratory.

Eight findings were generated during Phase One of this study. In Phase One, quantitative, taxono-bibliometric analysis of the library literature reveals a relatively equal contribution to collaboratory publications from the hard and soft sciences, and that the collaboratory is, by example, motivation, principles of interaction, and terminological hierarchy (Klein 1990, 56) an inherently interdisciplinary environment. Synoptic analysis of twenty-two Theory-Type Research publications produced four additional collaboratory principles:

- integration and adaptability are necessary and good
- change, choice, and personal power are requisite
- consensus, sharing and exchange are positive and practiced
- individuality and collectively are distinctly and respectfully maintained.

The absence of traditional male social and scientific behaviors, coupled with the traditionally female characteristics of these findings led to the emergent theory that the collaboratory is an ungendered environment, a theory that confirms, in part, the basic assumption that the collaboratory will fundamentally change the way science is done.

Two of these statements received unanimous agreement from Collaboratory Pioneers. Along with the comments, those statements are:

1. The collaboratory fundamentally changes the way science is done.

   Yes and no--science is still science, but I think Collaboratories do represent a revolution in flexibility and the ability to solve complex problems rapidly.

2. Integration and adaptability are necessary and good.

   Scientific experiments are by definition unique--collaborative problem solving software must be able to adapt to constantly changing procedures.

All but one participant (who had no response) disagreed with the statement "The collaboratory has been built from a relatively equal contribution from the hard and soft sciences." The statement generated only one comment:

> I think the deployment of Collaboratories is being driven by technologists and physical/biological scientists with collaboration needs. The soft sciences need to contribute more -- real world insights and advice, predictive models that help abstract the results of psychology, cognitive, group dynamics and other studies in controlled setting to the real world.

All but one participant (who disagreed) agreed with the statement "Change, choice, and personal power are requisite":

> Not requisite, but I think Collaboratories allow more change, choice, and personal power.

Two participants agreed with and two said the statement "consensus, sharing, and exchange are positive and practiced" did not apply.

> I agree, but Collaboratories are not communes--people share just as they did without a Collaboratory, except that Collaboratories make sharing easier, so (it) more naturally occurs, as appropriate.

Two participants agreed with, one had no response to, and one responded that the statement "Individuality and collectivity are distinctly and respectfully maintained," did not apply:

> Collaboratories do not change people's ideals about sharing, respect for individuality, etc., but by lowering barriers, they may bring practice closer to ideals.

All but one participant (who responded "does not apply') agree with the statement "The collaboratory is an interdisciplinary environment."

> Agree, although I think it used to be mainly one discipline and is perhaps still somewhat skewed that way. It is easier to get going in it if one is collaborating with remote colleagues in the same discipline.

> Collaboratories lower the barrier to interdisciplinary work, that's all. The drivers for interdisciplinary work come from outside (brought by researchers, sponsors, the public, etc.)

The statement, "The collaboratory is an ungendered environment" received the greatest variety of responses, a different response from each participant, including an agree, disagree, no response, and does not apply, but only one participant added a comment, "Agree, probably more so than a local environment."

"Testing Perceptions" - Analysis

The statements generated from Phase One of this study, and the reaction to them from collaboratory pioneers do not bear the weight of more than superficial analysis. Nevertheless, that collaboratory pioneers are unanimously unaware of the level and extent of social sciences' published contribution to the theoretical and practical research leading to collaboratory implementation warrants some comment and inference. First, the use of the word "built" in the question may have been misleading. Participants may have thought "built" meant actual, physical construction of the environment, and not theoretical or conceptual contributions to its development. Part of the knowledge gap these findings reveal is undoubtedly due in part to the library's failure to make collaboratory-related literature easily accessible (as discussed in Phase One) as well as to scientists' habit of reading and publishing in publications that are predominately within their own disciplines and specialties.

While it is not appropriate to project to the entire Collaboratory population from this thin study of collaboratory pioneers, it is appropriate to infer to the environment that an information opportunity exists within the Collaboratory for librarians and information specialists and researchers. Including librarians in collaboratory environments would benefit collaboratory participants and enhance online collaboratory resources; and a general understanding of collaboratory practices and culture will position librarians, as educators, to prepare prospective participants, and prepare for prospective participants' information needs.

That the "ungendered" statement received a different response from each Delphi participant is significant. The range of responses could be because the concept of "ungendered" is difficult, highly subjective, and perhaps cannot be disassociated from the multifaceted definitions and perceptions of feminism as discussed in Phase One. The range of responses may also be based on individual personal experience, situational perceptions, or lack of interest in the issues it raises. Certainly, the theoretical ungenderedness of the Collaboratory developed in Phase One warrants testing in the functioning work environment of the collaboratory and should be explored along with group size communication modes and experiment planning preferences.

Conclusion of Phase Three

Phase Three of this study constructs an intersubjective reality of the collaboratory by engaging Collaboratory Pioneers in a Delphi Study to determine the "rules of the road" for the collaboratory and identify skills they value in prospective participants. Six Collaboratory Pioneers associated with collaboratories meeting the CIRAL criteria for inclusion developed in Chapter Five, who have "big picture" positions within those collaboratories, and who are also practicing collaboratory scientists, where solicited for this Delphi and agreed to participate, although only four actually responded to the two rounds.

The first round of the Delphi asked two questions: "What are the 'rules of the road' for the collaboratory, a question raised in NRC's (1993) *National Collaboratories: Applying Information Technology For Scientific Research,* and "What skills do you value in prospective collaboratory participants. The Round One questionnaire generated twenty thoughts about "rules of the road" and twelve thoughts about "skills valued in prospective participants." Eight statements developed during the qualitative and quantitative analysis in Phase One were added, and a forty item web-based Round Two instrument was developed and resubmitted to participants. The instrument asked participants to indicate their level of agreement with thirty-two of the items, and to rank the value of eight items on a one-to-ten scale. A comment box allowed participants to expand, explain, or add new items to the study. Four participants responded to the Round Two instrument. No further reduction to consensus or stasis was necessary to preliminarily identify the "rules of the road" for the collaboratory and the skills Collaboratory Pioneers value in prospective participants, which are enumerated below.

Based on the four responses, following are the "rules of the road" for the Collaboratory:

1. **Be direct in your communication**. If you have an idea, complaint, or any comment, say it. If you need something you must ask. Don't expect anyone to read your mind.
1. **Get involved** and get someone in the collaboratory interested in working with you on a problem.
2. **Have a real problem** that the collaboratory can help solve. Be able to articulate the problem and accurately express to others how the collaboratory can be used to resolve it.

3. **Understand the opportunities and limitations of collaboratory work.**
4. **Stay flexible** within a formal framework of meetings and experiments. Collaboratories must include a balance of planned, regular collaboratory meetings, experiment sessions, and formal project meetings, and unscheduled, informal meetings and spontaneous experimentation.
5. **Make frequent contributions** to collaboratory data repositories.
6. **Working in a collaboratory is not the same as being physically present in a laboratory.** Remote collaborators need to find ways to contribute to and share the "chores" of collaboratory work to compensate for their physical absence.

Following are the skills Collaboratory Pioneers value in prospective participants, in descending order of agreement:

1. Tolerance for evolving technology and practices
2. Good communication skills
3. Experience in the scientific techniques used
4. Good to expert scientific knowledge
5. General team skills
6. Computer application and Internet competence.

It was tempting to continue the Delphi beyond two rounds just to probe more deeply into the individual perceptions and opinions revealed in the comments, but given the number of participants, such a probe would reveal more about the individual participants than it would about the cultural environment of the collaboratory generally.

Four themes that warrant further research surfaced during Round Two. The first, a statement derived from Phase One's findings that the collaboratory has been built from a relatively equal contribution from the hard and soft sciences, generated general disagreement from Delphi Pioneers. As discussed, this disagreement may stem from differing interpretations of the word "built." The respondents may consider "built" to mean physical construction and technologically implemented, rather than conceptual design or theoretic exploration, as Phase One's interpretation of the literature implies. It may also reflect the exact opposite attitude Wulf warned about in his *White Paper*: instead of theoretical researchers having problems accepting the value of practical, technological research, perhaps practical, technological researchers do not recognize the value of theoretical, conceptual research work.

The second and third themes that warrant additional research are closely related, if not intertwined, and concern the balance between informal communications and flexible experiment planning, and formal communication and rigid experiment planning. Group size is suggested as a possible reason for the differences of opinion and preferences. The fourth theme concerns finding a balance of contribution to or a new sharing ethic between on-site and remotely located collaborators.

That collaboratory pioneers underestimate the contribution that social sciences have made to collaboratory research is a knowledge gap that may also be attributed to shortcomings in the library's indexing and classification practices, and to scientist's tendency to maintain disciplinary focus in their reading. The issues of preferences in level and mix of communication modes, experiment flexibility, and the collaboratory sharing ethic may be attributed to group size. Expansive research in each of these four areas will be useful during continued design of collaboratory interfaces and will shed light on the information needs of collaboratory scientists.

The emergent population of scientists who practice in the collaboratory may also be fertile ground for future investigations. Since each of the pioneers is first a disciplinary scientist, and only secondarily an implementing technologist, this population may hold clues about the changing nature of the role of scientist, and the impact of technology not only on the way science is done, but the division of their labor between science and technology. It may also herald the emergence of a new discipline (Kuhn 1970), the collaboratory scientist.

CONCLUSION OF THE STUDY

Many different influences impinge on the creation of knowledge. Evolutionary-cybernetic epistemology as explored by the Principia Cyberneticia Project (http://pespmc1.vub.ac.be/) is concerned with the broad domain of cybernetics and general systems theory (Bertalanffy 1968), and specifically the transdisciplinary study of organizations, communication, control and modeling (Heylighen 1993, 1997). Their metasystem design theory identifies three "super classes" of influence that embody understanding and development of holistic knowledge: the objective, subjective, and intersubjective.

Objective knowledge is derived from an external object, is measured by the reliability of predictions to which it leads, and is judged by the criteria of distinctiveness, invariance, and controllability. Subjective knowledge is the measure of ease with which knowledge is individually accepted, and is judged by individual utility, coherence, complexity, and novelty. Intersubjective knowledge is a measure of fitness of knowledge with respect to the community of carriers, and is measured by formality, conformity, infectiousness or publicity, expressivity, collective utility, and authority (http://pespmc1.bub.ac.be/KNOWSELC.html).

This study explores the information environment of the collaboratory from each of these perspectives, in linear sequence. In Phase One, an objective reality of the collaboratory is constructed using quantitative taxono-bibliometric analysis of collaboratory-specific publications (n=86) that are made available through the world's libraries, and synoptic content analysis of the subset (n=22) Theory-Type Research publications. Phase One determines that the collaboratory literature reflects a relatively equal contribution from the hard and soft sciences, and that theoretically, the collaboratory, as an environment, is inherently interdisciplinary and ungendered.

Phase Two constructs a subjective reality of the collaboratory based on prolonged immersion in the online environment. Phase Two determines that the collaboratory is an instrumentally-determined social environment comprising unique and individual configurations that variously combine modes of communication and media, and generate unique combinations of data stores.

Phase Three constructs an intersubjective reality of the collaboratory via a Delphi among collaboratory pioneers. Phase Three identifies the "rules of the road" for the collaboratory and the skills Collaboratory Pioneers value in prospective participants. It finds intersubjective cognitive dissonance with Phase One's objective, theoretical findings of relative equality of contribution, and ungenderedness, and determines that in the collaboratory, size matters, exploring groups size is a determinant in the subtle yet distinct differences in preference for mix of informal and formal communication modes, and flexible and rigid experiment planning.

Traditionally, the objective, subjective, and intersubjective routes to knowledge construction are linear and sequential. The traditional academic route is from literature analysis, to laboratory experience, to interaction with peer groups though conferences and the peer review publication process. Implicit in the assumption that the collaboratory will fundamentally change the way science is done is the notion that the objective, subjective, and intersubjective will somehow fuse online, ideally resulting in new ways of knowing, and more pragmatically in a quickening in time of the thought-to-finish process. McLuhan observed that, at first, new technologies are always used to do old tasks until some driving force causes those technologies to be used in new ways. This study finds the collaboratory at the juncture of old tasks and driving forces.

Phase One's analysis of the library holdings reveals objectively that the collaboratory, as measured by collaboratory-specific publications generally and by Theory-Type Research publications specifically, has been built, at least theoretically and conceptually, from a relatively equal contribution from the hard and soft sciences. However, Phase Three's Delphi among collaboratory pioneers reveals a near unanimous perception that the opposite is true. This gap in understanding, or cognitive dissonance, can be variously attributed. First, the dissonance can be attributed to the use of and possible misinterpretation of the word "built" in this research. Second, the comprehensive identification and collection of the collaboratory literature as described in Phase One reflects the libraries' general failure to provide or facilitate adequate and easy access to the emerging body of knowledge, either because of shortcoming in existing cataloging, classification, and indexing and abstracting schemes that perpetuate disciplinary separation and lack of consilience, or its failure to develop access tools that overcome the disciplinary focus and isolating tendency of periodical publishers and database services.

The subjective reality created in Phase Two reveals no direct or continuing involvement by librarians and information professionals in the design and configuration of collaboratory interfaces and information resources, and a remarkable lack of standard electronic librarianship. Collaboratories have been built, that is, physically constructed, by collaboratory scientists, that is, scientists with a primary discipline like materials science, physics, or molecular biology, who have been motivated by need or interest to take their science online. The **CIRAL** criteria for inclusion as a functioning collaboratory developed in Chapter Six includes digital library resources and services. While each of the collaboratories explored in Chapters Seven and Eight provide links to external information resources, not one includes the services of a librarian, nor do the resources appear to have been developed by human information needs-centered professionals.

Despite the collaboratory's promise of new ways of doing science, Phase Two of this study finds that collaboratory work reflects the traditional ways of doing science, but that it is done with the new medium of computerized networks. Like the laboratory, the collaboratory is a "place to go" to do aspects of traditional science, namely experiments, but is not yet a holistic, integrated virtual information environment capable of supporting new ways of doing science. Scientists must still "go" elsewhere (even if electronically) to conduct literature searches, they must still relate their experiment and results to a disconnected and scattered body of knowledge, and they must still write and publish their findings elsewhere, they must still manually search and retrieve relevant and pertinent information to support their work, for themselves. Beyond overcoming the problem of space, that is, the necessity to be physically present at an instrument in order to participant in an experiment, the unique capabilities of the computer have not been exploited to maximize the information efficiency of the collaboratory. The processes of constructing a consilient objective, subjective, and intersubjective knowledge environment are in their very elementary stages. The potential information flows to support collaboratory work have not been automated to the collaboratory interface, and the extensive data stores generated by collaboratory activity have not been made accessible for expansive research.

Research Needs

The collaboratory was formally visioned by William Wulf in 1988 and first fully implemented in 1997. The environment is young. Collaboratory Science is now widening its focus from technological implementation to include cultural and psychosocial aspects of collaboratory work. The opportunity to address the information needs identified by this research is at hand.

This study identifies several areas of needed research:

1. The preliminary findings of this study need to be confirmed with more experts and in different collaboratories.
2. Evaluation and analysis of existing collaboratory data stores with an eye toward:
   - exploiting those stores to provide automated, intelligent information flow to the collaboratory interface, and
   - consilient, expansive studies of collaboratory work practices.
   - mapping and modeling the actual work practices and information needs of collaboratory participants as they relate to trust building according to collaboratory size toward

- informing the design of collaboratory interfaces, and
- developing a Delphi-based Collaboratory Expert System.

3. Evaluation and analysis of extra-collaboratory information practices of collaboratory scientists as they relate to the library toward
   - developing a collaboratory science library, and within it,
   - discipline-, instrument-, and experiment-specific information resources pertinent to practicing collaboratory scientists, and
   - exploring the usefulness of the discipline x focus, article type, and topic x approach taxonomies developed in Phase One as the foundation of an interdisciplinary classification scheme on which to build a virtual interface to the collaboratory literature.

These specific areas of research can be tackled from a variety of perspectives, both on-site and virtually. The perspective and question raised by Wulf (1988) and reflected in the National Science Foundation's current Knowledge and Distributed Intelligence (KDI) research agenda, "*Why* do scientists collaborate online?" will provide knowledge about motivation and insights into new tools that might be developed. The perspective "*How* do scientists collaborate online?" will provide knowledge about existing practices and how the current generation of tools might be improved. Each perspective generates a unique set of research questions, all of which can be tackled with both quantitative and qualitative information studies techniques. The purpose of this study is to create a foundation on which such expansive research might rest.

As the collaboratory continues its evolution from old science with new tools, to new science, and as the collaboratory becomes more widely available, careful attention to the emergence of new rules and the need for new skills is necessary. An expansion of this study's Delphi to a larger population will allow the rules and skills identified to be more widely extrapolated, will allow keener investigation of the size issue, and inform the development of Collaboratory Expert Systems. However, rules and skills are reflections of a culture in time, and care must be taken that the rules of one group are not imposed by perceived authority on subsequent groups.

The collaboratory is a new culture, inhabited by new class of scientist, the Collaboratory Scientist, who brings disciplinary expertise to the virtual environment. This study finds the cultural and organizational rules of Collaboratory Science remarkably, if not dramatically, different than those of traditional science, and supports Wulf (1988), and Lederberg and Uncapher's (1989) assumption that the collaboratory will bring fundamental changes to the way science is done. Certainly, the change is technologically-enabled, in that what was once done in person is now done via computer networks, but there is also theoretical evidence that the change is sociocultural and might be linked to the ungenderedness of the environment and the need to incorporate traditionally female behaviors. But, while this study finds no evidence of gender bias in either behavior or presentation of the online collaboratory, it also finds no compelling evidence that collaboratory participants agree. Of course, this could be because they are part of the system, a position that keeps them from seeing the system in its entirety (Bertallanfy 1968).

The collaboratory is a purposively designed and executed virtual scientific information environment executed from within the traditionally male-dominated environments of science and technology. It is remarkable, and to the credit of those scientists and technologists, that theoretically the collaboratory, by design, requires collaboratory scientists to practice traditionally female behaviors such as cooperation rather than competition, and group rather than individual work.

As a new and yet largely unpopulated environment the collaboratory is now available for use by scientists, technologists, and educators worldwide. Armed with the "rules of the road" and knowledge of the skills valued in prospective participants, educators, librarians, and other information professionals are positioned to assist and facilitate the transition toward and evolution of this newly constructed information and knowledge environment.

As the driving forces that lead to the new science of the collaboratory emerge, library information science has new opportunities to be of service. With its unique and specialized knowledge of the delicate nuances and proclivities of human information-seeking behaviors, and its special ability to recognize and mediate information needs, library information science is uniquely positioned to inform development of new tools and interfaces, and faces a grand challenge in organizing digital library and information resources and service in support of Collaboratory Science. The day of the Collaboratory Librarian has arrived.

This dissertation and its subsequent research are published on the web at http://www.intertwining.org/dissertation

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Weinman, Janice and Pamela Haag, 1999. Gender equity in cyberspace. *Educational Leadership* 56(5): 44-50.

Wilson, Edward O. 1999. *Consilience: The unity of knowledge*. NY: Vintage Books.

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APPENDIXES

APPENDIX A

THE COLLABORATORY LITERATURE RETRIEVAL SET, ANNOTATED

♦Bulleted articles are the theory-type research articles (n=22) analyzed in Chapter Five.

Agarwal, D.A., S.R. Sachs, and W.E. Johnston. 1998. The reality of collaboratories. *Computer Physics Communications.* 110(1-3) : 134-141.

General introduction to Spectro-Microscopy Facility of the Advanced Light Source, Lawrence Berkeley National Lab. Presents design of prototype, lessons learned, software architecture and components.

Allen, William H. 1993. The rise of the botanical database. *Bioscience* 43(5) : 274-279.

Advice on use of botanical database presented, new way of asking questions.

Allman, William F. 1993. Pioneering the electronic frontier. *US News and World Report* 115 (December) : 56-63.

News feature about people and how they use technology to collaborate. Rich description.

♦Andersson, Jan, and Jerker Ronnerg. 1996. Collaboration and memory: Effects of dyadic retrieval on different memory tasks. *Applied Cognitive Psychology* 10 (February) : 171-181.

Experiment, collaborative retrieval - 2 experiments: how different types of memory tasks were affected by two individuals working together compared to working on their own.

♦Ashton, Sarah, and Philippa Levy. 1998. European research letter: Networked learner support in higher education: Initiatives in professional development and research for a new role. *JASIS* 49 (July) : 850-853.

Libraries in support of networked learning, cultural change, professional development needs - teacher training, NLS - Networked learner support. U of Sheffield.

Banks, Peter M. 1993. "Collaboratory" principles. *Science* 262 (November): 974.

Pre-Wulf history of collaboratory, rebuttal to Wulf 1993.

♦Barua, Anitesh, Ramnath Chellappa, and Andrew B. Whinston. 1995. Creating a collaboratory in cyberspace: Theoretical foundation and implementation. *Journal of Organizational Computing* 5(4): 417-442.

Complementarity theory development. implementation description, theory-based approach to the development of collaboratories on the Internet based on complementarity theory. Provides conceptual foundation for designing to maximize users' value through judicious choice of complementary design factors, document-centric, multimedia iterations between users http://cism.bus.utexas.edu Univ of Texas MIS collaboratory.

♦________. 1996-1997. The design and development of Internet- and intranet-based collaboratories. *International Journal of Electronic Commerce* 1 (Winter): 32-58.

Web deployment, calls for shift from proprietary to open standard collaboratory tools, and integration with databases. Enumerates and analyzes requirements for three types of collaboratory: individuals with overlapping interests but no formal ties, special-interest groups, organizations with interdependent workgroups. Reports results of a survey of the first collaboratory's users, which supports the theoretical platform shift for integration.

Birrell, James R., et al. 1998. Cooperative learning returns to college: What evidence is there that it works? *Change* 30 (July/August).

Report, what is cooperative learning? Theoretical roots, history, research report, differences among theories.

Bradley, Diane, and Janet Frederick. 1994. The Clinton electronic communications project: An experiment in electronic democracy. *Internet Research* 4 (Spring): 64-70.

Research report. Determines degree to which White House material posted to net is more current and comprehensive than info available through more traditional means. Virtual vs. print currency.

Briefs: ARDIS e-mail support. 1995. *Computerworld* (December 11): 59.

Wireless multimedia collaboratory development.

Burns, Sara L., and Stephen E. Laubach. 1997. Virtual collaboratory, frac city, facilitates geoscientific collaboration and technology transfer. *Proceedings of the Geoscience Information Society* 28(46): 111-115.

Design, report of implementation, problems inherent in distributed collaboration. describes "virtual collaboratory" web-based, database, hosted by 3rd party, for quick deployment and retirement, to promote the research to the interested public (113). http://www.frac-city.org

Casper, T.A. et al. 1989. Remote experimental environment: Building a collaboratory for fusion research. *Computers in Physics* 12(May/June): 220-226.

Implementation - testbed - description of. advanced computing, control, and collaboration DIII-D Tokamak, interactive remote participation in experiments. 1987-development, magnetic-fusion-energy research. Are the infrastructure and reports hidden in the physics literature, inaccessible by keyword? See bib for url Lawrence Livermore, LLNL, General Atomics, Oak Ridge National Laboratory (ORNL) and Princeton Plasma Physics Lab (PPPL). Hidden history in journal titles that don't use the word.

Chellapa, Ramnath, Anitesh Barua and Andrew B. Whinston. 1997. An electronic infrastructure for a virtual university. *Communications of the ACM* 40 (September): 56-58.

Education implementation, goal-oriented. Virtual university- lacks conferencing.

Clement, John. 1992. Constructing the K-12 collaboratory on the NREN. *Educom Review* 27(May/June): 18-20.

Column. Scalability, types of projects, need for communication among K-12.

♦Citera, Maryalice. 1998. Distributed teamwork: The impact of communication media on influence and decision quality. *JASIS* 49(9): 792-800.

Research - media effects of communication, decision-making, evaluation apprehension, dominant communicators retain, regardless of media (face-to-face, telephone, computer); less dominant had higher levels of influence on phone, computer.

Computers seen revolutionizing research labs. 1991. *The Scientist* 5(18): 1-2.

News type article wish list of visionary scientists. "Except it's not really a place, it's a distributed electronic environment."

Cooper, Jim. 1993. "Collaboratory" hopes to drive superhighway. *Broadcasting and Cable* 123 (December): 58.

"Collaboratory on Information Infrastructure" formed to form superhighway, Bellcore and media companies...video transmission over copper wires.

Dede, Chris. 1996. Emerging technologies in distance education for business. *Journal of Education for Business* 71 (March): 197-204.

Report of research, "collective good" social network capital, knowledge captial, knowledge webs, communication, edu for business, disinhibition, CoVis.

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Education application. "distributed learning."

Denley, Ian, and Andy Whitefield. 1998. A case history in applying task analysis in the design of a multimedia cooperative document production system. *JASIS* 49 (July) : 817-831.

Describes design and analysis work in development of a multiauthor, multimedia document production system (MAMMDPP).

Dessy, Raymond E. 1997. Der Wir Prinzip. *Analytical Chemistry News and Features* 69 (December): 741A-742A.

Review of web configurations and considerations, lots of URLS. Refers to NetMeeting, mostly about conferencing. Change. "Bayesian" approaches.

Edelson, Daniel C, Pea, Roy D., Gomez, Louis M. 1996. The collaboratory notebook. *Communications of the ACM* 39 (April): 32-33.

CoVis software- url provided

Edelson, Daniel C., et al. 1995. A design for effective support of inquiry and collaboration. *CSCL '95 Proceedings* 36 (October): 107-111.

Examines the design goals of the collab notebook....software. (shared hypermedia databased to provide scaffold for students as they learn to collaborate). Reviews studies in sociology of knowledge.

Eroom 2.0: The easy way to collaborate. 1998. *PC World* 16 (July): 84.

Eroom 2.0 collaboration software introduction.

Finholt, Thomas A. 1995. Evaluation of electronic work: Research on collaboratories at the University of Michigan. *SIGOIS Bulletin* 16 (December): 49-51.

Research update (NSF supported), historical. Role of behavioral sciences. implications for studying digital libraries, UARC description. Medical collaboratory. Design philosophy, Role of behavioral science, implications for studying digital libraries.

Finhold, Thomas A. and Gary M. Olson. 1997. From laboratories to collaboratories: A new organizational form for scientific collaboration. *Psychological Science* 8 (January): 28-37.

General article. Examines collaboratories in physical sciences and potential impact on psychological science, collaboratories will not themselves change science, authors from umich. Contains TABLE OF ADDRESSES OF ONLINE COLLABORATORIES, 5 medicine, one humanities, 2 chemistry, 3 biology, 2 space. Includes MOOs as collabs. Research "has not been guided by a grand plan" (29).

♦Fox, Geoffrey C., and Jojtek Furmanski. 1995. The use of the national information infrastructure and high performance computers in industry. In *Proceedings of the Second International Conference on Massively Parallel processing Using Optical Interconnections.* Los Alamitos, CA: IEEE Computer Society Press: 298-312.

Infrastructure, future of the web. Open technologies. Application areas: business, health care, defense, education, collaboratory, manufacturing.

♦Glasner, Peter. 1996. From community to 'collaboratory'? The Human Genome Mapping Project and the changing culture of science. *Science and Public Policy* 23 (April): 109-116.

Research, culture. Attempt to conceptualize scientific communities in sociology, virtual has no real impact on accepted views of the culture of science, environment may be better for small, rather than "big science." Why some scientists don't use. Double-blind situations "Cyberplatonic Dream." Based on research of Human Genome Mapping Project Worm Community System nice definitions of science, 4 levels of published information (112).

♦Haga, Hirohide. 1996. Generic model of collaboration. *The Science and Engineering Review of Doshisha University* 37 (July): 34-44.

Theory. Model of collaboration based on participant and commitment functions by providing values to attribute to information flow. Model of asynchronous collaboration proposed. Five typical examples of new collaboration types, 4 elements: information flow with attributes, a set of participants, a function from one information flow to the subset of participants (participant function), and a function from one participant to the subset of information flows (commitment function).

Hardin, Steve R. 1998. Michael Schrage and collaboration: Delivering information services through collaboration. *Bulletin of the American Society for Information Science* 24 (August/September): 6-8.

Interview with Michael Schrage: information, relationships, augmentation, automation.

♦Harper, Richard, and Abigail Sellen. 1995. Collaborative tools and the practicalities of professional work at the Internatinoal Monetary Fund. *CHI '95 Proceedings Papers.* http://www.acm.org/sigchi/chi95/Electronic/documnts/papers/rh_bdy.htm

Cultural inertia argument for need for paper. Accessed 9/98. Which info good for paper, which for digital. Reuse of information. Media richness. Judgement.

Henline, Pamela, Compiler and Editor. 1998. Eight collaboratory summaries. *Interactions* 5 (May) : 66-72. NY: Association for Computing Machinery.

Brief summary of eight implementations with URLS and funding info. Book listing.

♦Huang, Milton P., and Norman E. Alessi. 1996. The Internet and the future of psychiatry. *American Journal of Psychiatry* 153 (July): 861-869.

Psychiatry model of Internet: four layers of people and technology that work together, must be grasped in entirety to be understood, factors.

IBM Develops Virtual City Web Site. 1997. *Newsbytes News Network* (May 16).

IBM forms institutional collaboratory http://www.ieg.ibm.com

♦Jeffay, K, J.K. Lin, J. Menges, et al. 1992. Architecture of the artifact-based collaboration system matrix. *CSCW 92 Proceedings* (November): 195-202.

Describes a component of the UNC collaboratory project, argues need not new tools but better infrastructure for using single-user tools collectively. Design of software systems as a single whole. NSF funding.

Johnson, David W. 1998. Collaboration, communities, and Covey: A Model for personal and professional change. *Clearing House.* 71 (July/August): 359-362.

Establishing collaborative relations, uses Stephen R. Covey's (1989) "The 7 Habits of Highly Effective People" as framework for initiating and sustaining teacher education reform in one elementary school within Brigham Young University Public School Partnership.

♦Karamuftuoglu, Murat. 1997. Designing language games in Okapi. *Journal of Documentation* 53 (January): 69-73.

Information retrieval from perspective of semiotics (signs). Two conflicting speech acts: "detonation" transmits info from database to user. "prescriptives" can be used to invent new connections between documents, thus create new knowledge.

Keis, Jonathan K., Robert C. Williges, and Mary Beth Rosson. 1998. Coordinating computer-supported cooperative work: A Review of research issues and strategies. *JASIS* 49(9): 776-791.

Review of research issues and strategies, roles different communication channels play in coordinating work in cooperative systems. Match to task, computer as a communication medium / outlines advantages, presents relevant socio-technical consideration, describes research methods available , Research issues and strategies for implementing CSCW.

Kiernan, Vincent. 1997. All the world's a lab. *New Scientist* 154 (April): 34-7.

Feature article. Description of various collabs -- good narrative, Tonner at Uwisc-Madison / Lawrence Berkeley Nat'l Lab , X-ray beam - spectro-microscopy facility.

Kilman, David G., and David W. Forshund. 1997. An international collaboratory based on virtual patient records. *Communications of the ACM* 40(8): 110-117.

Describes collaboratory patient virtual records. See TeleMed (Online), concept of collab, rich description of use. http://www.acl.lanl.gov/TeleMed Concept, culture of collab, international.

Kling, Rob. 1991. Cooperation, coordination and control in computer-supported work. *Communications of the ACM* 34(12): 24.

Conjunction of technology, users, and worldview, CSCW --- C words.

Kouzes, Richard T. 1995. Creating the cyberspace laboratory. *The World and I* 10. Washington, DC: The Washington Times Corp.

Collaboratory basics. Author is PNL molecular science lab collaboratory.

________. 1997. Collaboratories: Can we work together apart?. *Scientific Computer and Automation* 14 (January): 52-54.

Conceptual introduction. Complex intertwining. the sociology of collaboration, groupware, functional requirement. See list of URLS to collab resouces on the web, http://www.scamag.com

Kouzes, Richard T, James D. Myers, and William A. Wulf. 1996. Collaboratories: doing science on the Internet. *Computer* 41 (August): 40-46.

Overview, technical aspects, progress report. Technical, sociological challenges, barriers to adoption Prototypes, collaboratory types: peer-to-peer, mentor-student, interdisciplinary, producer-consumer.

Kovacs, Laszlo. 1998. Discovery of resources within a distributed library system. *Communications of the ACM* 41 (April): 78-79.

Technical limits, aims, expectations, intro, history of computational science, digital library, VRML color and spatial organizational structure. See URL for Digital Library collaboratory Working Group.

♦Kydd, Christine T., and Diane L. Ferry. 1991. Computer supported cooperative work tools and media richness: An integration of the literature. *Proceedings of the Twenty-Fourth Annual Hawaii International Conference on System Sciences* IV(5): 324-332. Eds. Jay F. Nunamaker, Jr. and Ralph H. Sprague, Jr. Organizational Systems and Technology Track. Los Alamitos, CA: IEEE Computer Society Press.

Literature review. tools evaluation, presents an evaluation of the successes and failures of computer supported cooperative work tools in terms of a behavioral theory which suggests that information processing occurs during group work to 1. Reduce uncertainty and 2. Resolve eqivocality., Matching the situation with the appropriate tool is important to implementation success. If uncertainty is the issue, tools that transmit large amounts; if equivocality, those which are media rich. Surprising results of actual tools use.

Lepkowski, Wil. 1993. Information revolution offers policy challenges to researchers, other users. Easton, PA: The Society. *News Edition of the American Chemical Society* 71(21): 25-26

Think tank reports from Council of Competitiveness and NRC 1993, Clinton agenda, dark side of the revolution: social polarization between information haves and have-nots.

Lewin, David I. 1996. An interview with Mark Ellisman: Building an imaging collaboratory. *Computers in Physics* 10 (Sep/Oct): 414-5.

Interview, report of project, molecular- and cellular-imaging collaboratory, National Center for Microscopy and Imaging Research (NCMIR) at UCSD. No url given.

Lyman, Peter. 1996. What is a digital library? Technology, intellectual property, and the public interest. *Daedalus* 125 (Fall): 1-33.

Visualization, collab= "a form of living textuality" see footnote 19. Digital library, social aspects, description. See footnote #4 re literacy. Reading. Space. "Is it possible to create public institutions in cyberspace?"

♦Mantovani, Giuseppe. 1995. Virtual reality as a communication environment: Consensual hallucination, fiction, and possible selves. *Human Relations* 48(6): 669-683.

Virtual reality as a communication environment from point of view of social psychology. Reviews research on quality of current VR systems integrated into self-identity theory. "technologies nurture specific political, ideological, and also mystical beliefs as essential aspects of their moral foundation."

McCune, Jenny C. 1998. Working together, but apart. *Management Review* 87 (September).

Intro to collaboration, collaboration gap - reasons for success and failure; need trust, technical and personal issues for failure.

McNamara, Sean. 1992. Australia: Cray and Swinburne form research center. *Newsbytes News Networks* (July).

Announcement of Australian Computational Research collaboratory (ACRC) for business and industry.

Metcalfe, Bob. 1997. Electronic Taj Mahals might reduce travel to and from session breaks. *InfoWorld* 19 (January): 44.

ACM collaboratory initiative, questions on design concepts, Wulf calls collabs "time machines." See urls and email addresses.

Migrating towards an European scientific collaboratory. *Lecture Notes in Computer Science.* 1995. Berlin: Springer-Verlag. 889(38): 190-197.

"Tell me and I forget, show me and I remember, involve me and understand" -Chinese proverb (190) E-collaboratory in Europe. Explores migration steps to provide functionality.

♦Mitchell, Will, and Kulwant Singh. 1996. Survival of businesses using collaborative relationships to commercialize complex goods. *Strategic Management Journal* 17 (April) : 169-195.

Research - effects of collaboration on businesses delivering complex goods.

NTIS DIALOG(R)File265:FEDRIP#00343290. 1998. *Molecular interactive collaborative environments (MICE).* Principal Investigator: Bourne, Philip. 84. UC San Diego.

Research grant award announcement - continuing, abstract.

Olson, Gary M.1995. An appreciation of Laurence Rosenberg. *Communications of the ACM* 38(4) : 75.

Obiturary NSF collaboratory pioneer.

Olson, Gary M., Daniel E Atkins, Robert Clauer, et al. 1998. The Upper Atmospheric Research Collaboratory. *Interactions* 3 (May): 48-55. NY: Association for Computing Machinery.

Feature Article. About Upper Atmospheric Research collaboratory. (UARC). Graphics of screen, traffic patterns, etc. information article.

Page, Heather. 1998. Remote control. *Entrepreneur* 62 (October): 149-153.

Overview of products, RULES. netmeeting, other software.

Paton, Graham. 1997. 'Information system' as intellectual construct--its only valid form. *Systems Research and Behavioral Science* 14(1) : 67-72.

Critique of the meme of information systems. proposes "holon" instead. Information and system deconstructed. Information is a particular parcel of knowledge acquired at a particular moment in time. Objects themselves are NOT information. Info system is an intellectual construct, its only valid form; computers are the tool. Layers, like ISO layers for internetworking...depends on what layer you are whether data is information, etc.

PNL plans environmental research on Internet. 1994. *Science* 265(5181) : 90.

Pacific Northwest Laboratories announcement

Reed, Daniel A., Roscoe C. Giles and Charles E. Catlett. 1997. Distributed data and immersive collaboration. *Communications of the ACM* 40 (November) : 38-48.

Feature article: technical limits, aims, expectations, introduction to concept. History of computational sciences follows same path as experimental science.

♦Rice, Ronald E., Elizabeth More, and John D'Ambra. 1995. Cross-cultural comparison of organizational media evaluation and choice. *Proceedings of the 58th ASIS Annual Meeting Vol 32: Forging New Partnerships in Information*. Ed., Kinney, Tom. Medford NJ: Information Today, Inc.: 189-193.

Research, statistics, analyzes correlation among richness, eqivocality, and preferences, and differences among means and relationships across four countries.

♦Robbin, Alice. 1995. SIPP ACCESS, An information system for complex data: A case studying creating a collaboratory for the social sciences. *Internet Research* 5 (November) : 37-66.

Review of NRC 1993 report. Report of infrastructure implementation, report of human resources in design and implement. and education of users. evaluates selected aspects of one implementation, examines obstacles to collaboratory development for the social sciences uses relational database, overview of pre-Wulf collaboratory. "c-cubed" = communication, cooperation and collaboration.

Roe, Eunice M. 1993. Current affairs and contemporary issues collaboratory: Criteria for selecting resources. *14th National Online Meeting Proceedings* (May). Medford, NJ: Learned Information : 355-364.

Proposed collab for current affairs and contemporary issues, new skills for librarians. Sets librarian's criteria for selecting resources to support collab work...electronic. Develops collaboratory learning model (sphere in pyramid)..."because of the cognitive nature of the collaboratory, in which information is not just received, but where it is evaluated and manipulated and knowledge is constructed, usability factor takes on special importance."(361) Suggests that librarian needs to develop additional knowledge and skills.

Rome, James A. 1998. Science from a distance: Molding a virtual laboratory. *The World and I* 13 (October) : 182.

Implementation. social issues, MMC use of telemicroscopes, Author from Oak Ridge National Lab see URL in body of article.

Rosenberg, Lawrence C. 1991. Update on the National Science Foundation funding of the "collaboratory". *Communications of the ACM* 34 (December) : 83-88.

Three programs: Coordination Theory and Collaboration Technology Special Initiative (CT2), Scientific Databases, Gigabit Network Project. collaboratory, cooperation, convivial, conflict, control, coercion, counter-productive conformity. "Need a more substantial shift from technological utopianism to social realism in the CSCW literature."(87).

Ross-Flanigan, Nancy. 1998. The virtues (and vices) of virtual colleagues. *MIT's Technology Review* 101 (March) : 52-59.

Collaborators may generate more ideas, but trust is hard to develop. Human aspects of working in Collab. Personal benefits and behaviors. See URLS for Collabs.

♦Rugelj, Joze and Viktor Svigelj. 1997. Computer supported multimedia environment for the support of long-distance collaboration in medicine. *Tenth IEEE Symposium on Computer-Based Medical Systems*. Los Alamitos, CA: IEEE Computer Society Press : 215-260.

Architecture of medical collaboratory is designed to enable close ties between the collaborating partners, to accelerate the development and dissemination of basic knowledge, and to minimize the time-lag between diagnosis and corresponding treatment.

Ruhleder, Karen and John Leslie King. 1991. Computer support for work across space, time, and social worlds. *Journal of Organizational Computing* 1(4) : 341-355.

Examines the assumptions of the model of collaborative work behind the collaboratory. Success WOULD be worthy prize; challenge is daunting. Two functions: processing and communication of information. Need integrated functions, to understand social and organizational factors. "fuzzy social organization" of academic collaboration....human glue.

♦Schooler, E.M. S. Casner, and J. Postel. 1991. Multimedia conferencing: Has it come of age? 83. USC, Marina del Ray, Information Sciences Institute.

Research report, multimedia teleconferencing as key component of collaboratory, abstract.

Schrage, Michael. 1991. Computer Tools for Thinking in Tandem. *Science* 253 (August) : 505-7.

Report...state of the art, articles that get published are really historical things, creating copresence. the most important mode of collaboration is the literature interact dynamically and dialectically author of "Shared Minds." More like dialogue than set of soliloquies, "information cliques," "now the reader can structure the knowledge."

Science from a distance: Security and collaboratories. 1998. *The World and I* 13(87).

Sheridan, Cormac. 1997. Come into the collaboratory. *Technology Ireland* 29 (September) : 32-4.

General report from UCD chemistry dept.

♦Swanson, G. A., Kenneth D. Bailey, and James Grier Miller. 1997. Entropy, social entropy and money: A living systems theory perspective. *Systems Research and Behavioral Science* 14(1) : 45-65.

Research paper, entropy as a measure of system disorganization. How entropy occurs and is measured in social systems. Role of money-information markers in the recurring organization and disorganization of social entities is identified as an aspect of social entropy, integrates living systems theory social entropy theory and macro accounting theory.

Thomas, Susan Gregory. 1996. Software that turns kids on. *US News and World Report* 121 (December) : 96-97.

Software. Children.

Towards a national collaboratory: The role of the electric library. 1989. *Information Intelligence, Online Libraries, and Microcomputers* 7 (December) : 1-4.

Report on role of Libraries in collaboratory: resources that would use telecommunications and computer technology to provide remote access to scarce and expensive national scientific assets as well as provide improved communications among the scientific community. three-fold research approach for Libraries proposed. Role of libraries in computer technology, telecommunication infrastructure and tools which would allow researchers to work with remote facilities (co-laboratory) and each other (collaborat-ory) as if they were in physical proximity.

♦Travica, Bob. 1995. Culture of collaboration: An exploration into the accounting industry. *Proceedings of the Twenty-Fourth Annual Hawaii International Conference on System Sciences* IV(5) : 194-199. Eds. Jay F. Nunamaker, Jr. and Ralph H. Sprague, Jr. Organizational Systems and Technology Track. Los Alamitos, CA: IEEE Computer Society.

Research, exploratory study. "Culture of collaboration" among professionals in accounting firm, dimensions of exchange: knowledge exchange, reliance on colleagues in gathering information, sharing of accountability within work teams, sharing of trust among office colleagues, communication over team boundaries, reliance on IT in everyday work (194).

Wehrwein, Peter. 1998. US National Cancer Institute creates Cancer Genetics Network. *Lancet* 352 (August): 460.

Announcement. of new network, cancer-bio. Databased. Internet provided: speed progress.

Weintrab, Hal, et al. 1995. Through the glass lightly. *Science* 267 (March): 1609-1618.

Scientists share their ideas of the future....to 2005. Genetics, biology, biochemistry, chemistry, physics.

♦Wilson, Paul. 1991. Computer supported cooperative work (CSCW): Origins, concepts and research initiatives. *Computer Networks and ISDN Systems* 23(1-3): 91-95.

Report . Origins, concepts and research initiatives, origins of CSCW. components of CSCW. CSCW products. networking requirements and opportunities. Applicability of collaboratory to Europe.

Wulf, William A. 1989. Government's role in the national network. *Educom Review* 24(2) : 22-16.

Background of NSFNet development, why collaboratory is important, report following Rockefeller U workshop. "Analog wet lab" analogy.

________. 1993. The collaboratory opportunity. *Science* 261 (August): 854-855.

Visualization...rehash of *White Paper* and Lederberg and Uncapher *Report*. See Banks (1993) for rebuttal about history of collab.

Zaluzec, N.J. 1996. Tele-Presence Microscopy/LabSpace: An interactive collaboratory for use in education and research. *Microscopy and Microanalysis Conference* 85 : 382-383.

Collab as merely an exercise in computer programming and digital control. Needs for "real collaboration" to happen.

Ziemba, Stanley. 1996. Ameritech Gives NU $1.8 Million. *Chicago Tribune* August 21. North Sports Final Edition.

Newspaper article, funding announcement, collaboratory. Northwestern University, Chicago.

APPENDIX B

THE CIRAL MATRIX FOR INCLUSION AS A COLLABORATORY

CIRAL (Criteria for Inclusion as a Collaboratory)	Issues and Factors							
	Individual				**Institutional**			
	Social	Organization	Technical	Practical	Social	Organization	Technical	Practical
Distributed Computing								
Networked Instruments & Tools								
Support Resources								
Data Archives								
Digital Libraries								

APPENDIX C

PHASE TWO CONSENT FORM

From: http://www.intertwining.org/dissertation/consent/p2consen.htm

From: joanne twining, Doctoral Candidate
School of Library and Information Studies
Texas Woman's University
twining@texoma.net

To: Collaboratory Gatekeeper:

Request for Access to Collaboratory for Environmental Research

I am a Doctoral Candidate in the School of Library and Information Studies at Texas Woman's University. I am conducting dissertation research about the Collaboratory. My research uses Naturalistic Inquiry and has three intertwined phases. I seek your consent to enter your Collaboratory to gather environmental information for PhaseTwo of my study.

Phase Two creates a subjective reality of the Collaboratory based on immersion in the online ENVIRONMENT. Information gathering for Phase Two will include prolonged engagement with, and persistent observation of the online ENVIRONMENT of the Collaboratory.

I am NOT conducting research about individual Collaboratory participants. I am NOT seeking permission to participate in or report on ongoing Collaboratory research.

I am seeking permission to enter your Collaboratory as an ENVIRONMENTAL OBSERVER only. I will be conducting this research in several Collaboratories simultaneously in order to arrive at generalities about the ENVIRONMENT.

While I expect to interact variously with individual Collaboratory participants during Phase Two, these individuals are NOT the subject of my study. While the names of the Collaboratories may be revealed in my research report, individual participants will NOT be identified, nor will individual behaviors or activities be investigated. All individuals with whom I interact will be informed that I am an ENVIRONMENTAL researcher and will be free to refuse contact.

Please grant permission for me to enter your Collaboratory as an environmental researcher by completing and submitting the brief consent form below. You will receive confirmation by return webpage. No further contact is necessary or anticipated.

If you prefer that your Collaboratory NOT participate in this research, or you wish to receive no further contact, please indicate by email.

If you have any questions about this request, you may contact me by email to twining@texoma.net or by phone at (903) xxx-xxxx. You may also contact my Dissertation Chair, Dr. John D'Angelo, by email at jdangelo@twu.edu or by phone at (940) 898-2617.

Texas Woman's University, Denton, Texas 76201
GATEKEEPER CONSENT TO ALLOW ACCESS FOR RESEARCH

Title of Study: A Naturalistic Journey into the Collaboratory: In Search of Understanding for Prospective Participants. Phase Two

Name of Investigator: joanne twining, email address: twining@texoma.net
Phone Number: (903) xxx-xxxx.

Name of Dissertation Chair: John D'Angelo, Ph.D., email address: jdangelo@twu.edu Phone Number: (940) 898-2617

I understand that this research study will gather information to create a subjective, interactive understanding of the online Collaboratory environment.

I understand that this research does not involve the investigation of or research into any individual Collaboratory participant.

I understand that his research does not involve the investigation of any ongoing Collaboratory research projects.

I understand that potential risk to the environment of the Collaboratory will be that the presence of the observing researcher might disrupt the normal work flow of and interaction between Collaboratory participants. I understand that the researcher will do everything possible to minimize this risk.

I understand that the researcher will keep all data securely stored on private computer and archival media. All data generated during this study will be erased immediately following completion of this study.

I understand that the personal benefits I can gain from participating in this study includes being able to provide input into research that will improve understanding about the Collaboratory by prospective participants.

I understand that participation in this study is voluntary and that I may withdraw the right of the researcher to enter the Collaboratory at any time. My refusal to participate or my withdrawal of right of entry will involve no penalty or loss of benefits to which I am otherwise entitled.

An offer has been made to answer all my questions and concerns about this study. If I have questions about the research or about my rights, I should ask the researchers. Their email addresses and phone numbers are at the top of this form. If I have questions later, or if I wish to report a problem, I may contact the researchers or the Texas Woman's University Office of Research & Grants Administration at (940) 898-3377.

The researchers will try to prevent any problem that could happen because of this research. I should let the researcher or the Doctoral Dissertation Committee Chair know at once if there is a problem and they will help me. I understand, however, that Texas Woman's University does not provide medical services or financial assistance for injuries that might happen because I am taking part in this research.

If you agree to allow access to your Collaboratory for environmental research, please provide the following information and SEND:

Name of your Collaboratory:
URL of your Collaboratory:
Your name:
Your title
Your email address
Your telephone number
Researcher access password (if required)
Please provide a verification code to confirm your consent:

Thank you!

If you prefer, you may print and return this page by postal mail to:
joanne twining
School of Library and Information Studies
Texas Woman's University
Denton, Texas 76204

If you would like to participate in a Delphi Among Collaboratory Pioneers to determine the "Rules of the Road" for the Collaboratory and identify the skills Collaboratory Pioneers value most in prospective participants, please read and complete the Delphi Consent Form.

You may also nominate other Collaboratory Projects for Phase Two of this study, or other Collaboratory Pioneers for the Phase Three Delphi by sending name, email address, or URL to twining@texoma.net

Complete information about this dissertation is at
http://www.intertwining.org/dissertation

Thank you for your help in this important research.
joanne twining
Placed May 04, 1999
-30-

APPENDIX D

PHASE THREE CONSENT FORM

From: http://www.intertwining.org/dissertation/consent/p3consen.htm

From: joanne twining, Doctoral Candidate
School of Library and Information Studies
Texas Woman's University
twining@texoma.net

To: Collaboratory Pioneers

Invitation to Participate in Dissertation Research:
DELPHI AMONG COLLABORATORY PIONEERS

You are invited to participate in an electronic Delphi Among Collaboratory Pioneers

The Delphi is Phase Three of my doctoral dissertation research at the School of Library and Information Studies at Texas Woman's University. The purpose of the Delphi is to create an intersubjective reality among Collaboratory Pioneers by determining the "Rules of the Road" for the Collaboratory, and identifying skills Collaboratory Pioneers value most in prospective Collaboratory participants.

The Delphi will be conducted online using email and the web. The results of your efforts will provide useful information for future Collaboratory participants.

To protect the integrity of this study, you will be provided the names and email addresses of all participants in this Delphi. You are asked to not communicate with Delphi participants about this Delphi during the course of its execution.

You will receive three or four consecutive questionnaires by email or the web, the number depends on how easily the group moves toward consensus, or shared understanding. The goal is for consensus or shared understanding to be reached by the end of the last questionnaire. Your responses will be tabulated after each round, themes will be determined, and your reactions to the relative importance of each theme will be solicited. You will be provided with information about how other participants responded to the questions so that you can see how your answers compared. Participant confidentiality will be maintained, however, since all identifying features, such as names, institutional affiliations, or revealing examples, will be removed from these instruments.

Your continuous participation throughout the entire process is highly desirable. If, however, extenuating circumstances require you to drop out, you may certainly do so without repercussions. It is important throughout for your participation to be completely voluntary.

Should you have any questions, please feel free to contact me by email to twining@texoma.net, or by phone: (903) xxx-xxxx. You may also contact my Dissertation Committee Chair, Dr. John D'Angelo, via email at jdangelo@twu.edu or by telephone at (940) 898-2617.

If you would like to participate in this Delphi Among Collaboratory Pioneers, please read the consent form below carefully, supply the requested information, and submit the form as soon as possible. You will receive confirmation by return webpage. Further instructions will be sent to the email address you provide.

If you prefer, you may print and sign this consent form and return by postal mail to:

joanne twining
School of Library and Information Studies
Texas Woman's University
P.O. Box 425438
Denton, Texas 76201-5438

Thank you for your consideration.

CONSENT FORM
Texas Woman's University, Denton, Texas 76201
CONSENT TO PARTICIPATE IN ELECTRONI DELPHI

Title of Study: A Naturalistic Journey into the Collaboratory: In Search of Understanding for Prospective Participants. Phase Three

Name of Investigator: joanne twining twining@texoma.net
Phone Number : (903) xxx-xxxx

Name of Dissertation Chair: John D'Angelo, Ph.D. jdangelo@twu.edu
Phone Number: (940) 898-2617

I understand that this research study will generate the "Rules of the Road" for Collaboratory and identify the skills that Collaboratory Pioneers most valued in prospective Collaboratory participants. I understand that I will be expected to complete and return three or four brief questionnaires in an attempt to achieve consensus. Each questionnaire is likely to take up to a half-hour to complete.

I understand that potential risks to me as a subject are
(a) the on-going commitment of time required and
(b) the danger of loss of confidentiality.

I realize that if I am not prepared to respond to each subsequent questionnaire, I should refuse to participate from the beginning, although if it does become necessary to back out of the study at some point due to unforeseen circumstances, I can do so without adverse repercussions. I understand that the researcher will keep all data securely stored on private computer and archival media. All data generated during this study will be erased immediately following completion of this study.

I understand that the personal benefits I can gain from participating in this study includes being able to provide input into research that will improve understanding about the Collaboratory by prospective participants. I understand that my anticipation in this study is voluntary and that I may withdraw from the study at any time. My refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled.

I understand that to preserve the integrity of the research, it will be necessary that fellow Delphi participants be aware that I am a participant. I understand that my name and email address will be included on a list of participants and that the list will be provided to all participants at the beginning of the study. I understand that I should not communicate with fellow Delphi participants about the Delphi during its execution.

I understand that in subsequent rounds of the Delphi the names and identifying features of individual participants will be removed from any information turned back to the group so that no individual can be linked to a comment. I understand that no individual's identifying features will be included in any reports of the study.

An offer has been made to answer all my questions and concerns about this study. If I have questions about the research or about my rights as a subject, I should ask the researchers. Their email addresses and phone numbers are at the top of this form. If I have questions later, or if I wish to report a problem, I may contact the researchers or the Office of Research & Grants Administration at (940) 898-3377.

The researchers will try to prevent any problem that could happen because of this research. I should let the researcher or the Doctoral Dissertation Committee Chair know at once if there is a problem and they will help me. I understand, however, that Texas Woman's University does not provide medical services or financial assistance for injuries that might happen because I am taking part in this research.

If you agree to participate in an electronic
Delphi Among Collaboratory Pioneers,
please provide the following information and SEND this form

No additional contact is necessary or anticipated

Your Name:
Name of Your Collaboratory:
URL of Your Collaboratory:
Your email address:
Your Telephone Number:
Your Mailing Address:
Please provide a Validation Code that may be used to verify your consent in event of Audit:

Thank you.

If you would like to nominate other Collaboratory Pioneers for this study, please send their name, email address or URL to twining@texoma.net
Full information about this dissertation research is available at
http://www.intertwining.org/dissertation

Thank you for your help in this important research.
joanne twining, Doctoral Candidate
School of Library and Information Studies
Texas Woman's University
Placed May 04, 1999
-30-

APPENDIX E

ROUND ONE DELPHI QUESTIONNAIRE

Subject: Delphi Among Collaboratory Pioneer
Date: Mon, 12 Jul 1999 08:52:32 -0500
From: twining <twining@texoma.net>
To: Delphi Pioneers via email

Hi. Thank you for participating in a "Delphi Among Collaboratory Pioneers." Please reply to this email by WEDNESDAY, JULY 21, 1999.

The Delphi Technique is a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with complex problems (Linstone and Turoff 1975). The Delphi is also being developed as a core technology for "Expert Collaborative Systems" (Turoff and Hiltz, in press). Delphi is accomplished though iterative rounds of individual expert responses and group synthesis.

This message is our first round questionnaire. It is an individual "brain storming" session. Please respond to the two questions below. Your responses need not be fully developed and your responses need not be justified. You do not even have to use complete sentences!

Participant responses will be synthesized and sent to the group as Round Two. You will not be identified and your responses will remain anonymous. You will have the opportunity to make comments, change your position, and make additions or deletions to Round One responses during Round Two.

Please feel free to contact me should you have questions or need more information about this research. I look forward to receiving your response soon, and hope to proceed to Round Two swiftly.

thanks again.
/s/joanne

ROUND ONE "Delphi Among Collaboratory Pioneers"

The executive summary of the National Reseach Council's 1993 report, "National Collaboratories: Applying Information Technology for Scientific Research," says

> "Collaboration tends to be easier on a small scale and when it is local: when a small number of individuals collaborate it is generally possible to proceed on the basis of mutual trust, but 'rules of the road' are needed for larger-scale collaboration." (NRC 1993, 3)

1. What are the 'rules of the road' for the collaboratory?

2. What skills do you value in prospective collaboratory participants?

--
joanne twining
twining@texoma.net
www.intertwining.org
-30-

APPENDIX F

ROUND TWO DELPHI INSTRUMENT

From http://www.intertwining.org/dissertation/round2.htm

Delphi Among Collaboratory Pioneers
Round Two

Thank you for your continued participation, and for sharing your time to support this dissertation research. This Round of our Delphi presents the ideas and thoughts generated in Round One. Please indicate your level of agreement with the thoughts below and freely add any comments you may have. There are 20 thoughts in the "rules of the road" section and 21 thoughts in the "skills" section. At the end of each set of thoughts you will have an opportunity to present new thoughts that we may have missed. Again, your thoughts need not be fully developed. Round Two responses will be synthesized and submitted to the group for comments.

Part One
"Rules of the Road"

Please indicate your level of agreement with each of the following thoughts by choosing one of the options provided. Please also use the comment box below each thought to explain, expand, or develop any of the thoughts (including any rules or practices, tips, or examples you may have developed for that situation).

1. Planned, regular collaboratory sessions stimulate a kind of frequent communication that colleagues "down the hall" might have.

Agree Somewhat Agree No comment Somewhat disagree Disagree

Comments:

2. Establish at the onset who will do which part of the experiment and followup analysis.

Agree Somewhat Agree No comment Somewhat disagree Disagree

Comments:

3. The difference between large and small collaboratories is not size but the informality of cross-organizational interactions.

Agree Somewhat Agree No comment Somewhat disagree Disagree

Comments:

4. Be flexible as experiments proceed, to change who does what, depending on how it goes.

Agree Somewhat Agree No Comment Somewhat disagree Disagree

Comments:

5. When researchers visit a collaboratory facility it is probably to complete an experiment resulting in publications; if a researcher pops into a virtual room/session and discusses ideas with colleagues, there may be no direct publishable artifacts.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

6. Decide how often to have a collaboratory session -- i.e. plan to have a daily, or a weekly or a bi-weekly session...to stimulate the kind of frequent communication colleagues down the hall might have.

Agree Somewhat Agree No comment Somewhat Disagree Disagree

Comments:

7. In the long run there are proven projects which can be enhanced by using a collaboratory.

Agree Somewhat Agree No comment Somewhat Disagree Disagree

Comments:

8. "Rules of the Road" are an attempt to find a balance between differing cultures.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

9. Collaborators must commit to making frequent deposits of data, notes, etc. to a shared electronic notebook or database or other appropriate repository so all collaborators can stay up to date and so progress of the research can be as efficient as stopping by a colleague's office down the hall to take a look at data.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

10. Be direct. If you have an idea, complaint, or any comment, say it. If you need something you must ask. Don't expect anyone to read your mind.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

11. In the Collaboratory the balance of trade in informal interaction may favor one person/culture/organization over another.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

12. Electronic interaction shifts work between collaborators. If a researcher goes to a facility to do an experiment, they are available to help with instrument maintenance and configuration, to get supplies from the storeroom, etc. A remote researcher is not.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

13. Trust takes time to build and the time constant is much longer when contact is less frequent due to time and/or distance.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

14. It is difficult to know what remote colleagues are doing daily since you don't pass by their office.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

15. Our inability to measure the value of informal interactions is one reason we organize--we get a common culture, i.e. people learn to provide similar amounts of informal help to each other; all the benefits of these interactions accrue to the organization; both these lessen the need to measure them.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

16. Like small-scale collaboratories, large scale collaboratories operate on trust, it just takes longer to get there.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

17. Because collaboratories are still new enough to be subsidized (we fund
development of tools and creation of virtual facilities, accept papers on these topics, etc.) buys time to get the rules right. As collaboratories become standard practice, the subsidies decrease, and the need to equalize the benefits will increase.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

18. You must get involved and get someone in the collaboratory interested in working with you on a problem.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

19. Unless collaborators embrace that collaboratory work will take extra time to get up to speed and is subject to glitches in technology and the Internet, the collaboration will be slowed down such that it will not compete as an effective alternative to traditional methods.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

20. We are at a stage where we realize that we will need 'rules of the road' but they are still ad hoc.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

Do you have new thoughts or additions to the responses to the original question, "What are the 'rules of the road' for the Collaboratory?"

Please share them here:

Part Two:
Skills Valued in Prospective Participants

1. Know why the problem is important to study...enough so to get people interested in helping as well as justifying the time spent on the study.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

2. Anyone who has a real project in mind (something they want to get done that is cumbersome using travel, email, fax) probably has the right mindset to go forward (trading difficulties of real-world interactions for the (hopefully) reduced difficulties of working via collaboratory.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

3. Have some basic knowledge of the science. You don't have to be an expert, but you must be able to discuss it and provide appropriate support at your end to do what is necessary on your part.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

4. Anyone looking for the perfect solution will probably be disappointed.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

5. Be willing to participate/help with other problems of appropriate nature. Don't expect to be helped without returning the favor at some time in the future, for some arbitrary participant.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

6. No one is an expert at everything, but everyone has some expertise in something. We expect you to offer to share it when the right time comes.

Agree Somewhat Agree No Comment Somewhat Disagree Disagree

Comments:

On a scale of one to ten (with one being unnecessary and ten being mandatory) please rate the value of the following skills in prospective participants:

7. Good to expert scientific knowledge

Comments:

8. Good communication skills

Comments:

9. Experience in the (scientific) techniques used

Comments:

10. Good computer skills /computer literacy

Comments:

11. Familiarity with Internet technology and software (not at a programmer level, but someone who uses a desktop PC on a daily basis and is familiar with spreadsheets, data processing software, etc.)

Comments:

12. Tolerance for evolving technology and practices.

Comments:

13. General team skills

Comments:

Please indicate your agreement or disagreement with the following theoretical statements as they are reflected in the actual practice of Collaboratory Science:

14. Integration and adaptability is necessary and good.

Comments:

15. Change, choice, and personal power are requisite.

Comments:

16. Consensus, sharing, and exchange are positive and practiced.

Comments:

17. Individuality and collectivity are distinctly and respectfully maintained.

Comments:

18. The collaboratory has been built from a relatively equal contribution from the hard and the soft sciences.

Comments:

19. The collaboratory is an interdisciplinary environment.

Comments:

20. The collaboratory is an ungendered environment.

Comments:

21. The collaboratory fundamentally changes the way science is done.

Comments:

Do you have new thoughts or additions to the responses to the original question, "What skills do you value in prospective participants?"

Please share them here:

Your Name: ______________________________

Thank you! Please SEND your Round Two responses.

Responses will be synthesized and presented to the group for comments.
See http://www.intertwining.org/dissertation for results