The Research Web:

Asynchronous Collaboration in Social Scientific Research

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A dissertation submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

University of Washington
2002

Program authorized to Offer Degree: Department of Geography

UMI Number: 3062948

University of Washington
Graduate School

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Abstract

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The dissertation examines the issue of large-scale, long-term social scientific collaboration in a research environment populated with highly specialized and geographically dispersed scholars. The recent expansion of the Internet's communication capacity and diversity in genre categories has fueled an explosion in collaborative capabilities. The World Wide Web is adopted as the vehicle for interactive collaboration.

The nature of scientific collaboration is examined in depth, including barriers to collaboration. The current research environment is explored: how it serves knowledge-building; where it is likely to change as a result of recent social and technical conditions: and what support that new environment requires. Because of the fragmentation of specialist communities, collaboration within interdisciplinary and intercultural teams is emphasized. The limitations of asynchronous methods are discussed, along with the limitations of synchronous methods that are their analogs.

The proposed research environment is based on a realist philosophy that defines theory as being embedded in models. Several types of models and their representation are

explored. Model building is integrated with a research methodology, the Validity Network Schema, that provides a framework for bringing modeling into the research process. The Research Web (RW) is the original concept that supports the modeling of social processes by linking descriptive and process models to the science. The RW supports open scientific dialog through annotation with a critical apparatus called DocReview. The scholarly apparatus of the RW is embodied in a new genre of documentation called the Research Web Essay, a hyperdocument. Several original tools provide support for the scholarly apparatus: bibliographic services, a glossary, annotation and management of content preparation. Topics for the RW Essays are extracted from the models. The essays, through critical refinement, eventually become canonical documents and the basis for research papers. The principal product of the RW is the production of new shared knowledge; the principal reward is authorship of research papers.

The Research Web concept is examined through case studies of three attempts to establish them. Case studies of 100 DocReviews examine not only the efficacy of the programs, but also the social and task-oriented nature of discourse expressed as annotation in the RW.

Table of Contents

List of Figures

List of Tables

Acknowledgements

Dr. Mary Ann Hawke remains to this day my prototype of an engaged scientific coordinator of Research Webs. She not only saw the advantages of conducting research under this new regime, but also worked on intellectual content far beyond the call of the requirements of her funding organization. She is a Gold Star Collaborator of the first water.

I would like to thank Professors Richard L. Morrill and William H. Rodgers. Jr. for their participation in my road to the degree. Bureaucratic rules leave no place other than this page for acknowledgement of their kind and very helpful contributions.

Thanks also go to my colleagues at CRESP who supported my work and assisted in working out the bugs in the software developed for Research Webs that they so readily adopted in their work. Standout participants include Bill Griffith. Gerald van Belle. Scott Bartell. Christie Drew. Alan Smith (911). Maurice Robkin. Stan Curtis. Tim Nyerges. Clint Farr and many others who will forgive me for my short memory of their help.

Professor Stephanie Chang worked enthusiastically with me on her Research Web. but was not rewarded with success due to the nature of her research team and the structure of the granting mandate. Thanks Stephanie. may the next one be successful: the last one was informative!

Much of this work was supported by CRESP through Department of Energy Cooperative Agreement #DE-FC01-95EW55084.

Dedication

This work is dedicated to Laura Larsson, my Bride of twenty-five years. She was always there with words of encouragement and words of substance where our interests intersected. Her patience and innate cheerfulness is exceeded only by her ability to put knowledge into practice. We do make a good team, the ultimate collaborators.

And a word of thanks to my late mother Lucille Marie Messinger Hendricksen. A child of the Great Depression from a hardscrabble timber town, she taught me to read and reckon at a very early age. Let this doctorate be her belated compensation for having, for economic reasons, to forgo her scholarships at this very institution.

Chapter 1 -- Introduction

In the twenty years that elapsed between the award of my Bachelor's degree in Geography and my entry into graduate school, I made my living practicing software engineering. I had eventually specialized in the design of embedded systems, systems whose behavior was managed by a computer. The software for these systems always arises from an elaborate behavioral model. Designers of such systems invariably anthropomorphize their system, attributing its behavior to a being that has a personality that is sometimes proper and placid, and at other times wretchedly wicked. When the system decides to be wicked, it's time to get out the software knives and do a little brain surgery.

Why couldn't a model of some small facet of human behavior be built using the same tools? Dismissing the problems of infinite complexity and the open system nature of human behavior, I decided that it could be done. The model of the system would have to be based on observations of reality. Causality would have to be modeled on theory derived from observation and experiment. A final model, a simulation equivalent to the behavioral model of software developers, would provide a validating test. Certainly such models would be superior to simplistic black box math models that used aggregated data and were empirically derived without recourse to cause.

While doing my Master's work, it became quite obvious that the major difficulty presented in such modeling was the immense amount of work to build such a model. A behavioral model of an activity such as human migration[1] would have to connect the best work that had been done over the past century, and more. Furthermore in order to incorporate the work of contemporary scholars, it would have to be maintained constantly. Clearly, models of this nature would have to be properly scoped and developed within a well-funded, long-term, large-scale collaborative effort guided by a team of dedicated researchers. Such a team would need a set of tools to make their work manageable, and would also need an organizational system to keep the team working harmoniously. This dissertation is a description of the design and use of such a system. the Research Web, and its tools.

1.1 Importance of Asynchronous Collaboration in Research

Over the years scientific research has become more difficult because the research that produces new scientific knowledge is supported by a long and ever more complex body of established knowledge. The hypotheses that suggest new lines of research emerge from a professional reading of the existing body of knowledge. Original research pushes beyond existing knowledge and thus requires more specialization and/or synthesis and often more effort, including mastering the research legacy of the problem. Increased effort requires either a larger research team or more time. If one subscribes to the view that research costs and results are roughly proportional to person-hours expended. then time becomes the limiting resource. and a larger team must be assembled. This team then needs to be drawn into an effective collaboration. There is a long-standing trend toward larger collaborations[2,3,4]. The scale of research is often much larger than in the past. and continues to grow each year.

> *... the complexity and subtlety of the constitutive problems that must be faced by the sciences we populate. the diverse requirements for both relevant information and understanding that they now impose. and the rapid emergence of a wide range of sophisticated technologies that are potentially of great value to us. all converge to make obsolete the "Mom and Pop enterprise" (i.e.. the single investigator with a few relatively inexperienced graduate students) that virtually all of us have operated in the past and that most researchers still operate.*
>
> --- William Bevan[5]

Specialization in scholarship has fragmented disciplines. so a good deal of interdisciplinary communication is often necessary. Not only have specialties been created by fragmentation. they have been created by new discoveries. by integration of disciplines. and by scientification of art and technology[6]. Specialists often find themselves isolated due to the increased specialization of scholarship. The isolation is an outgrowth of academic staffing policies; there is simply no need or economic justification for more than one specialist at most universities[7]. As a result, groups of specialists, hence potential collaborative teams, find themselves geographically dispersed. As a consequence of geographic dispersal, people are operating on very different UMT time schedules and are frequently unavailable for synchronous communication.

The recent, and continuing, burst of innovative communication technology has provided research teams with capabilities that augment conventional scholarly collaboration. Software to facilitate most aspects of scholarly research is in some stage of planning or implementation. Activity in both the software and hardware to support research is flourishing. Driven in part by this intense engineering activity, scholars have been providing the intellectual grounding for improving collaborative technology. Much of this research, especially that associated with commercial software, is pedestrian automation of existing methods, but some research has laid open the intellectual basis of collaborative activity. The intellectual pieces are beginning to emerge; but scholarly collaboration cannot realize its potential if recent research and new technology are not utilized.

> *The change from paper-based to electronic text is one of those elementary shifts – like the change from manuscript to print – that is so revolutionary we can only glimpse at this point what it entails.* ---- Jerome J. McGann[8]

Over the past half century, English has become the language of science. In several nations the English language is taught to all students in the common schools (e.g. Holland and Norway). English is the language of instruction in elite Universities in India, Russia and China. English as a Second Language has become an educational industry throughout the world. This slowly unfolding event has, by lowering a primary communication barrier, opened many more opportunities for collaboration. The Internet has provided the spark that might ignite an age of collaboration.

Politically and philosophically, the tenor of the times has changed to a more inclusionary and collaborative imperative. Elitism is recognized and usually banished from discussions affecting the public. Science, engineering and technology permeate our lives and are now subject to the same public scrutiny as political issues. Funtowicz and Ravetz[9] characterize much of today's science as being "Science for the Post-normal Age." This new science is applied to problems that are either highly risk-laden or have very high stakes. Both these situations call for a dialog that is extended beyond the elite to all groups and citizens holding a significant stake in the issue. Post-normal science is a more hopeful reaction to the Kuhnian "normal Science" than is the more fashionable, cynical and pessimistic postmodernism. The environment proposed in this dissertation is designed for post-normal science.

1.2 Key Assumptions, Novelty, and Bias

This dissertation proposes the adoption of methods that apply new technologies and management techniques to the existing world of scholarship. Some very basic assumptions about the nature of scholarship were used to design the collaborative environment. The environment that emerges is not revolutionary, but introduces some novel methods that will require some minor adjustments to behavior in scholarly collaboration. I owe it to myself and to the work to discuss my biases, which are, I believe, benign.

1.2.1 Assumptions

The two major assumptions in this work are that scientific research is framed in documents[10], and that scientific progress is made through critical dialog about those documents[11]. Many scholars and philosophers support these assumptions[12]. Two additional propositions, supported below, are of great importance: the importance of reflection and the importance of recording information transactions.

The software components for the collaborative environment are designed to be compatible with the World Wide Web; they are therefore, going to be effective only as long as the WWW remains the dominant information-sharing facility. Obsolescence of materials on the WWW and tools designed for WWW support is certain to be evolutionary due to the enormous body of content in place today. An example of the evolution is seen in the current challenges to HTML (Hypertext Markup Language) as the formatting language for web pages. XML (eXtensible Markup Language) is the favored language now, but HTML will continue to be accepted by web browser software for the foreseeable future.

When discussing collaboration and communication this research looks to the near future when most researchers will be facile with the equipment and software. Access problems due to economic or infrastructural limitations are given little attention under the assumption that such problems will be temporary, and also that most scientific researchers are properly equipped. On the other hand, this research does not espouse the most advanced technology, but rather the technology readily accessible to most researchers: access to the Internet and WWW, and a competent desktop computer.

This research focuses on collaboration supported by asynchronous communication. Synchronous communication, especially face-to-face verbal communication, is today considered the "Gold Standard" of communication. This research joins others[13,14,15] in challenging that assumption by showing not only advantages of asynchronous communications, but also the shortcomings of synchronous communications for the purpose of scientific collaboration or learning. The complementarity of synchronous and asynchronous methods is discussed.

> *... communities that combine both f2f [face-to-face] and CMC [asynchronous] systems would be able to bond better and share values more effectively than communities that rely upon only one or the other mode of communication.*
>
> — Etzioni and Etzioni[16]

The growing tendency of research teams to be geographically, and thus temporally, dispersed is thoroughly discussed. The time geography of these teams is described and used as a basis for the assumption of a growing need for asynchronous collaboration and communication. This research will lead to the definition of an environment for asynchronous distributed collaboration based on existing research and extended with theoretical support. The collaborative team and support personnel will form a "Network of Excellence" enabled by the proposed collaborative environment.

The human behavior exhibited during collaboration must be analyzed in order to design the environment and tools for the new environment. This behavior is studied in psychology, social psychology, sociology, management and political science. Each component of the proposed environment will be understood through scientific realism[17,18]and general systems theory[19,20,21], but is examined in greater depth and less abstraction by means of conceptual frameworks developed by scholars who have studied the embedding system of each component. Each tool developed in this research is considered an artifact cooperating with other tools in the environment and is examined on its own terms. It is shown that the components rest conformably within realism and general systems theory and fall within a common conceptual framework.

> *Social science is the science of social systems.* For this reason, it will have to use the approach of general systems science. --- Ludwig von Bertalanffy[19]

Interaction is the principal measurable attribute of collaboration. In order to evaluate collaboration, I analyze the records of interactions captured by the tools. Each tool having an interactive capability is equipped with programming to store a record of interactions in a log file. The time dimension of interaction can be extracted from the log files. The content of the interactions is permanently recorded in the textual dialog produced by the tools. The content of the dialog is analyzed using two qualitative coding schemes: Bales codes[20], and the structurational argument coding scheme[21].

1.2.2 Conflict with existing methods

The preference herein for asynchronous collaboration methods as opposed to synchronous methods is heretical and needs to be explained. One does not need to look far into the past to find the greatest advance in asynchronous methods since the movable type printing press: the Internet. Scholarship has been built on both synchronous methods. principally face-to-face conversation, and the asynchronous methods of postal services and scholarly journals. The Internet has marginalized the postal services. and will shortly do the same to the hardcopy journals. This dissertation proposes that a similar marginalization, or at least a marked improvement, needs to be made to synchronous methods. Why? Synchronous methods of collaboration have several major defects: they force all participants to schedule participation: they are the enemy of reflection. forcing all participants into rapid response and implied acceptance; synchronous methods are usually verbal. and thus difficult to record: synchronous dialogue or monologue cannot be searched [yet]; and finally. synchronous methods favor the rhetorically skilled and powerful. not always the knowledgeable.

- The emphasis on asynchronous communication is not due to weaknesses of synchronous technology. but rather the suitability of asynchronous dialog to scholarship.
- Asynchronous communications allows permanent documentation of dialog. and access to that dialog.
- Asynchronous communication gives plenty of time to reflect and compose.
- Synchronous communication provides advantage to the rhetorically facile. and it disadvantages those in isolated time zones.
- Use of synchronous dialog cannot be disallowed. but is discouraged unless the synchronous dialog is documented in minutes or archived e-mail.

The emphasis this dissertation places on asynchronous collaboration and communication will shock many scholars accustomed to communicating in synchronous modes. Remember that. at the time of writing. the Internet had only been in widespread use for a decade, and the WWW for eight years. Before the Internet Age, effective asynchronous collaboration was practically impossible. The ideas presented in this dissertation are in conflict with the collaborative methods most of today's scholars were taught.

Large-scale, long-term collaboration is an unusual idea to established scholars. The goal of collaboration in the past and today, especially in the social sciences and humanities, is the production of a single research paper. This is short-term, small-scale collaboration. The goal of a large-scale, long-term collaboration is learning about the issue domain, the development of theory and hypotheses, and the production of a stream of research papers.

1.2.3 Bias

There is, of course, the presumption of objectivity in any scholarly research. I have thought about my biases and attempted to reduce them, with some success. I do admit to being impatient with the glacial reaction of the scholarly community to the opportunities offered by the new technology. Despite this impatience, I've been able to examine the reasons for the conservatism exhibited by scholars. That examination opened my mind to the beauties of the existing techniques that scholars have developed over the centuries. Thus my designs do incorporate the best of the established methods, and offer some improvements. In other words, the technology is made to enhance the established methods of scholarship, not to supplant them.

The search for objectivity in examination of social issues in computing is, according to Mowshowitz[22], rather hopeless, since the research is motivated by questions of policy. The best one can do is to avoid the excesses of the positions that one must take. The worst danger is the tendency to suppress debate. Since an expanded version of this dissertation will be published on the WWW and every section made annotatable by anyone, I certainly have avoided that problem. Moshowitz outlines five positions that reflect contemporary thought on social issues in computing: technicism, progressive individualism, elitism, pluralism, and radical criticism. The social issue at stake here is the use of information technology in dialog; in our case the dialog is scientific argumentation.

Technicism is a view of the issue that equates the computer and its software system with an instrument of progress. One symptom of technicism out of control is the tendency to apply the system to problems that do not need it. The view that the issues deserving of research are either exceedingly complex, or very specialized, argues for the use of all the power we can apply to the research process. Yet, for the small-scale, short-term collaboration leading to the publication of a single research paper, current practices are adequate. While I certainly advocate the application of computing technology to collaborative research, I avoid the principal pitfall of technicism: placing the social activity under control of the system. The system serves the team, and the individual team members. There are some behavior modifications requested of the members, such as recording the essence of private conversations that contribute content to the dialog. These modifications are nothing more than what is called for in responsible team behavior.

Progressive individualism is a view that doubts the abilities of technical systems, social groups, and human judgment -- all in the favor of individual initiative. The views put forth in this dissertation all favor the ability of each individual to criticize any position held by institutions or individuals. Open individual criticism is seen to be the engine of refinement of research and its products, thus the proposed technical system empowers the individual and simultaneously protects the research team from domination by powerful members. It is my hope that the system serves the researchers without constraining their actions.

Elitism favors either technicians or managers. The danger in this outlook is that there may be controls built into the system that preferentially empower a single group. Certainly the proposed environment has controls built into the system. They take the form of restrictions of the genres that can be employed in the team's documentation. Every page on the web site is a WWW page. All e-mail in the archives is a WWW page. Fortunately the WWW page is one of the most flexible communication genres ever invented. This flexibility, and the almost universal ability to annotate the documents, saves us from elitism. Furthermore, the proposed system invests technical services and know-how in a facilitator who is subordinated to the scientific leadership.

Pluralism supports both conflict and consensus. The ability of all to participate is restricted by required membership in the research group. The members of the group may represent themselves or others, but are each constrained by several rules of dialogic behavior. While rules are put forward, individuals are also constrained by the characteristics of the system: open criticism is a great leveler, and the asynchronous nature of the dialog reduces the power advantages held by the powerful or those skilled in rhetoric. The proposed environment does not require consensus, nor does it require conflict.

Radical criticism is a position that challenges the other four positions defined by Moshowitz. This view is characterized by an appeal to determinism or devolutionism. Determinism centralizes power in the hands of the technicians and managers and, in conjunction with a powerful system, subjugates the humans that the system is to serve. The proposed environment tends to turn each member into both a beneficiary and a servant. Devolutionism insists on redistribution of social power. While the environment proposed in the dissertation does limit power and hopefully encourage universal participation, it seeks to work within the existing power systems: the ethos of science, the institution, and cultural practices.

1.3 Examples of Large-scale Collaboration

While there are several described examples of large-scale, long-term collaboration, most of these enterprises are organized by funding agencies and concentrate their management on the organizational aspects of the collaboration, leaving the management of the substantive research collaboration to the teams[23,24]. Many more examples exist, but their public realization is just a public area describing the mission, the members, and the research results. There is certainly research, perhaps in intranets, behind these public sites, but no indication of a collaborative character, or methods employed. I have found no examples of large-scale long-term research sites equivalent to Research Webs.

Collaboration initiated by funding agencies proceeds in a common pattern: first is the identification of candidate topics by an elite group from the management of the funding agency; next meetings are held to recruit scholars and plan the research effort; finally the plan is executed by research teams and research results are published and discussed. The management of substantive research is left to the research teams. In short, the agency provides funding and guidance; but its contribution to substantive research is largely limited to the organization of meetings.

1.3.1 National Center for Geographic Information and Analysis (NCGIA)

The NCGIA was founded in 1988 with a National Science Foundation (NSF) grant. In the last 13 years the NCGIA has supported numerous Initiatives, Conferences, workshops, and curriculum development committees; and has provided financial support for many scholars and research associates. Most of NCGIA's research activities are now under the aegis of Project Varenius.

> *The objective of NCGIA's new research plan, entitled Project Varenius, is to advance geographic information science through basic research, education, and outreach. The research is motivated by scientific, technical, and societal concerns. First, the research serves science and scientists in two ways, focusing on areas in which our knowledge of formalizable geographic concepts is currently incomplete, and contributing to the development and refinement of tools and methods that scientists can use to study geographically distributed phenomena. Second, the research provides basic understanding of geographic concepts, which is required for the production of new technologies. Third, the research examines the impacts that these technologies have on individuals, organizations, and society, and that other digital technologies have in the context provided by geographic space.* --- Varenius Project Description[25]

Like other funding organizations, the NCGIA identifies and debates candidate topics inside a select group of scholars. This group contains the geographic information scholars of the invisible college of Geography, many of which are from the NCGIA. The candidate topic is then discussed in specialist meetings where the focus is sharpened and plans are made for funding and promotion of research outside the NCGIA. Research is conducted by participating scholars and is reported and discussed in workshops, seminars and in the literature. No provisions are made by the NCGIA to facilitate substantive collaboration at the detailed level.

1.3.2 Cochrane Collaboration

This very large and successful distributed enterprise is devoted to the establishment and practice of evidence-based medicine. The principal product of the Cochrane Collaboration is a set of systematic reviews of clinical trials that examine specific health problems or intervention practices[26]. While the work is nowhere near complete and will take decades to provide the information all physicians and health care workers need, the Collaboration is a very active and growing concern.

It is in the Systematic Reviews where collaboration takes place. Each Review is prepared by a group of collaborating authors called a Cochrane Reviewing Group. The work of the group is very highly formalized in order to maintain a rigid set of quality requirements. The formal methods are published in *The Reviewer's Handbook*[27]. The methodology that guides the work is complete and well established; but there are, in the implementation, many opportunities for criticism and discussion.

The Reviewer's Handbook does not specify methods to resolve disagreements or how to engage in collaboration. The Review Group is required, however to document the methods used to make decisions on selection of studies and how they resolve disagreements. The Handbook suggests using outside colleagues to help identify unpublished studies that might be examined for inclusion.

When one examines the details of how the Review Group must go about its business, it becomes clear that many of the tools and methods used in the Research Web could be applied to the Systematic Reviews. For instance, the Handbook suggests the use of Procite, a personal bibliographic manager, to establish a bibliography of studies that may be examined. The Annotated HyperBibliography, an important tool of the Research Web, is based on a personal bibliographic manager. Use of the Annotated HyperBibliography would allow very rapid access to the studies, with their abstracts (usually structured abstracts), and perhaps full text accessible at a click; and would provide the reviewers with an annotation area that might serve as an information base sufficient to exclude or include a large portion of the identified studies. As the study progresses several sections of the final Review will be drafted. DocReview, the critical apparatus of the Research Web, could serve as a tool to attach annotations to the draft for use in writing later editions. The information repository function of the Research Web would serve to organize and store much of the documentation, such as formal letters of request for information.

It appears that the Cochrane Review Group is exactly equivalent to the Research Web's authoring team. The Cochrane Review itself could be DocReviewed after release, thus opening the product to annotation and suggestion from the user community. Since the Reviews have a mandated peer review prior to release, that would be another use for DocReview. Bero and Rennie[28] point out many mandated demands for review and make a very strong case for continual review and updating. Presenting the Cochrane Review as a RW Essay, a hypertextual augmentation of research reports, would be quite appropriate; but their use would require some changes to the document formatting and methods of distribution (the reviews are currently distributed on CD). The hypertextual nature of the RW Essay would allow direct linking of the Review to its data.

1.3.3 MacArthur Foundation: Research Networks

In 1980 the MacArthur Foundation embarked on the establishment of "an experiment in scientific organization." Following two years of study, two Research Networks were established to study facets of mental health. The constellation of Research networks reached sixteen in 2000[29]. The Research Networks are organizations that support interdisciplinary long-term collaboration in research domains of particular interest to the Foundation[30].

The management of a Research Network is very flexible, featuring a close association of a scholar-representative of the Foundation and the Network Chair, who is selected by the Foundation. Members of the Network are selected solely on the basis of their scholarly potential, not on any institutional or geographic affiliation. Funding from the Foundation is intended to support the infrastructure: seed money, administrative support and bridging. The Members are expected to acquire funding for the substantive research through the normal grant proposal process.

During early organizing meetings, the scope of the issue domain is settled. The issue domain must be specific enough to attract members intellectually, but general enough to provide room for individual growth. The Networks have a *core group* of between seven and sixteen member who are organized into *subgroups* formed on the basis of research interests, rather than discipline, institution, or geographical region[31]. Membership in a subgroup is quite stable, though not permanent or exclusive. Networks also create *temporary working groups* designed to fulfill a task defined by a subgroup. These groups usually include investigators outside the core membership. Some temporary working groups may be organized to perform pilot studies, or exploratory research under the direction of one of the members of a subgroup.

The methods for substantive collaboration are left to the members of the Network, and what exactly occurs in that collaboration has not been described. There is fundamental agreement with the organization and funding of the Research Networks and the collaborative research methods of the Research Web. The working groups of the Research Networks correspond exactly with the authoring groups of the Research Web. The Network Chair corresponds to the RW's Scientific Coordinator. The Core Group corresponds to the RW's Principal Investigators, plus the Scientific Coordinator.

Placing the responsibility for modeling with the Network Chair could easily rectify the absence of modeling as a principle in the MacArthur Research Networks. As the Network chairs have administrative assistants assigned to remove the details of management from their shoulders, so might a modeler be provided to remove that task from the leadership by taking information directly from the temporary working groups. The modeler could also be assigned to assist the working groups with the detailed models of their subdomain.

1.3.4 Daimler-Benz Foundation: Ladenburger Diskurs and Kollegs

The Gottlieb Daimler and Karl Benz Foundation was founded in 1986 with the intention of examining the interrelationship between humankind, environment and technology. To that end, the Foundation has established a 'think tank', the Ladenburger Diskurs, to identify topics for further examination in actual research to be carried out by interdisciplinary research associations, the Ladenburger Kollegs. There have been seven

Kollegs formed, five of which have completed their work. One of the recently completed Kollegs studied organizational learning in rapidly changing environments[32]. This Kolleg had seventeen projects lead by 40 social scientists, managers, consultants and administrators from 11 countries.

The Ladenburg Diskurs establishes potential topics, recruits researchers, and submits a proposal to the Foundation. If the Foundation accepts the proposal, a Ladenburger Kolleg is formed. The Kolleg and its projects are funded by the Foundation and the Foundation provides facilities for several meetings of the Kolleg at the Foundation's Estate in Ladenburg. There are no provisions made for collaboration at the project level, as the Foundation is concentrating its efforts on the introduction and implementation of communication processes and publication of findings[33]. Based on the history of the Kollegs, it is also apparent that most Kollegs are designed to have a determined lifetime and specified output. Research Webs, on the other hand, have an indeterminate lifespan and do necessarily have predetermined products, except for the models of the issue domain.

1.3.5 What's Missing?

Research Webs need a home, a virtual location that would be the equivalent to a research laboratory or Institute. For social science issues, the Institute model, with its physical collocation property, is simply incompatible with the spatially fragmented nature of academic research. Distributed institutes are unlikely to be formed simply because it is the nature of Universities to want to "keep the money at home." Favoring researchers at a given University flies in the face of an imperative to recruit scholars who are qualified, available and committed to study of the issue domain.

Where is the model for a large-scale, long-term, well-funded, distributed research community? I see two close approximations: Research Webs administered by endowed chairs and the MacArthur Research Networks. In both of these models the central administrator is a respected scholar, and is free to recruit anywhere. Since the non-labor expenses of running a Research Web is small, existing University infrastructures will support the technical requirements. Labor in both cases is provided by grants obtained by members of the research team. Seed money is provided by either the endowment or the Foundation.

1.4 Geographical Aspects of the Research

There are several geographic factors that influence this work: the potential application of the concepts to academic research in geography; the influence of spatial distance on collaborative research teams; and the effects of geographic differentiation, especially cultural, linguistic, and economic differentiation.

1.4.1 The Benefits of Collaboration for Geography

Morrill, while president of the American Association of Geographers, stated in his Presidential Address[34] that, " if geography is a meaningful part of knowledge seeking and if it deserves to survive, it has to concentrate on creating a coherent body of theory that others recognize as significant." He suggests that research can best be strengthened in centers of excellence devoted to the development of theory in single issues for long periods of time. Such centers would concentrate intellectual power into a critical mass, enable much-needed collaboration and feedback among the participants, and would support and encourage visiting scholars and postdoctoral students to become the next generation of research leaders. Morrill's speech was given on the cusp of Internet acceptance, so was cast in the physical presence mode of Institutes. This dissertation suggests the application of the new technology of the WWW to create "cyber-places" that will defeat the tyranny of distance within the very discipline that is based on distance. Not only will cyber-places provide immense savings in time and travel expenses: but they will enable a wider audience to participate, usually from their own offices or homes and on their own schedules, changing a research setting that Morrill characterized as having "astonishingly little feedback or interaction."

Most of the sub-disciplines of Geography are international in scope. Systematic studies such as transportation and economic geography are taught and practiced all over the world. While international collaborations to write journal articles and edited books are common in geography, there is little evidence for collaboration on a larger scale. Since most of these collaborations are joined to produce a single paper. they usually dissolve after the paper is accepted. Occasionally a set of authors collaborates on a series of papers over the years, but usually the collaboration is short-term and limited in scope. A notable exception to small-scale collaboration in Geography is the National Center for Geographic Information and Analysis (NCGIA) initiatives. These initiatives are cooperative agreements between scholars and teams of scholars from many institutions. There are elements of collaboration and coordination at the more abstract levels of their broad issue domains; but true scientific collaboration is present in some specialized projects within the initiative's framework. The initiatives are more "incubators" of collaborations than they are themselves collaborations.

Relatively large-scale and long-term collaborations are common in the physical and natural sciences (e.g. the LTER. Long Term Ecological Research). less common in the social sciences. and nearly absent in the humanities[35,36]. These scholarly collaborations assemble around the physical presence of large machines in physics. and around well-funded laboratories in medicine and biochemistry. The poorly funded social sciences. including geography. could join in large-scale long-term collaborations by creating their laboratories in cyber-places called Research Webs (see Chapter 3).

1.4.2 The Influence of Geographic Distance on Scientific Collaboration

The international character of science mentioned above is not the only factor putting distance between scholars. The economics of higher education are such that in many academic departments there is only one position open for the specialist[37,38]. The hiring of single specialists will provide the instructional coverage. but will not create the critical mass for research work[39]. There are even elements of competition for students – a department may choose to avoid a specialty if a nearby university is serving the local needs well. Thus even within a given country the specialized scholars are dispersed. Distance effects are expressed as communication expenses and quality impacts. Unless the scholar is well equipped and facile with communication methods other than face-to-face conversation, the communication is severely degraded and collaboration unlikely. The cost required to participate in face-to-face meetings is often too great for the limited budgets of most social science collaborations. The airline fare alone for one intercontinental trip is more expensive than all the hardware and software necessary to equip a researcher for computer-mediated collaboration over the Internet!

Another important effect of geographic dispersal is the difficulty of coordinating synchronous communication. In countries with multiple time zones, like the United States, Canada, and Russia, in each day there are at most only a few hours when one can expect colleagues to be in their offices simultaneously. When one adds a few inevitable time commitments and a mid-day meal, telephone calls are difficult to complete unless scheduled in advance. Conference calls spanning several time zones are virtually impossible to arrange without major inconvenience to at least one party.

Travel and communication expense are avoided if the collaborators communicate over the Internet. The time zone differentials are defeated if the bulk of communication occurs asynchronously. If collaborators are willing to learn a few new methods, distributed asynchronous collaboration over the Internet through a Research Web can support most tasks of communication and collaboration.

1.4.3 The Influence of Geographic Differentiation on Collaboration

Collaboration, the creation of new shared knowledge, is profoundly influenced by the heterogeneous nature of culture, politics and economic well-being. The inclination to collaborate is profoundly influenced by the culture of the society. Within a given pluralistic nation, religious and ethnic communities, and class differences create a mosaic of attitudes affecting collaboration. For instance, in British Columbia, some native North Americans practice "information bartering"[40]. Asking a question is likely to be met with evasion unless some information is offered. The pervasive influence of Confucianism in Asia has been cited as an obstacle to the practice of science[41,42]. National character is yet another layer of attitudes[43]. For example, in the United States individualism is instilled into the children, especially males, of the society at an early age and reinforced by the national mythology.

Language is not as great a difficulty (for anglophones) as it was in the early 20th century. English is now the de facto language of science[44] and most international conferences use English as the working language. Of course in many specialized areas such as regional geography knowledge of the local language is a powerful requirement. English is not the native language for most of the scholars of the world, thus when non-native speakers communicate written English is often preferred to spoken English[45]. Even a small time lag allows the writer to reflect before sending and the reader time to study the message reflectively[46].

The political attitudes toward communication technology have recently been in turmoil. Religious fundamentalism has caused legislation restricting Internet access in many Muslim countries. In the United States, "Computer Decency Acts" have been placed into law, and then overturned by more liberal courts. In Germany and France, the presence of Ultra-Nationalist and Neo-Nazi WWW sites has generated a great deal of political debate. The People's Republic of China has many restrictions on Internet activity and no stable policy[47].

The distribution of wealth between nations and among their citizens has a profound influence on the ability to collaborate. Very poor nations do not have the communication infrastructure to support access to the Internet, even assuming that the prospective collaborators have the necessary equipment. International consortia sometime fail to recognize the needs of their poorer partners[48]. Though computers capable of accessing the Internet are routinely discarded in the developed world, the means to distribute them to the needy are not well developed.

National telephone monopolies sometime charge exorbitant prices for Internet access, leading to "internet strikes" in Brazil, China, France, Germany and elsewhere[49]. Even within the United States, Internet access costs are extremely variable. All aspects of the access situation are extremely fluid. For instance, the Village Internet Program of the Grameen Communications and Grameen Foundation USA is beginning to provide "Cyber Kiosks" to village entrepreneurs in Bangladesh[50]. Wireless communication technology may alter the economics of telephony to the advantage of the currently disadvantaged.

1.5 Contribution to Knowledge

This dissertation describes the collision between the new information technology and the established methods of collaborative scientific research. The opportunities presented by the Internet and associated technologies offer research teams powerful new methods of managing collaborations. These methods have a profound impact on every phase of research activity. It is not technology alone that disturbs the equilibrium of the past: management of the collaborative effort is confronted with new challenges. The behavior of collaborators is also in need of reconstruction as the old methods are replaced with the new.

The impacts of the Internet and the World Wide Web are so new that software is just now emerging that will capitalize on the capabilities of the technology to solve old problems or to facilitate collaborations. I present a coordinated suite of web-based tools that were designed and implemented to facilitate research collaboration in the new information environment.

A concept called the Research Web (RW) is presented. The Research Web is a generalized environment for asynchronous scientific collaboration in the new information environment. The RW has a baseline configuration of tools useful to any research team. The nature of the research topic will determine any additional specialized tools that the collaborative team needs. The concept is flexible and can meet almost any needs. The unifying technology is the WWW -- every document is accessible as a web page, and web-based forms guide most interaction.

A new research communication genre is presented. This genre, the Research Web Essay, makes research papers interactive. The reader can annotate the paper publicly, thus turning the paper into a means for collaborative dialog within the research team or the "invisible college." Marginal notes can once more be used by authors, rather than footnotes (which have no meaning in a scroll document) and endnotes (very inconveniently placed). Citations can be clicked to present bibliographic data, including abstracts. The bibliographic data window contains paths to allow the user to annotate the reference, and to display full text if available. Definitions of terms used in the Essays can be displayed from a glossary at a click. The user may annotate the definition. Ancillary documentation such as images of proper nouns and notes to team members may be popped up at a click. References and footnotes are included at the end of the document and include return links to all places cited. The reader can then quickly see the context in which a work is cited.

The critical apparatus of the RW Essay is presented in DocReview[51] (see §4.3). DocReview is an annotation program that allows the reader to attach an annotation to a predetermined segment of text or to images by clicking an icon, an orange colored W.

Clicking an orange colored R allows reading existing annotations. This annotation process is the principal means the research team has for refining working documents. Any document may be DocReviewed and, in a collaboration, most should be. Meeting minutes, position papers, agendas, proposals, specifications, and even spreadsheets have been DocReviewed with success.

The tools and concepts presented herein were applied to several collaborations with mixed results. The collaborations are described and analyzed and the results are used to develop a series of recommended practices. The nature of the collaborative team is investigated. The roles that members need to play (collaborator, facilitator, scientific lead, research assistant, etc.) are discussed.

While the target activity of this dissertation is scientific research, the arguments presented and the tools described will apply to a large variety of group activities. With modifications and incorporation of tools that match the problem domain, activities such as public participation in decision-making can be supported. Problem-solving activities such as planning in engineering and architecture can benefit from the Research Web environment. The constants in the arguments presented herein are:

- The collaborator is given the freedom to schedule personal participation.
- The asynchronous format allows the collaborator to reflect while reading, to reflect on a response, and to reflect on the phrasing of the response.
- All documentation and dialog is permanently recorded.
- All documents are presented as WWW pages, a universally understood genre.
- The entire web site, documents or e-mail, is capable of being searched on line.
- Access to the collaboration can be made from any Internet enabled computer anywhere in the world.

1.6 Organization of Dissertation

The conceptual framework for this work, a triad of foundations, is presented in the following Chapter. The proposed new research environment, the Research Web, is presented in Chapter 3. Chapter 4 discusses the tools developed for or planned for inclusion in the Research Web. Empirical field studies of three Research webs and of 100 document reviews using DocReview, the critical apparatus of the Research Web, are found in Chapter 5. Conclusions and directions for future research are presented in Chapter 6.

Notes to Chapter 1

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[1] Hendricksen 1994

[2] Price 1963

[3] Merton 1973

[4] Thagard 1997

[5] William Bevan 1989, 5

[6] Niiniluoto 1995

[7] Walsh and Bayma 1996a, 667

[8] Jerome J. McGann 1997, 40

[9] Funtowicz and Ravetz 1993

[10] Ziman 1976, Chapter 5

[11] Weimer 1979, 78

[12] Latour 1987

[13] Etzioni and Etzioni 1997

[14] Sudweeks and Rafaeli 1996

[15] Etzioni and Etzioni 1999

[16] Etzioni and Etzioni 1999, 247

[17] Aronson, Harrè and Way 1995

[18] Sayer 1992

[19] Ludwig von Bertalanffy 1968, 195

[20] Bales 1950

[21] Meyers, Seibold and Brashers 1991

[22] Mowshowitz 1981

[23] Schade and zu Putlitz 1996

[24] Kahn 1993

[25] Goodchild *et.al.* 1997

[26] Bero and Rennie 1995, 1935

[27] Clarke and Oxman 2000

[28] Bero and Rennie 1995, 1937

[29] MacArthur Foundation 2000

[30] Kahn 1993, *passim*

[31] ibid., 17

[32] Anon 1998

[33] Schade and zu Putlitz 1996, 279

[34] Morrill 1987

[35] Thagard 1997

[36] Endersby 1996

[37] Walsh and Bayma 1996b, 346

[38] Koku, Nazer and Wellman 2000

[39] Pickering and King 1992, 359

[40] Hébert 1986

[41] Tsou 1998

[42] Hsü 1992, xxii

[43] Hofstede 1991

[44] Garfield 1967, 19

[45] Sanderson 1996, 107

[46] Friermuth 2001, 176

[47] Xiaoming, Zhang and Yu 1996

[48] Cohen 2000, 2157

[49] New York Times, Circuits, 14 Jan 1999

[50] Yunus 1998

[51] Hendricksen 1998

Chapter 2 — Models, Research Process, and Collaboration: A Review of Literature.

This dissertation proposes a new way of conducting long-term. large-scale social science research. In order to understand both the present and proposed social systems of research. we need to examine many issues. These issues include the nature of the research process itself, the nature of the scholarly establishment, the supporting technology that served in the past and the technologies that are necessary to support research in the future. While the success of large-scale long-term research in the physical sciences is quite clear. social science research is dominated by solo or small-scale efforts. We need to know why: and when we do we may see how new research efforts can be conducted on a scale that matches our ignorance of social processes and problems.

Figure 2.0 below shows some of the shortcomings of current research methods. This is to be contrasted with Figure 2.5 that shows the conceptual framework of this dissertation.

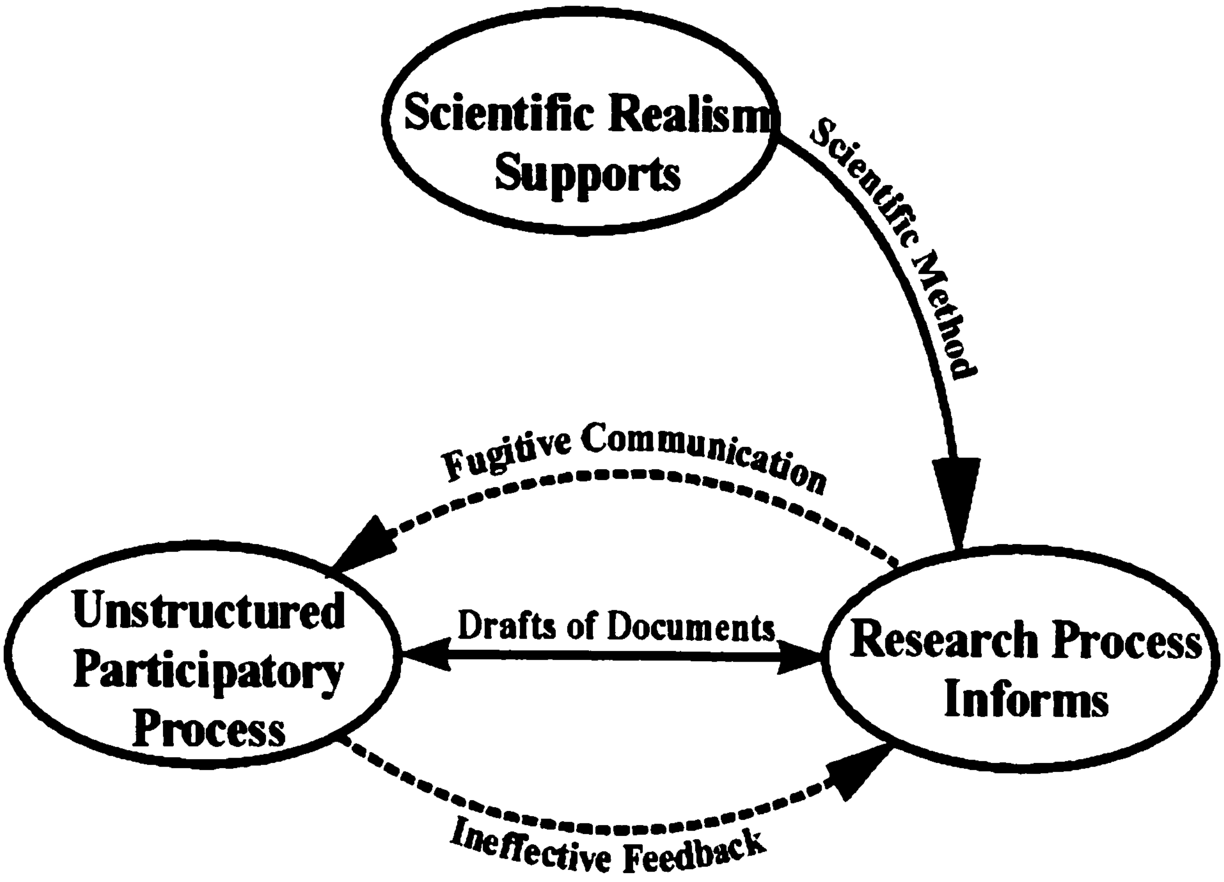


Figure I Existing Collaborative Environment

We start with the selection of scientific realism as an underlying philosophy. The research process is currently driven by the team's understanding of the scientific method and by the customs of their discipline. The participatory process, so necessary in large-scale research, is currently typically unstructured, dominated by unrecorded dialog between the participants -- often on a dyadic basis rather than on a team basis. Participation is now dominated by the sharing of document drafts in a process where criticism is not shared, but is generally channeled to the team leader. This concentration of power is antithetical to current concepts of social participation.

We hope to remediate many of the problems in current research environments with a new process that again begins with the selection of scientific realism to guide our research. A methodological approach to research will guide the research team from its conception to maturity; we select a methodology that resonates with realism. We end with a proposed conceptual framework that allows us to relate the interacting elements that comprise a research process and technological environment suited to large-scale long-term social scientific research collaboration.

2.1 Scientific Realism and Models

> *"There are only real things and the real ways they behave. And these are represented by models, models constructed with the aid of all the knowledge and techniques and tricks and devices we have."*
> --- Nancy Cartwright[1]

> *"The Fact is the basis, the foundation; Imagination, the building material; the Hypothesis, the ground plan to be tested; Truth or Reality, the building."*
> ---J.H. van't Hoff (1852-1911) Chemist, Musician, Mathematician, Positivist

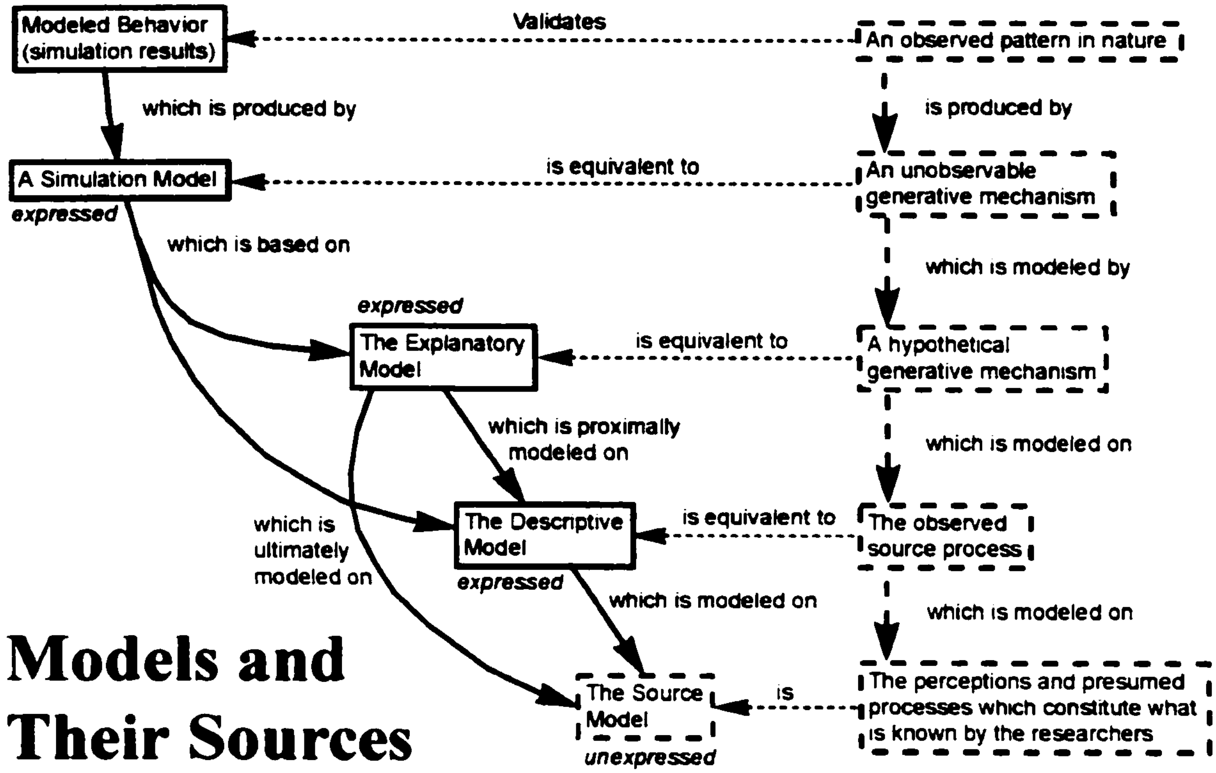
A realist believes in an objective existence of the objects found in the research process. The scientific realist might be one who is persuaded by the arguments found in *Realism Rescued: How Scientific Progress is Possible*[2]. The principal argument in that work is that theory is actually embodied in a suite of three models. These models are the source, descriptive, and the explanatory models. The source model is an unexpressed model of reality from which the descriptive and explanatory models are derived. The source model is the union of the tacit knowledge of the team members, the literature that has been identified by the team, and the intellectual content of the current received wisdom. The model may include myth, ideology, and dogma[3]. The descriptive model is a representation of the objects and relationships between the objects of the issue domain.

The explanatory model is a representation of the causal power of objects and the mechanisms driving the processes[4].

I have extended the philosophical argument to include a simulation model. This model takes findings from the descriptive and explanatory models and creates an environment that can be used to investigate the effects of change in the system. The simulation model, if provided the state conditions existing in reality at a past time, and the inputs subsequent to that time will produce a description of the system state at the end of the input actions. If the output of the simulation model consistently produces results practically resembling the actual behavior of the system, then the entire chain of modeling from source to simulation is validated by correspondence[5].

The support that scientific realism provides to research is a rationale for modeling practice. The descriptive model is an organized representation of all the information acquired and developed about the objects and their relationships. The explanatory model provides information of an operationalizational nature to the simulation model: qualitative and quantitative parameters. Both the descriptive and explanatory models may be represented by diagrams and supporting text derived from existing genres, especially from software engineering and artificial intelligence[6,7,8,9,10]. Simulation modeling requires much more formality in modeling and calls for the rigor of Unified Modeling Language
(UML)[11,12], Object Role Modeling (ORM)[13] or other formal methods. The simulation model is a computer program represented by algorithms, which are in turn supported by a variety of graphic models and textual documentation. The model representation, as a genre, is discussed at length below (see §3.2.4.2).

We will see that the Research Process, described below in Figure I, is composed of three interdependent domains that are supported by the modeling rationale of scientific realism. The research work within the substantive domain, the observed world, is represented in the descriptive model. The Explanatory model represents the relationships among elements of the conceptual domain, the causally driven world. The experiments undertaken in the methodological domain, the manipulable world, are reiterated in the Source (simulation) model.



(Harre, 1970, 1978, Aronson, Harre and Way 1995, and Hendricksen)

Figure II Models and Their Sources

2.1.1 The Source Model

The descriptive and explanatory models are based on the team's source model. This source model is simply all the knowledge the team has about the issue domain. the perceptions and presumed processes that constitute what is known by the researchers. It is the union of the tacit knowledge of all research team members. the scientific literature known to members. and any new knowledge produced by the team. Note that tacit knowledge may contain knowledge that is in fact not true[14]: knowledge that is false, myth, or error. Philosophical myths and dogma may also be a part of each member's tacit knowledge[15]. To a large extent, the source model is the union of all the team member's mental models. Mental models are cognitive categories, beliefs about the world, held by individuals[16]. The source model is unexpressed; but as it becomes expressed its objects and its processes become part of the descriptive model. Like any other model, the source model changes with new knowledge; errors are excised and new knowledge, beliefs and conjectures are incorporated.

Tacit knowledge exists on a continuum of codification of the mental model through culture and routines into expressed knowledge. The qualities of codifiability and teachability influence the rate of knowledge transfer[17]. Moving tacit knowledge to more explicit codified forms is one of the principal jobs of the knowledge network known in this research as the Research Web. The means of transforming knowledge is communication, and communication of tacit knowledge is dependent on the strength of social ties: strong ties are needed to transfer tacit knowledge, while explicit knowledge is easily transferred through weak ties[18].

Since the source model is unexpressed, it cannot be criticized. As elements of the source model become transformed to explicit knowledge and expressed in other models, the other members can subject the elements to critical review. The Research Web is designed to support this criticism.

2.1.2 The Descriptive Model

The Descriptive Model (DM) is the repository for knowledge related to the observed reality of the issue domain. A description of every type of tangible entity (object) that exists within the issue domain has a place in the DM. Every process that is observed to operate in the issue domain is described in temporal, spatial and/or social terms.

Processes relate objects within the issue domain and relate parts of the issue domain to reality outside the issue domain.

As the elements of the source model are expressed they become part of the descriptive model. Objects are identified and refined by extension and criticism. Relationships between objects are expressed and entered into diagrams that organize the knowledge about the objects. Observed processes are described, showing the actual operation of some of the activities within the issue domain. The Research Web, through hypertextual organization, takes its shape from the hierarchical organization of the objects into natural types. Process models relate all the objects and show how they operate in time and space and perhaps socially as well.

The Descriptive Model is created, extended, criticized and refined by the entire team, but most especially by those members who work in the Substantive Domain of the Research Process (see §2.3.2.1, below). As time passes, regardless of the stage of completeness, the Descriptive Model is continually revised and those changes cause ripples to perturb the other models of the system. The DM is the model that the Explanatory Model is modeled on.

2.1.3 The Explanatory Model

The Explanatory Model (EM) is inextricably paired with the Descriptive Model[19]. While the DM seeks to represent the issue domain, the EM seeks to provide causal mechanisms driving the issue domain. The EM is built on the elements, objects and processes, from the descriptive model and the set of hypotheses that emerges from the research. The EM provides a model of a hypothetical generative mechanism for the observations of the DM[20]. For each observed process from the DM there will ideally be a set of explanations based on testable hypothesis. The testing is carried out by experiment to corroborate the developing theory.

The construction of the EM is the principal responsibility of team members working in the Conceptual Domain of the Research Process (see §2.3.2.2 below). The EM becomes the basis for hypothesis generation. As findings accumulate from experiment and research, the EM becomes more mature and comprehensive and eventually becomes a definitive representation of theory.

2.1.4 The Simulation Model

The simulation model (SM) is derived from the DM and the EM. The SM is the model driving the work of those researchers operating in the Methodological Domain of the Research Process (see §2.3.2.3 below). The SM can be used to develop describe hypotheses and develop experiments. In this way the SM provides results for the further refinement of the DM and EM. The SM will be implemented late in the research process, in stage 3 (see §2.3.3.3 below) or the corroborating phase. In many research projects the SM will not be fully implemented due to both time and expense. The simulation model will be a very major undertaking which can really only be justified in long-term, large-scale research projects -- just the project configuration proposed for the Research Web.

Of great importance to the development of the Simulation Model is another model, called the Auxiliary Model, which explains the operationalization of the elements of the SM from their origins in the DM and EM. The auxiliary model concept was proposed by Blalock[21]. A carefully designed auxiliary model insures that measurements of a given attribute of a DM variable are properly represented in the SM[22]. Blalock[23] later suggested that auxiliary models are necessary "whenever our theories are about postulated properties (such as attitudes, values, and abilities) that are only indirectly inferred on the basis of directly observed behaviors." He explores four specific situations calling for careful use of auxiliary models, including very common situations such as the need to use data from two or more levels of analysis, and situations where the measured variable is intrinsically fuzzy or boundaries are rather arbitrary. The auxiliary model is also necessary to operationalize variables whenever an experiment is designed to explain any phenomenon[24].

The hypertextual organization of the RW is essential to demonstration of the operationalization rationale of every element of the simulation model. Since the auxiliary model is diagrammatic and textual, it may be easily criticized. In short, the auxiliary model provides validation of the SM, under the assumption that the DM and EM are correct.

> *...it seems wise to develop a hypercritical stance that brings many ... hidden assumptions into the open as possible, and then to examine very carefully their implications.* ... H.M. Blalock[25]

In practice the auxiliary model will not exist as an entity, but will be expressed as augmentations to the DM. The nature of the augmentation is to explain how the attributes of objects are measured. The auxiliary model can be thought of as the argumentation that validates every operationalization decision in the SM. Each of these arguments can be independently criticized and refined. With multiple operational definitions of objects multiple versions of the SM may be implemented each with different results to discuss.

The simulation model is based not only in scientific realism, but in general systems theory[26] as well. General system theory considers hierarchy to be fundamental in all systems[27] just as scientific realism bases its models on a hierarchy of natural kinds. This philosophical conjunction supports the existence of a hierarchy of models at different scales or levels of abstractions. These nested hierarchical models would seem to fulfill Morrill's[28] wish for methodology that would support "several levels of explanation for the same phenomena, depending on the question asked."

2.1.5 Grounding of the Use of Models

The models, when well developed, provide support for processes fundamental to the scientific investigation. Charles Pierce argued that scientists engage in syllogistic reasoning in their work, and this results in a 'logic of discovery' of four steps[29]:

1. observation of an anomaly.
2. abduction of hypotheses for the purposes of explaining the anomaly.
3. inductive testing of the hypotheses in experiments.
4. deductive confirmation that the selected hypothesis predicts the original anomaly.

In a well-developed model, an anomalous qualitative or narrative datum will likely be noted and perhaps critically discussed. Certainly numerical data may be subjected to statistical tests that will identify outliers and other instances, which beg explanation. In the development of explanatory models these data represent problems that need to be disposed of, as they defy the current explanations.

The means of explaining anomalies begins with a process of abduction. Abduction is not well understood philosophically, but is well enough known to be identified as a practical tool. Shank[30] associates abduction with 'ground-state' or ordinary thinking. Abduction is applied any time we find ourselves in an ordinary situation and know what to expect[31]. Six modes of abductive reasoning[32,33] are identified as:

a) reasoning to the omen (or hunch)

b) reasoning to the clue

c) reasoning to the metaphor or analogy

d) reasoning to the symptom

e) reasoning to the pattern

f) reasoning to the explanation

In the research environment, omens, hunches, clues, metaphors, analogies, symptoms, patterns and explanations are supplied in abundance through data, observations, ideas, proposed explanations, etc. The primary repository of these data are: the Descriptive Model; the RW essays, data stores and e-mail archives; and, to a limited extent, the Explanatory Model. Hypotheses developed through abduction to explain anomalies may be presented in documents that may be criticized.

Inductive reasoning is used to examine the formalized and operationalized hypothesis through experimentation. The results of the experiment will then be used as evidence in the Explanatory Model. These explanations should also then be linked from the observation of anomalies that started the abductive examination leading to the hypothesis.

Deductive reasoning is seldom employable in the social sciences. Deduction is the examination of truth based on axioms and rules of logic, and rules and axioms are absent or weak in most social sciences; thus formal deduction is not seen there. In the research environment, however, we do have axioms and rules. Due to the impossibility of knowing everything about an open social system, we build the Simulation Model to summarize and operationalize our knowledge about the system. The Simulation Model must be realized as a computer program, and computer programs operate with rules and axioms.

So, to the extent that our rules (logic and synthesized explanatory processes) and axioms (observations) are true, we can deduce or predict. Now, if we submit a scenario to the Simulation Model, and the Simulation Model predicts an outcome that is compatible with the expected outcome, then we have a weak confirmation of the models. That weak confirmation is, in effect, an observation made by the Simulation Model and is no more to be trusted than an abductive conclusion. These conclusions are, however, usable in several ways: first they do, if in adequate quantity, provide a demonstration of robustness; second, they may be used to abduce the fuzzy boundaries of the issue domain without running very expensive experiments; and finally, they may be used to examine new hypotheses before subjecting those hypotheses to actual, and very expensive, experimentation.

2.1.6 Validation by Correspondence with Systems Analysis Practice

The computer entered our lives in the late 1940s and became a business tool in the 1950s. Early software applications were simply automations of existing business applications. These programs required very little analysis, just programming. In the 1960s and 1970s software became ubiquitous throughout the business world and with it came the realization that something had to be done to control its cost and quality. The answer that business found was software engineering, a professionalization of the trade of programming. The basis of software engineering was not programming, but systems analysis.

In the late 1970s a number of techniques were developed for software engineering. One of these was Structured Analysis and System Specification (SA), popularized by Tom DeMarco[34]. The technique was designed for and applied to information systems development, but as we will see, that application is a very good analog to any research project managed as a Research Web.

SA starts with a study of the current environment. That study results in the production of a model called the current physical model. In our vocabulary, the current physical model is exactly equivalent to that part of the descriptive model that deals with the physical objects of the system. The next process in SA produces another model called the current logical model. That model is exactly equivalent to the part of the descriptive model that deals with the processes that are observed in the system. As we will see later, the equivalents of the current physical and current logical models are built in the first stage of the research project. In realist terms, we call these models the descriptive model.

The next SA model is the new logical model. As DeMarco puts it, this is the model that represents the system, as it *should* operate as opposed to how it *does* operate. Clearly that is a model of an artifact to be constructed; not, as we might hope, a model explaining *why* the system operates as it does. Yet, in this step of the SA system modeling of the new logical system there are parallels to the realist explanatory model. The new logical model applies business rules to the system -- rules that may not have been well implemented in the observed system. In the realist explanatory model, we might discover *causes* that make it necessary to go back and do some more observation of the issue domain for some more subtle objects or processes that cause the system to act as it does.

When the new logical system is implemented we have a new physical system. This new physical system is exactly equivalent to the simulation model I've proposed. The simulation model runs scenarios with data based on the descriptive model. The activities that are simulated are drawn from the explanatory model and results in an outcome that should be recognizable as some behavior that the real system would or has produced. The simulation model in the realist system would be the equivalent of the SA information system in operation with human activities simulated as well as the information system.

There is little doubt that there has been more effort poured into modeling for software system design and database design than in modeling for all other purposes in the entire history of mankind. Large portions of software engineering modeling practice are excellent analogs of the realist models, validating the realist model by correspondence. In the 24 years since DeMarco's work was published, software engineering tools have been much improved. The object-orientation paradigm and universal penetration of relational databases into information science have resulted in not only a rich literature, but also a great number of computer-aided tools to produce both the graphics and text needed for models.

While accepting that software engineering has shown that modeling is effective and an established methodology, we must take note of the fact that software engineering is focused on the building of information systems. Modeling of reality, an open system, is a much more demanding task than modeling the closed system of a business information system. In our proposed new environment, the Research Web, the descriptive models are more complete than those used to model information systems. Our team members must model a wider range of attributes because they do not have a goal in mind. In an open system we do not know when a relatively obscure attribute may become important.

2.2 Adapting the Existing Research Environment to Collaboration

The existing research environment is the result of several hundred years of evolution punctuated with occasional periods of turmoil when adapting to new technology. It has taken fifty years to adapt to the computer, and now we are in the most chaotic period of adaptation to the Internet revolution. We have, in the past, adopted many revolutionary technologies that remain with us today as integral parts of our research environment. Most adaptation calls for coevolution: the tools of the past are modified to work with new tools that improve the conduct of research. So it is with the environment proposed in this work. The document remains with us, the journal remains, the academic environment remains, older communication technologies remain, and above all, culture and the human psyche remain.

This section examines documents, general systems theory, reward systems, organizational behavior, and communication technology in order to provide knowledge that serves the design of new tools and the organization of research teams to use them. We will discuss the old along with the new and benefits as well as pathologies.

2.2.1 Research as a Literary Enterprise

Speech is the representation of the mind, and writing is the representation of speech.
— Aristotle, *De interpertione I*

It is abundantly clear that science cannot progress without the recorded artifacts of research. Scientific research is framed in documents[35], and scientific progress is made through critical dialog about those documents[36]. While a lecturer can influence the lives of students and change the direction of colleagues; unless the lecture materials are recorded, they will have a very short life. Early scholars wrote books, an expensive medium that did not offer an outlet for short articles. It is probably the scientific journal that is responsible for the industrial revolution and the flowering of science that followed. In the latter seventeenth century the scientific journal began an expansion that is not yet spent[37 38].

Publication of research findings in scientific journals allows alignment of an author's work with previously published works supporting parts of the author's hypothesis. In a scientific paper, propositions other than the hypothesis being investigated must be supported by reference to supporting documents[39]. The references in a paper recognize the contributions of earlier scientists. Citation analysis[40] is the quantitative study of the scientific contribution of an author as measured by published works and by the appropriation of the author's work by peers. Recognition by peers is the leading reward in science.

The scientific paper is clearly the dominant expression of scientific findings. The current Internet revolution will not change that fact: the genre is embedded in the practice of science. The Internet revolution will, however, change the form of the scientific paper. While the physical representation of the research paper is currently inseparable from the printed page, that is rapidly changing. Many prestigious journals are now publishing facsimiles of their printed articles on the WWW. Physics is driven by electronic preprints, with journals serving more as archives than as the primary mode of article communication[41]. Usage of electronic journals shows a growing acceptance, but there are reports of a (probably transient) sharp age-based differentiation in usage with 56% of academics under 40 using e-journals, as opposed to only 14% of those over 40[42].

The question of submission of scientific papers to e-journals is quite a different question[43]. Disciplinary and departmental norms frequently deprecate e-journal publication, for good reasons. Several general problems with electronic documents served from the WWW contribute by association to the deprecation of e-journals[44 45]: web-based documents are so easy to copy that originality and authorship is uncertain; ephemerality of the document is unavoidable without long-term institutional support; and revision control methods to prevent multiple versions are not widely enforced. The debate about the relative merits and problems of paper and electronic publication rages on, but the advantage seems to be with electronic publication. Odlyzko[46] suggests that on economic arguments alone, e-journals will become dominant. From the reader's standpoint, cost, accessibility, and utility favor e-publication; while from the institutional standpoint, archival standards, the weight of tradition, and the multi-billion dollar influence of the scientific publication industry favor paper. Lawrence[47] reports that every academic year from 1989-1990 to 1999-2000 showed a substantial increase in the percentage of research articles available online. While Lawrence studied articles in computer science, it seems unlikely that similar increases are not present in the social sciences and humanities.

This dissertation proposes a form of the scientific paper that is more useful than the current printed genre or its electronic facsimile. While no less literary than the printed research paper, the HyperDocument (see §3.4.4.1) remediates many of the shortcomings of the current representations of the research paper. The HyperDocument allows the reader to quickly access references and associated documents while avoiding some shortcomings of paper-based documents: expense, difficult access, linear organization, and its inability to display animation and sound. Even the argument of portability fades because a HyperDocument printed from the WWW on a color printer contains all the features of a printed document. The HyperDocument is annotatable online, permitting reader criticism of the scientific paper.

Within the RW, there are many other forms of documentation in use. In the detailed work of research, contributions such as critical commentary, definitions of terms, experimental data, opinions, and position papers all serve to advance the argumentation surrounding the research. The RW serves as a repository for all this knowledge.

2.2.2 Research as a Dynamic and Open System

The issue domain of the Research Web provides the focus or organizing principle for the RW, usually expressed as a system model. System models in the social sciences and life sciences are almost always models of open systems[48]. Closed systems exist mainly in controlled experiments, those largely in the physical sciences. The RW must, then, have the flexibility to respond to the unexpected. Even more importantly, the RW must be able to assimilate the unexpected fact or event into its models.

The scientific research most suitable for expression in a RW is long-term large-scale research. This class of research is characterized by frequent changes and additions as research continues. The frequency of revision is directly proportional to the size of the research team and inversely proportional to the amount of current knowledge about the issue domain. Interdisciplinary research is also subject to changes due to discoveries and changes in the dominant paradigm in each discipline. However we choose to look at our knowledge, it is likely to be full of numerous feedback loops[49].

The RW is designed to facilitate the revision of content. The RW Essays can have information appended to them by annotation in DocReview. New literature can be posted to the Annotated HyperBibliography quickly by the facilitator. While preparing a new edition of an RW Essay begins with authoring that is equally arduous in all media, the facilitator has software that makes the re-presentation of the web page quite easy.

With its emphasis on modeling, the RW makes modeling of open systems an interactive and participative design activity. If any member recognizes an omission or error in any model, there is an immediate and obvious way to annotate the model so the changes can be incorporated. Modifying the simulation model programming is a technical task to be sure, but those modifications must be preceded by changes in the graphic/textual descriptive and explanatory models. It is very important to document the presence of influences from outside the current boundary of the modeled open system[50].

2.2.3 Reward Systems in Research

Yes, Virginia, scientists do love recognition, but only since Pythagoras.

— Leon Lederman[51]

Rewards systems are social constructs. The major influences have been the practitioners of science, followed closely by politicians, ethicists, philosophers and business people. The rewards systems have legacies rooted in the past, and like any legacy has a dominant paradigm and an elite, both of which serve to give the reward systems great inertia. There are two ways to look at reward systems: normatively and realistically. Both approaches uncover desiderata and practical fact. The normative approach gives us the public face of how scientists should be rewarded, and the realistic approach yields a somewhat more sanguine story.

According to the normative approach, the reward system should serve to encourage successful adherence to the four factors in the ethos of science expressed by Merton in 1942[52]: universalism, organized skepticism, communism and disinterestedness. In order to be published a scientific work must adhere to the ethos of science while introducing new knowledge. Only through publication can a scientist gain peer recognition. Merton, in 1957[53], establishes recognition as the jewel in the scientist's crown, with recognition of priority as its brightest facet. Reward systems are central to the study of the sociology of science.

A realistic approach examines personal motivation as the builder of reward systems. Cohen[54] says, "In science, as in so many other professions, the coin of the realm is not collaborative generosity but credit – credit for individuals." The psychology of reward systems is at odds with Merton's idealistic ethos of science. The deepest motivation to scientists may be the desire for power. Power is achieved through recognition[55]. And recognition is achieved by publication of research, but enabled through the exclusive professional structure of science: degrees, awards, memberships and position.

> *Thus recognition is not merely a passive phenomenon. During both revolutionary and normal periods of scientific growth, it is a rite of passage which confers the right to recognize others: it represents a source of power in the scientific community.*
>
> — Beaver and Rosen[56]

Recognition is based on intellectual achievements, mostly published research that is cited by others, leading to acknowledgement of the origination of ideas. The most effective publications are in peer-reviewed journals of high reputation. The citations must be from established scientists also writing in quality journals. The ultimate reward is to have principles and ideas attributed to oneself permanently[57].

No discussion of reward systems within the collaborative environment can be meaningful without referring to the dominant rewards systems operating today: professional recognition; academic tenure and promotion; and industrial career advancement. The outstanding characteristic of all three systems is that authorship of research papers dominates all evaluation factors. A scientist's reputation rests on credibility which waxes and wanes with the scientist's publications. A "cycle of credibility" strengthens with the volume of quality publications. This body of produced knowledge is the driving variable in obtaining funding for more research and equipment to produce even more publications[58]

While the professional reward system evolved by scientists operates at the highest institutional levels, much of a scholar's career is engaged in satisfying the requirements of the academic tenure and promotion systems. Academia has two or more masters: educating the populace and serving science. There is a great tension in serving masters with conflicting goals. The usual factors for evaluating performance are: teaching, research and service. All take time, but in practice teaching and research compete for the scholars time, while service is largely incidental. Our interest is primarily with research, but the tools and concepts presented here can also serve in teaching and service. Our research will focus on the impacts of rewards systems on research activities.

In defining the nature of scholarly faculty work, Rice[59] defines four forms of scholarship: discovery, integration, practice, and teaching. The first three components are types of research: basic, synthetic and applied. Basic research is new original research, usually intradisciplinary; synthetic research is integrative and interdisciplinary; and applied research is the application of research to the solution of problems. Each of these types of research is treated differently in the reward systems. In academia, basic research is favored, while synthetic research is acceptable though marginal, and applied research is disdained. Boyer[60] points to several forms of scholarship that are seldom recognized, including writing computer programs and writing for the public press and even popular television. Tool building is simply not rewarded at all[61]. In the humanities, computing is sometime regarded with suspicion and scholars so involved may find themselves marginalized in their departments[62]. Since all three types of research can benefit from the application of asynchronous collaboration in Research Webs, we need to find how the contributions to the RW can be rewarded.

2.2.3.1 Rewards in Practice

The ultimate incentive for participation is reward. Without rewards, participation in a Research Web (RW) will likely wither after the first flush of enthusiasm is spent. Each person on the research team is encouraged by rewards coming from internal satisfaction, peer approval or institutional rewards. Research groups can receive encouragement from peers or from their sponsors or other interested institutions. Rewards reinforce participation while the barriers operate to discourage participation. The response by individuals or groups to the pros and cons is complex and idiosyncratic.

Since participation is central to collaboration and the concept of the Research Web, we must develop new means to reward the team members for contributions other than research papers. We must also attempt to ameliorate the more corrosive effects of current practice. Reward driven behavior as well as the products of such behavior can be used to measure participation in a Research Web.

Contribution of content by authorship is without question the most important single category of participation. The rewards attending authorship are highly developed, though not without problems. Existing rewards for authorship are deficient in dealing with new forms of publication. In the "pecking order" of professional literature, the single author peer-reviewed research paper in prestigious journals is premier. Publications in peer-reviewed electronic journals are often heavily discounted due primarily to the newness of electronic journals[63]. The most prestigious journals in many fields frequently disregard critical or controversial work and emphasize "institutional" research that extends the current dominant paradigm in the field[64].

Unpublished position papers, working papers, essays and conjectural works that are published on the WWW as part of a RW or personal home page can be important contributions even though they might not be considered for publication by the journals due to length, style, content or prior publication strictures. Writing software for research purposes, even if useful and freely shared with colleagues, is seldom rewarded. Invocation of a scholar's name on the WWW in the RW's public partition or within the RW's working area may become a reward. Study of invocations on the Web may eventually allow alteration of existing methods of performance evaluation by recalling the scholar's name from unusual genres of communication such as commentary, acknowledgments, reports of professional activity, e-mail messages and meeting minutes[65].

Criticism is extremely important: it is the means by which content is progressively refined from a draft to a canonical document. Criticism of a RW essay can eliminate "holes", pose new hypotheses, and contribute to quality. Criticism of references in an annotated bibliography can point out errors and where those errors are corrected. Criticism of the annotated glossary can sharpen meaning of a term or introduce new nuances of meanings. A three-sentence note can change the direction of a paper. Criticism must be rewarded. The RW provides a permanent record of annotations that establishes a record of critical contribution.

Leadership provides the necessary social glue to coordinate the efforts of the research team, to deal with the administrative details, and to keep the work going forward by encouraging participation by the members. While the scientific leadership is generally vested in the Principal Investigator (PI), in practice the PI often shares many of the functions of leadership. Foote[66] suggests faculty who build or maintain collaborations do not often receive much credit for their efforts. The members who shoulder the day-to-day burdens of leadership should be rewarded.

An analysis of reward systems can proceed from two directions: first is an analysis from the viewpoint of the recipient of the rewards—individual, research team, or cooperating agencies (psychological, sociological, political); second is an analysis of the rewards that may be granted from distinct sources.

2.2.3.1.1 Received Rewards

Individuals are motivated by internal satisfaction, recognition by peers and by the team at large and by organizations cooperating with the research. Internal satisfaction stems from numerous sources: pleasure at the reduction of cognitive dissonance, closure of tasks, learning, etc. Individuals are stimulated by their peers, especially those on the research team; by the team itself, expressed as pride in the team's accomplishment; and to a certain extent by approval of cooperating agencies, often expressed in letters of commendation and in press releases. In the RW, as in other academic groups, social academic rewards are received by two main mechanisms: potential enhancement of reputation, and by reciprocity expressed as permission to use the information contained in the group's knowledgebase[67].

Membership in an active community of scientists is itself a reward. Senior scientists expect this reward, but it is carefully doled out to junior members of the team, post docs and graduate students. This reward is the principal mechanism for socialization of new scientists. Lave and Wenger have named this mechanism *legitimate peripheral participation* and have thoroughly explored the issue[68].

The research team receives rewards of recognition from professional peers in the form of mentions in the press, citation of reports published by the team members, and by communications directed to the team; and from cooperating agencies in the form of additional support in the form of encouragement, additional equipment or support personnel and ultimately the reward of financial grants. Cooperating institutions receive rewards in the form of prestige due to their sponsorship of successful research, recognition of public service, recognition of fulfilling a mandate.

2.2.3.1.2 Granted Rewards

Major rewards offered to individuals by the research team are: inclusion of their essays in the RW, inclusion as author on papers submitted to journals, public acknowledgment of contributions[69], financial support from grant funds, invitation to join the research team, and employment as a staff member. Another class of rewards is ceremonial support that lends official recognition for service and the passing of milestones[70].

The importance of ceremony in team dynamics is often minimized. This minimization may be caused by intellectual hubris. Ceremony does play a large role in our lives and to neglect it is to ask for suboptimal performance. Ceremony is easily overdone, especially when it is obviously artificial. Ceremonies should be sincere occasions that show realistic expectations of participation and the desired effect. Since conventional ceremony always requires physical presence, the distributed research team ceremony faces a special problem: celebration in isolation.

Ceremony in our special environment suffers greatly from the lack of media richness. Lack of personal presence prevents the use of tone of voice, gesture, touching and other forms of communication. We have great difficulty in reinforcing the message of the ceremony by engaging the members emotionally. On the other hand we do have some advantages: the ability to very carefully express one's self verbally, the ability to reflect on the message rather than react to it, the ability of the receiver to recapitulate each communication, and the suppression of intemperate reaction. If we recognize our weaknesses and capitalize on our strengths, we can successfully incorporate some ceremony into our Research Webs.

Rites of passage, especially those encountered in professional socialization such as graduate school, may be made less traumatic by collaboration with peers[71]. Daniels[72] has teased elements of rites of passage from the ordinary group meeting: Birth (introduction of a new person or idea); Maturation (recognition that a product or project has reached a new stage of usefulness); Marriage (restructuring in the organization); Leadership (promotions, appointments or assignments); Thanksgiving (recognition of awards or acquisition of new resources); Discipline (identification of poor performance and determination of penalties); and Sickness and Death (the identification of problems and allocation of resources to remediation, project, product, or performer termination). While Daniels' insights are useful, Trice and Beyer present a more academic analysis (see Table I below). They have developed a typology of rites that is quite useful for design purposes.

Table I

A Typology of Rites by Their Manifest, Expressive Social Consequences

Types of Rites	Example of rites in the Research Web	Manifest, Expressive Social Consequences	Examples of Possible Latent, Expressive Consequences
Rites of passage	Welcoming a new member to the team. Announcement of retirement of a team member. Rotation of the scientific leadership.	Facilitate transition of persons into social roles and statuses that are new for them.	Minimize changes in ways people carry out social roles. Reestablish equilibrium in ongoing social relations.
Rites of degradation	Dismissing a member and changing group passwords. Removing an author from a writing team.	Dissolve a relationship.	Publicly acknowledge a problem. Defend group boundaries and membership.
Rites of enhancement	Announcement of awards or prizes. Passing on notes of appreciation.	Enhance social identities and their power.	Provide public recognition of individuals for their accomplishments; motivate others to similar efforts. Enable organization to take some credit for individual accomplishments.
Rites of renewal	Announcement of a new essay topic. Announcing an author and team for a paper.	Refurbish social structures and improve their functioning.	Reassure members that something is being done about problems. Legitimate and reinforce existing systems of power and authority.
Rites of conflict reduction	Discussion of conflicts by means of DocReview commentary.	Reduce conflicts and aggression	Compartmentalize conflict and its disruptive effects. Reestablish equilibrium in disturbed social relations.
Rites of integration	Face-to-face meetings at professional conferences. Teleconferences. Conference calls.	Encourage and revive common feelings that bind members together and commit them to a social system.	Permit venting of emotion and temporary loosening of various norms. Reassert and reaffirm, by contrast, moral rightness of usual norms.

(adopted from Table 1, Trice and Beyer 1984)

Except for rites of integration, there is an asynchronous solution for any type of rite. As befits the medium these solutions are all documents. These documents are likely to be issued by the scientific leader, and should anyone else care to issue them, they should coordinate the release with the scientific leader. Announcement of awards with potential professional value to the recipient should be forwarded to organizations, such as the recipient's academic department, that might find them important.

There are likely to be other types of rites emerge from the genre of the Research Web. For instance, one of the likely events in a mature RW is to develop a spin-off RW to investigate a new idea. Perhaps the RW will be incorporated into a RW of larger scope. Leadership of new RWs is likely to be awarded to outstanding performers, either substantive or collaborative.

Cooperating institutions can grant rewards far more valuable than the offerings of the RW team. Academic departments, colleges and universities may grant tenure, make promotions, award cash grants, change the scholar's duties, or many other coveted rewards. Granting institutions can offer endowed chairs, financial grants or fellowships. Professional organizations or private foundations may grant prestigious prizes. It is important to realize that none of these rewards are likely to materialize without a great deal of persistent effort on the part of the RW leadership.

2.2.3.2 Determining and Distributing Rewards

> *Designing the incentive to collaborate is just as important as designing the technology for collaboration.* --- Michael Schrage[73]

Collaboration is quantifiable in a RW. Most contributions are documented as authored essays, comments and e-mail to the team. Gone are the days when the ability to work in a team is measured by guessing at popularity around the water cooler. The results of evaluation of participation in collaboration may be surprising as it becomes clear how each member behaves: who takes the time to review a document: who comes up with new ideas; who volunteers to do humble chores; and who offers little to others.

Rewards for collaboration are very poorly developed. At a psychological level, most people feel self-satisfaction with their contributions. The contributions also need to be appropriately rewarded at the sociological level, or at the professional level[74]. In the RW, rewards may be thanks, an acknowledgment in a published paper, or authorship, or may be the first author. Thanks and other expressions of appreciation should be offered consistently as a matter of human courtesy. At a more formal level, the authors of papers should acknowledge everyone who contributes commentary or minor bits of substance to the paper. These contributions are characterized as subauthorship collaboration[75]. The papers produced by the RW team will be part of the RW as essays. There is plenty of room to acknowledge everyone who contributed, perhaps in order of value to the authors. While journal editors may request that acknowledgments be abridged or eliminated, the team controls the RW essay (which may be made public). The acknowledgment is a neglected genre that may, in the coming full-text world, lead to better recognition of collaborators.

As a standard procedure, an advanced draft of any paper that is published should be recast as a RW essay and placed in the public partition of the Web Site. This will provide an annotatable version of the paper. As time has passed, publishers have become more willing to grant permission to allow the placement of an annotatable draft of the paper on the WWW. This will increase the exposure of the authors and those acknowledged.

Authorship is the most visible prize and should be (and almost always is) very carefully determined in advance of the first draft release for comments by DocReview. Additions to the author list, the order of the author list and perhaps the deletion of an author can be made as the project moves forward. Occasionally a valued commentator may be invited to join the authors. Endersby[76] suggests that all individuals making an active contribution share authorship, while those whose labor could easily be replaced by others, be acknowledged. The APA (American Psychological Association) recommends that only those contributing to the content be awarded authorship, thus eliminating complimentary authorship to heads of departments and laboratories.

The RW team is frequently very independent of academic departments, especially if the team is interdisciplinary. Since the team members are not usually subject to oversight by their academic supervisors, the scientific coordinator should appropriately commend each academic on the team to his or her academic chair. If this is not done, collaboration other than authored papers will likely not be rewarded in the academic department. The prevalent failure of academic administrators to appreciate collaborative behavior is cited in a special study sponsored by the Association of American Geographers:

> *Finally, we recommend that academic administrators and faculty acknowledge that reward mechanisms are now based almost entirely on individualistic conceptions of faculty roles. Without exception in the committee's experience, rewards accrue to individuals evaluated in isolation. That view of faculty roles may prevail for some time. We opine, however, that the kinds of collaborative and team efforts that have proved productive in other industries eventually will prove useful in geography, probably in the form of instructional teams using several complementary methods of instruction.* ***Research in geography also may move beyond the artisan or craft scale that currently prevails, to projects that are addressed collaboratively by organized groups.*** *[emphasis provided]*
>
> **— Toward a Reconsideration of Faculty Roles and Rewards in Geography**[77]

2.2.3.3 Penalties

There is a variety of counterproductive behavior that must be prevented. Besides abiding by the normal mores of professional behavior, all participants must avoid or at least reduce certain behaviors peculiar to working in a group. Since most of the work will be done over the Internet, all members should be aware of the rules of "netiquette." Much more serious is the problem of non-participation or reluctance to participate publicly. Many individuals, especially those in the social sciences and humanities, have been socialized in a world that rewards individual effort. Some people may be shy or embarrassed with their language skill; others may feel that their stature is too elevated to bother with details. Non-participation is a problem that can be solved by three paths: example, training, and leadership. A well-functioning collaboration is an example to newcomers and to team members who are slow to join the party. The facilitator can tutor team members who need help in learning the tools of the environment. Leadership is just as important in a distributed on-line community as it is in person. If a PI lacks leadership skills, the job of scientific coordinator can be passed to someone who possesses the needed skills.

Collaborators who fail to participate can be removed from the team. This penalty may be necessary in order to prevent demoralization of the team. Resentment is a natural reaction toward free riders. David Coleman has established online communities of managers roughly equivalent to Research Webs[78]. These groups have an annual subscription fee for members, and if a member is not contributing, Coleman suggests that these "checkbook members" be asked to resign.

Members who are on authorship teams may be removed if they fail to fulfill their responsibilities. Since authorship is the principal reward in science, such a strong penalty must be used cautiously, with the concurrence of not only the lead author, but the scientific coordinator as well. Another, more effective, class of penalties is admonishment. Admonishments should be considered whenever one of Pröpper's rules of engagement (see Table II in §2.2.4.6.2) are violated. If admonishments are not effective, then removal seems to be the only alternative. Antisocial or disruptive behavior is unlikely unless the RW is open to the public. The team must be able to marginalize or exclude such people[79].

The penalties suggested above are very severe and are unlikely to be applied in an academic environment. Recent research in game theory in economics suggests another control over the free-riding problem. Fehr and Gächter[80] show that if team members are offered the opportunity to punish free riders, they do so, even when it comes at some cost to them. Assume management was to provide a bonus pool to be publicly distributed among the team members based on their peers rating of their collaborative behavior. If the team members were allowed to distribute an allowance to other team members as they chose, then the free riders would be publicly identified by their poor bonus, and of course the prime collaborators would also be identified by a generous bonus.

2.2.4 Participation and Collaboration

Collaboration is, of course, impossible without participation. Participation is developed only through hard work on the part of the team members, and especially the members placed in leadership positions. Participation is encouraged by several mechanisms, among them professional ethos, pay, emotional commitment, curiosity, altruism, recognition and avoidance of the negative consequences of non-participation.

2.2.4.1 Participation as a Covering Term for Interaction

> **Participation**: *n.* 2b. A taking part, association, or sharing (with others) ***in*** some action or matter [emphasis provided]. -- Oxford English Dictionary.

Obviously nothing happens in a group effort unless people interact. The activities are the dimensions of participation. The word *in* links the activity with the object of the action. The object of the activity may be decision making, learning or scholarly research, or any other activity that humans or their surrogates engage in. The principal terms used to describe the *dimensions* of participation are: collaboration, communication, coordination, cooperation and contribution.

Even in the scientific literature, the terms collaboration and cooperation are used loosely. Sanderson notes the close relationship between collaborative and cooperative research[81]. Both forms of participation are working together to a common end, but collaboration calls for a much more dedicated relationship between the participants marked by the creation of new knowledge. Cooperation is a less intense relationship marked by the sharing of resources. The boundary between collaboration and cooperation is seamless. I believe another distinction may be made, by denying that organizations can collaborate, since collaboration is a synthetic intellectual action joined only by individuals. Representatives of organizations may collaborate, but the organizations can only cooperate.

As an illustration of the confusion between the terms collaboration, and cooperation, the "Nairobi partnership" is a pastiche of programs that has grown over the years as a vehicle for studying and attacking the problem of AIDS in Kenya. Some of the institutions involved are universities at Nairobi, Winnipeg, Toronto, Antwerp, Ghent, Oxford and Seattle. Funding comes from various sources and totals over $4.8 millions per year. In the over twenty years of its existence the partnership has produced nearly 300 papers. In a recent Science article[82], the partnership is referred to as a collaboration, yet the Kenyans involved complained at a retreat held in 1998 that key collaboration practices were underdeveloped. Specifically cited was a need to incorporate Kenyans when they draft research proposals, manuscripts, and conference presentations. Also, University of Nairobi staff that currently does not work with the project should have more opportunities to participate.

Of additional interest to this discussion are some parallel relationships: that of objects or symbols of communication -- data, information and knowledge; and terms describing representations -- analogy, metaphor and model[83]. Of particular interest is a modern model of the participating social group: the model of distributed artificial intelligence (DAI)[84]. Artificial intelligence (AI) is an interesting model in that it is based on the reality of individual human thought, yet treats that thought as a network of separated activities within the mind. DAI adds to the model the concept of interactions between intelligent entities (human or machine).

Why introduce a model using artificial intelligence to the discussion of a very venerable and intelligent human activity? First, DAI is a simplification of the bewildering complex of human collaboration; and second, it allows us to include, as actors, non-human agencies such as organizations, cultures, and yes, even computers. By identification and inclusion of these non-human agents we can better understand the activities of the humans participating in the collaboration.

2.2.4.2 Communication as Participation

> **Communicate:**
> *v. trans.* 2. To impart (knowledge, information and the like); to impart or convey the knowledge of, inform a person of, tell. -- Oxford English Dictionary.

Communication is the process of diffusion of objects in a network of active or passive nodes. The objects that diffuse over the network may be pieces of raw data, information or knowledge. The nodes may be active, as humans are; or passive, as are machines, just responding to requests for information, or accepting information for storage. A library may be considered a passive node that may for instance provide a copy of a paper for a researcher.

Communication has dimensions of bandwidth, or capacity, and path, or connectivity. Bandwidth may be further described as the effectiveness of communication; that would in turn be divided into effectiveness of production, transmission and reception. Bandwidth is a measure of both quality of transmission and volume of information contained in the transmission. Communication is seldom even close to perfect. Communication degrades as thoughts are collected, symbols assigned to the thoughts, preparation of the symbols for transmission, noise in the transmission, errors in reception of the transmission and finally errors in interpretation of the symbols transmitted[85].

Path is described in terms of impedance of the linkage between two linked nodes. Direct connection is the most effective, and the effectiveness of indirect connections is proportional to the number of intervening nodes and the transformations that may occur in those nodes. Extremely indirect connections are very unreliable and ineffective. Complete lack of connection is possible. Links are directed, that is they are either one way or bi-directional. The impedance in a bi-directional link is not likely to be equal in both directions due to differences in productive or receptive capabilities.

Participation by communication need not be interactive. People often participate passively in discussions, simply reading the interactions of others. This sort of participation is a mode favored by those interested in the topic, but not prepared to engage in the discussion. The reasons for failure to engage may be unwillingness to invest the time required, insecurity (evaluation anxiety), or a conscious recognition that their contributions may not be up to the standards of the group. This behavior is commonly termed *lurking*, and is often wrongly equated with non-participative behavior (free-riding, social loafing, self-censorship, or surrender to authority). Lurking is quite often used to learn about the community, its language, problems, and methods of dialog[86]. Toleration of lurking by the active and elite members of a group is in fact the most democratic example of legitimate peripheral participation[87]. Lurkers are given the privilege of listening to the dialog in hopes that they may eventually join the group as a qualified participant.

Within a Research web, the social ties of the members are strong to weak, but certainly are not non-existent. As time passes, and as the occasional face-to-face meetings occur, the team's social ties will become stronger. Gächer and Fehr note that theory suggests that desire for social approval and avoidance of social disapproval are the mechanism for maintaining custom[88]. They note the weak empirical support for the suggestion that custom encourages participation; but then show in experiments[89] that while free-riding is only slightly and insignificantly affected by social approval. within a group with at least weak ties, social incentives give rise to large and significant reductions in free-riding.

2.2.4.3 Cooperation as Participation

Cooperate:

v. intr. To work together toward a common end or purpose.

-- American Heritage Dictionary

Cooperation is the act of agreement with the objectives of the participation and the commitment to facilitate the process of reaching those objectives. People cooperate by agreeing to participate. and by agreeing to deliver work in a timely fashion. Organizations cooperate by agreeing to facilitate the participation by supplying data. information. resources. or funding to the participants. Cooperation is frequently promised in the spirit of building an enterprise. but less frequently granted in practice without a contract or memorandum of understanding. Cooperation exists on a continuum of participation that is bounded on the high end by becoming collaboration and on the low end by simply not interfering with the enterprise[90].

Cooperation from academic institutions has. for interdisciplinary projects. often been poor. Disciplinary parochialism has been cited as a problem[91]. For collaborations beyond two-author papers. institutional support is necessary. even if it's only favorable notice in tenure reviews[92].

2.2.4.4 Coordination as Participation

Coordinate:

v.t. To work together harmoniously. -- American Heritage Dictionary

Coordination is a management function. Tasks must be assigned to individuals or groups in order to maximize the efficiency of movement of a team toward a goal. These tasks may need to be related in a network of temporal precedence. Recall that the final action in a task must by definition be preceded by all other activity. Every other act, except the beginning act, has both preceding and following acts. Tasks can be organized in linear or branching networks (serial or parallel). There is an excellent model of coordination, PERT/CPM (Program Evaluation and Review Technique / Critical Path Management) that uses time as its basis.

Coordination is managing dependencies between activities.

---- T.W. Malone & K. Crowston"

Communicating task descriptions can result in healthy discussion of the team's overall plans. Criticism of tasks may eliminate unnecessary tasks and point out new requirements. The work performed in coordinated tasks may be thought of as efficient use of resources. To the extent that efficiency declines so does the quality of the product. Very large projects do have plenty of routine work that can benefit from coordination by management. Collaboration, on the other hand, is seldom routine so has little need for coordination.

2.2.4.5 Contribution as Participation

Contribute:

v. intr. To give or supply in common with others; give to a common fund or for a common purpose. — American Heritage Dictionary

Without contribution of content and resources there is no product. Intentions do not produce results; they are the precedents of production. Contributions are tangible offerings from individuals and institutions to the enterprise. There is a difference in the character of the contributions an institution can make as opposed to the contributions of individuals and groups. Generally speaking institutions are enablers, contributing resources such as services (libraries, computing power) and funding. Team members and their colleagues may contribute resources, but they are primarily contributors of knowledge and the intellectual effort required to bring that knowledge to publication.

2.2.4.6 Collaboration as Participation

Collaborate:

v. intr. To work together, especially in a joint intellectual effort.

— American Heritage Dictionary

Collaboration is the creation of new shared knowledge[94]. The collaboration takes place within a context. The context, the issue domain of the RW or the focal topic of a RW Essay, is what transforms information into knowledge. Sharing demonstrates a commitment to the common goal as opposed to personal interests. Sharing information and criticism are critical components of collaboration. Criticism is original contribution: the means by which consensus is reached or alternatives created.

Collaboration is a narrower term than cooperation. People who cooperate come to agreement on goals, but often proceed to those goals independently. Collaboration implies a close relationship and mutual responsibility for the products of their work[95].

2.2.4.6.1 Contribution of Content

Content is King, no matter if the site is a Research Web studying marriage among the Lesser Andaman Islanders or is a commercial site selling shoes. This mantra originated in teaching and is now well established among managers of WWW sites. The Research Web site is a collection of conscription devices[96] for all researchers studying the issue domain. If there is little content, or if the content is static, there is little incentive for returning to the site or for participating. There must be a critical mass of content as well as a critical mass of participants since a small number of participants cannot be expected to contribute at a uniformly high rate.

> *A positive correlation between interests and resources is highly favorable for collective action, as it increases the probability of there being a few highly interested and highly resourceful people who are willing and able to provide the good for everyone.* -- Oliver, Marwell, and Teixeira[97]

The success of the RW depends on universal access, universal adoption, and universal use[98]. Each member must possess the hardware and software necessary to make use of the RW. Each member must be willing to learn how to use the RW by browsing the WWW and becoming familiar with the contents and interactive tools of the RW. And finally, every member must use the RW by criticizing and contributing content, and by actively supporting its use.

Content for the Research Web comes through three mechanisms: commission, acquisition, and reader creation[99]. The RW depends on its members to provide content through all of these mechanisms. Authors of new materials contribute essays, position papers, and research reports in response to a commission. All team members can acquire content for the RW by contributing bibliographic references, and providing definitions of terms of the vocabulary of the dialog. As readers, the team members turn to criticism of essays, glossing definitions, engaging in e-mail dialog, and reviewing the references.

One early contribution expected from each member is a set of contributions, or perhaps a position paper, that summarizes the relationships of the issue domain to his or her discipline. Basically, this contribution makes the tacit knowledge of the member explicit and open to discussion by the other team members. Researchers engaged in interdisciplinary research projects, as the RW is likely to be, are likely to encourage each other to make the implicit explicit[100].

To hell with tacit knowledge. Go for tacit documents instead. — David Weinberger[101]

It is very important to remove barriers to the contribution of content. Contributors must not be burdened by needing to become facile in the technology of the WWW. A facilitator must be responsible for reformatting content for presentation on the RW. The contributor should be held responsible only for some representation of the content: word processor file, e-mail attachment, or even hardcopy. Software for direct contribution of commentary and annotation must be designed for novice use.

As one becomes known as a scientist by publishing science, so one becomes a collaborator by contributing content to the RW. Scholarly publications are basically any recorded document that can be accessed by other scholars interested in the topic; similarly, contributions are documents available to the members of the research team. Scholarly publication is a process that has a very restricted set of document genres, so the contributor cannot participate in scholarly publication as fully as one can contribute to the RW with its much fuller set of document genres.

Contributions are organized knowledge and information that include all publications and extend into ephemera such as lectures, performances, and conversation. Contributions of very special importance are documents that exist on the far boundary of conventional publication: criticism. Criticism in the form of reviews is firmly within the bounds of conventional publication, but letters to the editor are on the boundary, and direct criticism of documents such as might be directed to the author, or discussed in workshops or seminars is infrequent in conventional publication. Yet this criticism is the fuel of scientific progress and the hone that puts the edge on our canonical documents. The reward systems have considered authorship of research papers and books almost exclusively, and have not adequately accounted for smaller contributions, such as collaborative behavior and criticism[102].

Contributions may form the basis of valuation of collaborative effectiveness. The primary difficulties in establishing the value of a contribution are the vast range of the individual contribution and the difficulties in establishing a fungible unit of measurement. Rewards are based on the value of one's contribution. Since evaluation has a large subjective and even political component, it is clear that rewards are not always distributed equitably: how many revered teachers are Nobel Laureates? How many penetrating commentaries equal authorship of a paper? How many annotations does it take to earn an acknowledgment? And, how are acknowledgments valued in a tenure defense?

Commentary that expresses support or disagreement is not valueless, for such commentary does influence the behavior of the author and other contributors. So most commentary is of some value, even if it is merely reinforcing the recognition of a team effort. Sadly there are comments of negative worth that occasionally emerge, such as unwarranted attacks or senseless graffiti.

While valuation of contributions may appear to be a hopeless task, such is not the case. A skilled collaboration leader, if aided by evaluation tools can evaluate the collaborative performance by team members much better than an unaided novice leader. The collaborators and other team members can also contribute to the evaluation. Intangible bases of evaluation can be incorporated along with automated measurement tools, such as word counts, to develop a well-rounded, largely rational evaluation. This evaluation can be forwarded to the member's employers or can form the basis of letters of recommendation or nominations for awards.

2.2.4.6.2 Collaboration in Development of Content

> *The performance of cognitive tasks that exceed individual abilities is always shaped by a social organization of distributed cognition.* --- Edwin Hutchins [103]

In the Research Web environment, collaboration always results in the development of content. Content ranges from Research Web Essays on the high side, through critical commentary, e-mail communication, reports of meetings or phone calls, to the information gathered in the more tedious tasks of literature research. Certainly all content is not equal in importance, nor is all collaboration on a professional level. All members of the research team from principal investigators to data analysts contribute to the success of the RW, but the rewards and credit are dispensed in accordance with the nature of individual contributions.

The modern research environment is, for three principal reasons[104], a collaborative environment. First, the scope and quality of scholarship has advanced to the point where individual labor is insufficient. Second, collaboration provides credibility, especially for students and less well-known researchers. And finally, the times are right for creation of communities of specialized scholars, and for tightly defined interdisciplinary research topics. The means for collaboration are communication and resources, and the ends are knowledge expressed in documents.

A Research Web must, like all medium-to-large scale human enterprises, be managed. Management is responsible for maintaining an environment that fosters collaboration: all members need to be granted respect and rewards for what they contribute. All members should adhere to some standards of conduct, as participation is social interaction. In the Research Web, that social interaction is dialog, usually asynchronous. The goal of dialogic behavior in the RW is to attain the ideal speech situation proposed by Habermas and modified by Webler to incorporate competence and responsibility.

> *1. Every potential discourse participant must meet minimal societal standards for cognitive and lingual competence.*
> *2. Every discourse participant must have access to the knowledge needed to make validity claims and criticize others.*
> *3. Speakers must verify the results of any attempt to translate expressive claims.*
> *4. Judgments about conflicting validity claims must be made using the most reliable methodological techniques available.* --- Thomas Webler[105]

Pröpper's Model Procedure for Discussion[106] (Table II below) holds dialog on a professional level to an even more stringent standard. Keeping in mind that research may be viewed as an argumentation process[107], we can adopt a set of behavior elements designed to ensure professional dialog that includes the basis for translation of dialog into formal argumentation. The table below provides rules that not only will bring order into the dialog, but will also enable measurement of the quality of the dialog.

Table II

A Model Procedure for Discussion

1. A committed attitude

1.1 One is committed to the objective of the discussion.
1.2 One is committed to the things one has said and implied therewith
1.3 One is committed to the arguments being solid

2. Accountability

2.1 Every participant in a discussion supports his or her statements with the help of arguments, when other participants (may be expected to) demand this, unless he or she gives plausible reasons justifying a refusal.
2.2 When one doubts the arguments relating to the point of view of another participant in the discussion, one may only challenge these if one gives counterarguments.

3. Consistency
The participants in a discussion act and speak in a consistent way.

3.1 The participants in a discussion are not allowed to contradict themselves.
3.2 The participants in a discussion are consequent.

4. Relevancy

4.1 The arguments one gives, and the information accompanying them, must be relevant.
4.2 when making a statement that (apparently) does not refer to the statements and arguments which are the subject of the discussion, one has to state one's reasons for making this statement, if other participants (may be likely to) expect this.

5. Objectivity
The participants in a discussion adopt an objective attitude.

5.1 One is not allowed to prevaricate.
5.2 One is not allowed to ascribe to another person points of view that one does not support.
5.3 The points of view held must not be tendentious due to ambiguity.
5.4 The participants in a discussion are not allowed to present their own contribution(s) to the discussion tendentiously, by means of incorrect or incomplete information.

Table II (continued)

5.5 One should not become personal.

6. Openness

The participants in a discussion must see to it that the discussion is open to others and to their contributions.

6.1 It must be possible for everyone (to the same extent) to take part in the discussion.
6.2 The participants in a discussion are allowed to raise any point of view and advance any information they consider relevant for the defense or challenge of a certain point of view.
6.3 One is allowed to challenge any statement brought by another participant to the discussion to justify or refute the expression of an opinion.
6.4 The participants in a discussion are to provide as much information as necessary (for the aim of the discussion at that moment).

--- Igno Pröpper[108]

2.2.4.6.3 Collaboration for Labor-sharing

Labor sharing is necessary in any project that requires more than one person by virtue of its size, breadth of disciplinary scope or scheduling pressure. The lone scientist may very well find many projects beyond his means[109]. Research Webs are always of a size that requires labor sharing. Labor sharing applies to all professional tasks: authoring, researching, computing, designing of experiments, designing of statistical analysis, and above all, controlling the quality or validity of the products. Labor sharing is a form of delegation. The delegation of the work is under the control of a scientist who is managing part of the team's efforts. The delegation determines who does the work: the rewards for doing the work seem to flow from a combination of three mechanisms: professional recognition, pay for work and legitimate peripheral participation.

The use of research assistants is almost universal in large-scale research enterprises. Research assistants may perform library research at the direction of the project's scientists. Assistance in data gathering, coding, or analysis is often assigned to research assistants. Volunteer amateurs may perform field research under the direction of the investigators: archeology is the most frequently cited example, but paleontology and astronomy now use volunteer helpers.

Another form of labor sharing is the utilization of outside technical specialists. These specialists are not necessarily professionally competent in the issue domain, especially where non-traditional tools are employed in the research. Geographic information systems (GIS) are often employed in research in fields not usually associated with the use of GIS. Maienschein cites another example: in 1895 a cytologist was compiling a text on cell fertilization; at that time most illustration was done with artistic methods, but he called on an early microphotographer to provide illustrations of the early stages of cell fertilization[110].

Load sharing in the authoring of RW essays and research papers usually divides the product into sections based on the knowledge and interests of an author. Experiment design and statistical analysis may be shared among the members of the authoring team, and perhaps with other members of the RW team. Reviewing load is also shared among all members of the authoring team. Paper renderings, faxes, and /or DocReview can be employed depending on the quality of the draft. DocReview is especially useful for a "local peer review" where colleagues of the authors and RW members review the final draft before release for publication in the RW.

2.2.4.6.4 Collaboration for Credibility

In interdisciplinary projects representatives of each discipline will provide credibility for their specialty. When a proposal is submitted for an interdisciplinary project review committees can, without regard for the capabilities of the team, reject any proposal that does not have a "certified" member from each discipline[111]. Maienschein cites several examples where the demonstration of community led to increased credibility in the eyes of funding agencies due to a stated or implied compliance with the communitarianism of the Mertonian ethos of science[112].

2.2.4.6.5 Collaboration for Community

Collaboration serves several social functions[113]. For some, engaging the research process with others is simply more enjoyable than working alone. Pre-existing social contacts are maintained and improved through collaboration. Careers can be advanced by collaboration with leaders in one's field. Some perceive that the quality of research can be improved through joint participation[114]. Poole cites interdisciplinary work as a potential savior of thinly populated specialties[115].

In order to survive, every human system needs to reproduce itself. There is a constant turnover in personnel due to death, retirement, or changes in interests. Academic disciplines are a good example of a self-reproducing system, as they place an emphasis on creation of new professors. In the research community, there is a need to socialize new members of the community, and for established members, a need to reinforce the social bonds and professional ethos through collaborative practice. New members of the community (graduate students, post-doctoral fellows, interdisciplinary members of the RW team) are introduced to the operation of the research by a collaborative process[116]. This process is called legitimate peripheral participation.

Legitimate peripheral participation[117] permits the learner to participate in the work of an expert, under the tutelage of an expert, but without complete responsibility for the outcome of the work. Not only learning takes place, but also to some extent, an emotional bond is formed – to science, to the work, to the mentors, and to the team.

Types of social collaborative links

<u>Peer Similar</u>: professional to professional within the same discipline. These scholars may be drawn to participate in order to avoid isolation. Austin and Baldwin call this

collaboration "complementary collaboration[118]." This type of collaboration usually begins socially in the discussion of ideas. As soon as a kernel of a unique idea is formed the collaboration begins to take the form of a research project leading to authorship[119]. The most typical contribution of peer similar collaboration is in the professional dialog operating within existing projects. Peer similar relationships usually operate on the theoretical plane[120].

Peer Different: professional to professional between disciplines. This is a looser collaborative link, but often leads to the same reward as peer similar, authorship. Collaborations among specialists are termed "supplemental collaborations" by Austin and Baldwin[121]. They tend to be loose confederations with limited interdependency. Often the collaboration leads to a project in only one of the disciplines, the other discipline contributing only enrichment. Acknowledgment rather than authorship is often the reward in this case. Thagard points out that, as in peer similar collaborations, the relationships are more on the theoretical plane than the empirical[122]. Peer different collaboration also requires cross-disciplinary education. The RW contributes to this learning by encouraging each member to contribute an essay about the issue domain describing his or her discipline's relationship to the issue domain; in other words, making each member's tacit knowledge explicit and subject to criticism and query. The criticism offered by any scholar will bear the imprint of his or her discipline, offering another opportunity to see the point of view of that discipline.

Maienschein mentions another collaboration combining the two forms of peer collaboration: the Textbook Project[123]. A Research Web could easily be constituted to produce such an artifact, especially if the issue domain was multidisciplinary. A more general name for such collaboration might be the Encyclopedia approach. Collaboration becomes relatively less important than coordination under a single editor. Maienschien points out that the existence of multiple or interdisciplinary authors lends considerable credibility to the project. The RW environment also contains tools to facilitate the enterprise, especially the Annotated HyperGlossary and DocReview.

Professor-Student: Sharing the workload with a student leads to several beneficial results for both the project and the participants. The student can offer skills that are professional, sub-professional, or technical. The professor in this relationship clearly is bound to train the student while the student must contribute to the scientific progress of the team[124]. The mechanism whereby benefits flow both to the student and to the professor, and to the team as well, is legitimate peripheral participation.

Professional-Worker: Sharing the labor load with an employee leads to more speed and allows the professional staff to work more efficiently[125]. Work that can be done by anyone with similar skills needs not be accorded professional rewards[126]; pay alone is sufficient reward, though of course the worker may very well gain personal satisfaction from helping the team move toward its goals. Such collaboration may be called "subauthorship collaboration[127]" because it is usually rewarded by acknowledgment rather than authorship.

Action Research: When the research team is engaged in the solution of a practical problem or is participating in the improvement of an existing practice, such as land use planning, they are likely to be teamed with practitioners[128]. The feedback and reflection between theory and practice produces an enrichment of both theory and practice[129]. Problems of this sort are often described as "participatory" and usually involve intervention, on the part of the practitioners, in an ongoing process. Certainly in this sort of research work, there is an "extended peer community[130]."

"Standard" action research into a problem is practiced by looping through a cycle of fact finding, action planning, action and evaluation. McKay and Marshall suggest that the standard iteration pattern might be shadowed by a complementary research pattern that would provide the backing for action planning with a rigorous development of research questions, hypothesis development, data collection and analysis of results[131].

In terms of the conceptual framework of this dissertation, action research involves a rather radical methodological shift, but no great change in the substantive domain or the conceptual domain. It seems clear that the substantive domain would be much better served by the participation of those researched. The conceptual domain could also benefit from greater participation, though probably to a lesser extent. The methodological domain would be dominated by the research methodologies of participative action research (PAR). The principal impact of action research on the RW would be on the simulation model, if one exists. Since the purpose of action research is to change behavior, parts of a simulation model would be made obsolete every time action is taken to alter the behavior of those researched, the "reference group."

The prototypical Research Web is designed to serve a more conventional research team than an action research team. An RW designed to serve an action research team will need to include provisions for access of those "researched on," those "researched for," and stakeholders who may be affected as well as the researchers[132]. The RW could have facilities for conducting questionnaires and voting on the WWW. Certainly some more "democratic" facilities such as chat rooms and less structured discussion forums could be valuable.

2.2.4.6.6 Collaboration for Posterity

Collaboration for posterity is an underappreciated act. Frequently the foresight of past researchers enables future researchers to engage in longitudinal studies. The data collected in the past was frequently documented in ephemeral documents such as lab notebooks. With the constantly decreasing cost of memory, storage and maintenance of knowledge and data will soon be able to remain on a RW indefinitely. Death, retirement and loss of interest result in the loss of vast amounts of data, information and knowledge[133]; the RW can preserve most of this material.

Because many observations made in the course of research are far below the "minimum publishable unit" threshold, much data is lost forever. The nature of the Research Web is such that there is always room to save observations even though they become peripheral during the course of research. Like a good lab notebook, The RW can preserve false starts and blind alleys. Since all textual documents in the RW are in HTML, they may all be displayed in the browser. Even more important, they are all searchable as a body and individually. E-mail archives, DocReview commentary, RW Essays, all are visible.

The scholarly press has a bias against research that does not show significant statistical results, even though the research constitutes an affirmation of insignificance. In the past, results that were not "positive" were so unlikely to be published that the authors did not even submit them for publication. Fortunately, funding agencies such as the National Science Foundation now demand that data and reports from "inconclusive" research be made available. In the Research Web, there is a prominent place for such results. These studies can be made available not only for access to results and data, but to annotation from other scientists that might suggest alternative hypotheses or methods.

2.2.4.6.7 Collaboration through Criticism

The important place of criticism in science as a basic epistemological tool is very well established by scholars such as Popper and Polyani and is far beyond argument in this dissertation. For a philosophical discussion of the issue see Miller[134]. Criticism poses problems that stimulate research and open new directions and keeps researchers from becoming complacent. Criticism can support theory by showing the errors in competing explanations.

The best way to advance knowledge, it follows, is to foment a constant stream of criticism and response. — Marshall Scott Poole[135]

Critical social theory suggests that research include all those affected by the research. This call to collaboration also clearly states that criticism cannot be separated from reason[136]. Critical social theory also points clearly to the use of action research as a method for effecting change through inquiry. The Research Web concept is fully compatible with these ideas.

The Research Web is designed to promote criticism: of assertions in essays through DocReview; of definitions and glosses in the Annotated HyperGlossary; and of the quality of references in the Annotated HyperBibliography. Responses to the criticism may be made within the critical apparatus of the tools or by publishing new editions of the essays. As a matter of course, new editions should include a hypertext link to a "preface" that summarizes the changes made in the new edition. As criticism is received it is announced to the members automatically by notification services in DocReview and "What's New." Any e-mail dialog on a given topic can be extracted from searchable e-mail and discussion forum archives.

2.2.4.6.8 Mandated Collaboration

Granting agencies and other organizations that sponsor research often have political policies that mandate collaboration between researchers, disciplines, or organizations. During the 1920's the Rockefeller Foundation was instrumental in encouraging a collective, communitarian, attitude in science[137]. More recently the National Science Foundation has very explicitly sponsored collaboration in its grants[138]. NATO's Collaborative Linkage Grants require collaboration between scientist from NATO countries and certain specified countries in Northern Africa, the Middle East and the former Soviet Union[139].

In 1945 the United States created the Atomic Bomb Casualty Commission to study the health effects of the Hiroshima and Nagasaki bombs. The collaboration of Japanese professionals was essential to the project, yet the cooperation of the victims of atomic war was not going to be obtained without considerable political, sociological, and psychological manipulation. In short, the occupation authorities mandated the Japanese to collaborate[140].

Collaboration in an externally mandated collaboration is influenced by the formal position the scientific leader, PI or convener may have been invested with by the mandating agency. The participation of the members may be insured to some degree by what they might lose if they do not participate[141]. Internal mandates are also imposed by disciplinary practice or professional ethics[142]. Participants are also bound by the ethos of science and funding obligations.

2.2.4.7 Cooperation in Supporting the RW

Cooperation is the act of supporting first the objectives and operation of the RW and secondly, the support of the members of the team. The sources of support are either institutional or personal. Those with the means of production (land, labor and capital) must support the production of content. In our context, office space and a WWW site represent land. Labor includes the members of the research team and all their supporting staff. Labor must be rewarded for their efforts. While payment in intangible rewards is sufficient for those who spend little time on the research, salaries and office space must support those directly and seriously involved. Capital expenditures may be needed to purchase equipment or to hire consultants or special services, such as laboratory procedures. In University-based research these contributions are all delineated in the research proposal. For long-term collaborations, means other than grants must be assembled. Endowments may pay for laboratory operation, or for intellectual involvement. But for long-term, low budget research efforts, the leadership of the research team will depend on intangible rewards to the intellectual contributors and on the good will of cooperating institutions for facilities.

2.2.4.7.1 Institutional Support

Institutional support of the RW can be financial, persuasive through sponsorship or endorsement, or in the provision of resources. Members of the team may be supported with salaries or grants, lab and office equipment, offices, and privileges of use of facilities such as libraries and computing. Institutions benefit from support of successful Research Webs by gaining stature or fulfilling some institutional goals or mandated duties.

The distributed nature of the RW provides some unusual resource sharing opportunities. Software licenses are often granted to institutions without restriction to the number of users. If a team member is an employee of an institution that has a license for a specialized piece of software, the RW can utilize that institution's WWW server and the software license to support the RW. For example, one major feature of the RW is the e-mail discussion group or list server. The list server software supports the discussion group by distributing e-mail, and by maintaining archives of the team's e-mail that may be searched from the WWW. That list server can reside at any institution with a site license. Courtesy accounts may be provided to team members from other institutions in order to give them access to computing power and on-line journal access.

Institutional support for the members of the research team is excellent in most industrial enterprises. University supported grants, on the other hand, usually are awarded to individuals or very small groups for the purposes of generating narrowly focused scholarship that is usually monodisciplinary. Departmental support for scholars collaborating outside their department is often lacking, even to the extent that the time required for outside collaboration is expected to be done "on the scholar's own time[143]", or as a "night job[144]". Faculty rewards for working collaboratively on the WWW are few, even though in the opinion of some collaborative projects are where the future lies[145].

2.2.4.7.2 Personal Support

Personal support of the RW can be in the form of contribution of intellectual capital, criticism, resources, or endorsement. Personal support of team members can take the form of recommendations, tutoring, advice, assistance, or simple encouragement. Individuals benefit from support through association and acknowledgment, not to mention the considerable value of personal alliances.

Members should familiarize themselves with the resources available through their institutions. Often site licenses are available that can be used for the team's benefit through a member's institution. Members may have personal resources and abilities that can be applied to the team's efforts, for example the ability to compile programs in "exotic" languages, convert database formats, write programs, or create graphics.

There are three sources of personal support for team members: the scientific leader, the facilitator and each other. The scientific leader has a support role to play, one of assisting and encouraging the team members on a personal level. This sort of support is basic leadership and the ability to exercise such leadership is a basic qualification for the scientific leader. The facilitator is usually not a resource for scientific content, but should be able to help team members learn the methods required for effective asynchronous communication. This help should extend beyond teaching the use of the special tools such as DocReview and the Annotated HyperGlossary and HyperBibliography. The facilitator should be able to detect problems that a novice is experiencing and then tactfully assist the novice in learning even the most basic Internet skills. Before embarking on a mission of assistance, the facilitator should discuss the problem with the scientific leader so as to avoid potential "pride" problems. All members need to be aware of any adjustment problems anyone is having with asynchronous methods.

2.2.5 Barriers to Collaboration

> *... the greatest barriers to development of effective collaborations on the World Wide Web may revolve less around advances in the technology itself than around the institutional dynamics of higher education—human and organizational barriers that are more difficult to change.* --- Kenneth E. Foote[146]

2.2.5.1 Ownership

The commerce in ideas and services functions through exchange just as commerce in goods. Intellectual commerce is a great deal more complex than trading in goods. Just what are the objects of intellectual commerce? Who owns these objects? Who can own these objects?

Authorship of research papers and books belongs to those who wrote the work. Copyright generally is held by the author(s), though it may by contract be assigned to an employer or publisher, or to the RW if it is incorporated. Acknowledgment of contributors is the scholar's courtesy[147].

Models are almost always the work of the authors, but if not they should be cited and/or acknowledged. The diffuse 'ownership' of the models represents a serious threat to participation in the modeling process. As the organizing 'glue' of the RW web site, the models are communal property. The models, much more than products such as the Annotated HyperGlossary and HyperBibliography, are the products of the entire team. The RW Essays are the product of authoring teams, and the rewards will go primarily to the authoring team. Authoring teams, especially solo efforts, may be reluctant to contribute their submodels to the communally held models. Scholars that see no personal rewards from modeling may resent the granting of scarce resources to the construction and maintenance of the models. Short term thinking by authoring teams that choose to terminate their research efforts after the research has produced most or all the papers it is likely to inspire will result in damage to the modeling effort and also to the quality of the research articles by truncating the development of robustness (phase 3 of VNS. see §2.3.3.3).

Unpublished essays. substantive ideas. RW essays and annotations are owned by the author(s) on the byline. Copyright defaults to the author(s) by default. Common courtesy on the part of scholars demands that important ideas be attributed to the person who suggested them. Ideas may be cited by URL if expressed in e-mail. as personal communications, and/or mentioned in an acknowledgment section. In the RW. if annotations are made in DocReview. important critical contributions cannot only be attributed, but can be made available in full text. The RW records provide better provenance (URL) than the "personal communication" citation treatment usually given this material.

In the RW. maps. charts. graphs. photographs. other images not made by the authors can be attributed to the makers. Materials of this nature need not be attributed if done for hire. Due to the hypertextual nature of the RW. a sidebar may be made available that discusses the technical aspects of the image. including metadata. interpretive notes. and warnings. The maker may separately copyright images.

Software can be copyrighted and sometime patented. If done for hire. the sponsors may copyright it; otherwise the copyright belongs to the programmer. Certainly software critical to the research must be cited and/or acknowledged. Algorithms cannot be patented, but they can be acknowledged in the software code. With patents. the inventors of record are those who were responsible for the development. Acknowledgments are not made in the patent documentation. Ownership of patents is usually assigned.

It should be understood by all contributors that, unless otherwise stated, all commentary and email directed to the team's listserver is open to the team. If one does not wish to make any communication public, then normal communication channels are available for private use. In the normal functioning of any social group there are communications that need to be private. Constant resort to private communication within the research team is somewhat pathological. One function of the scientific leader is to lead reluctant members away from private communication of information that should be public. Not only is such communication an attack on the efficacy of the work of the team, but leads to the establishment of cliques within the team. There are significant psychological mechanisms in operation within the research team, such as the impostor syndrome, and evaluation anxiety[148].

Most documents mounted on the RW have a byline. The byline establishes the ownership of copyright of the document. The byline also establishes "ownership" of an idea within the team, if the document is substantive. Ideally, a white paper will establish a topic for a RW essay. The team's commentary of that white paper should give the author some idea of who might be co-authors. As soon as a publication is planned, the author(s) and scientific leader need to establish who are the authors and the order that their names are to appear on the publication. Authors may later wish to drop out, and others may be added.

Unless legally incorporated, the research team has no legal standing. The team members cannot jointly own any copyrights unless all members agree to jointly register copyright on those documents. Copyright automatically defaults to the authors listed on the byline. The models produced by the team are the embodiment of the long-term research into the issue domain as contrasted with the constituent topics that are the subject of essays produced by authoring teams. The models should be copyrighted to the entire team, past and present.

2.2.5.2 Copyright

At the time of writing copyright practice is in great flux, even anarchy. The law is far behind the times as it was largely drafted in the pre-internet age. We are not concerned with the obvious violations such as plagiarism, "mirroring," and unauthorized excerpting, but in the more subtle area of technical illegalities that are almost universally tolerated.

Copyright is extremely important to the Research Web, as it is likely to include copyrighted materials. The Annotated HyperBibliography is in violation of copyright law unless public availability of its abstracts is permitted by each of the abstract copyright holders. The Annotated HyperGlossary is likely to contain verbatim copies of dictionary definitions. Only a completely private RW can use the abstracts or definitions under "fair use" laws. The argument that a RW is closed to all but the research team is insufficient, as fair use is generally applicable to individual scholarship and teaching.

With the revolution now underway in scholarly publishing, copyright customs are being challenged by universities. For decades scholars have surrendered their copyright to journal publishers. Research reports produced by public funding have been ceded to publishers who then have the right to charge the public for copies of the reports that they have paid for with their taxes. Both the government and the Universities are beginning to question the status quo.

Publications arising from the RW cannot be mounted on the RW without permission of the copyright holder. This absurd situation can be easily resolved by obtaining the permission to publish on the RW prior to submission to the target journal. In the author's experience such permission has never been refused, as it is made clear that the document is a "highly augmented hypertext version of the research report that is likely to change frequently."

2.2.5.3 Tenure and Promotion

Academic rewards are, especially for junior faculty, focused on the tenure and promotion (T&P) process. These rewards are structured to serve the academic department and the college, not the scholar, students or state. T&P are to some degree determined by score-keeping formulae. The formulae are strongly entrenched for several reasons: custom, ease of administration, and (in the United States) the presence of a defensive strategy to avoid discrimination lawsuits. With a mixture of publication categories and quality weights, a basic score for scholarly research is computed and then merged with scores for public service (outreach) and teaching to determine the eligibility for tenure or promotion. The prevailing perception of the importance of research generally leads to the devaluation of other goals of the academic institutions[149].

Solo publications are, other things equal, usually rated above multi-author publications regardless of publication quality[150]. Review groups generally accord low value to being third or more down the author list[151]. While single-author publications may arise from the RW, most publications are multi-author efforts. Acknowledgments, almost obligatory in RW works, carry no weight whatsoever in most T&P formulae[152]. Ruhleder reports that in the humanities, though tool-building is a scholarly activity, "developing computer-based tools is not even on the list[153]." But the most corrosive barrier to collaboration erected by academic departments is the stricture to publish within the discipline and in the leading journals of the discipline[154,155]. Interdisciplinary work published outside the discipline's journals is somewhat deprecated in T&P formulae. The pressure on junior faculty to publish quickly and frequently tends to promote shallow work[156]. Due to the limited time available to build a winning tenure case, few junior faculty members have the inclination to risk becoming involved in groundbreaking work[157,158]. This sort of work is, of course, just the sort of work that usually requires interdisciplinary collaboration.

Collaboration itself is not valued by T&P formulations[159]. Building and maintaining collaborations on the WWW, or helping to build the necessary infrastructure are not often rewarded[160]. Bohen and Stiles are of the opinion that participation in collaborative enterprises are not usually factored into the scholar's workload, so such participation must be "night work[161]."

2.2.5.4 Institutional Barriers

Each discipline nuances the language used in its science[162,163]. Terminological problems are one of the easiest disciplinary constraints to overcome[164]. Understanding the meanings assigned by different disciplines can be a long process. The author sat through two hours of meetings with geographers, ecologists, statisticians, worker safety specialists, and toxicologists that discussed a single term—hazard. Interdisciplinary collaboration may also be constrained by disciplinary methodological biases[165166].

Journals, with the exception of the few major general journals, are designed to serve the needs of a single discipline. This can introduce barriers to publication of collaboratory and especially multidisciplinary research[167]. Journals may have a policy restricting multiple authorship, clearly penalizing collaborative work. Multidisciplinary research may be seen to not be "cutting edge" research, and publication of articles outside the discipline's dominant paradigm may threaten to lower the journal's prestige. Journals in sociology and psychology are "hard to crack" for scholars outside those disciplines[168].

In some disciplines, especially those in the humanities, scholars are socialized into a culture that customarily performs solitary research[169]. This isolation promotes secrecy and competition rather than openness and cooperation and collaboration[170]. This isolation and competitive environment pervades the scholar's life from primary school through undergraduate days in the form of competition for grades. The struggle for tenure is usually a solitary extension of graduate research designed to yield enough publications, preferably single author[171], to fulfill the requirements of the T&P formulae[172]. Isolation is augmented by the new scholar's socialization into the department, not into the college, discipline or the larger society[173].

Disciplinary boundaries are neither eternal nor eternally useful. — R.L. Kahn[174]

Damrosch uses the cultural myth of the isolated scholar to drive home his points regarding the corrosive effects of academic culture on collaborative activities[175]. He points out the natural tendency of the young to collaborate and the institutionally encouraged collaboration that pervades learning from elementary school through undergraduate education. Suddenly, upon entry into graduate school the student is forced into the isolated scholar role. Collaboration takes a new name—cheating. Should the student earn a professorial appointment upon being awarded the Ph.D., the six or eight years spent earning tenure reinforces the mold. The isolated scholar often develops a tendency toward secrecy rather than urges to collaborate. Accompanying the myth of the isolated scholar is another myth especially prevalent in the humanities and social sciences: that of mentalism. Mentalism proposes that all good ideas and the publications that come from them can only be the product of a single mind[176].

Collaboration has suffered greatly by academic policies that have sometime produced effects that act as barriers to collaboration. Colleges and academic departments have created and maintained rules and policies that serve their interests as administrative units and instruments of implementation of public mandates such as teaching, research and public service. Unfortunately, they are often not questioned due to their canonical nature. Drawing from official documents from their University, Ervin and Fox point out numerous policy statements, both subtle and frank, that discourage collaboration in both theory and practice[177].

Academic culture in the humanities works against student/professor collaboration in three ways[178]: grant funding is often meager, allowing no support for graduate students; research in the humanities does not lend itself easily to division of labor, in sharp contrast to the social and physical sciences; and finally there is a strong tradition of solitary research in the humanities, most scholars did not work with their advisors, so they seldom work with their own students.

2.2.5.5 Scholarly Competition

Since priority in publication is such a powerful prize, there is an understandable tendency to hide certain key pieces of information. Career advancement goals may become a disincentive to information sharing. Individuals sometimes lose sight of the team goals and press for incorporation of their own expertise into the team's research[179]. Brody suggests that scientists need an easy technique for making some components of their work publicly available while making key components available to a restricted group[180]. Such discrimination in information access is now available by depending on preprint distribution networks. In a RW, a public partition can be created for public information release, and restricted information can be secured by utilizing private e-mail or a passworded partition of the RW (the team partition).

2.2.5.6 Funding Mechanisms

Funding by governmental agencies dominates support for research. Unfortunately funding by these agencies tends to support narrowly drawn goals that can easily be achieved within a short time period. Reviewers for these agencies also frequently disallow the added expenses of sustained collaboration[181]. Short term goals and lack of support for collaboration doubly penalize research webs. Turning the RW's long-term large-scale outlook into a positive attribute is a challenge to the creative grant writer.

Committees of peers award grants, and these committees have topical biases. Jared Diamond points out disciplinary bias in grants awarded to researchers in mental disorders[182]. The National Institutes of Health award many grants for biochemical work, but only a few for 'talk therapy' despite the obvious success of counseling, for example. Fortunately for collaborative teams, there is a positive bias toward collaboration. So we see just what one would expect from a committee of peers: tendencies to select research that supports the dominant disciplinary dialog.

2.2.5.7 Human Culture

National character affects collaboration profoundly. The principal support for this proposition is the work of Geert Hofstede that investigated IBM employees throughout the world[183]. In a survey that produced around 117,000 answers, Hofstede found significant differences in cultural behaviors on four theoretical dimensions: power distance; uncertainty avoidance; individualism; and masculinity. Another dimension was added in 1984: Long Term Orientation/Short Term Orientation[184]. This dimension was found to differentiate Asian workers from the "western world", and was for a time referred to by Bond as "Confucian Dynamism".

National character is molded by the culture of that nation. For example, in the United States individualism is instilled into the children, especially males, of the society at an early age and reinforced by the national mythology. Collaboration and cooperation is also damaged by competitive customs represented in speech as Machiavellian clichés such as "Knowledge is power," and its corollaries "Don't volunteer information" and "Don't give anything away." The pervasive influence of Confucianism in Asia has been cited as an obstacle to the practice of science[185]. Confucian training teaches the student to accept the training of his masters, leading to a scientific inertia. Hsü describes an epiphany received when he found himself disbelieving physical evidence that passed before his eyes[186]. The evidence, drill cores, supported sea-floor spreading, the primary evidence supporting the then new theory of plate tectonics; that theory was in conflict with the teachings of his professors. Within a given pluralistic nation, religious and ethnic communities, and class differences create a mosaic of attitudes affecting collaboration. For instance, in British Columbia, some native North Americans practice "information bartering[187]". Asking a question is likely to be met with evasion unless some information is offered. Harvey, in comparing Geographic Information System installations in the USA and Germany, attributes the Germanic propensity for regulation to Hofstede's observation that Germanic cultures exhibit high risk avoidance[188].

Bantz isolates four empirical difference factors that affect intercultural interaction, all embedded in communicative patterns: Language, Cultural Norms, Status, and Politics[189]. Arguments have been put forward that occupation is a greater determinant of behavior than nationality[190] but Hofstede's data is based on behavior in a corporate culture that is a classic of conformance. I certainly would accept the degree of conformance in the international scholarly community somewhat greater than in the corporate culture of IBM. Heaton points out that occupational culture and national culture are distinct and interrelated[191]. Kurland and Egan suggest that engaging in dialog on the Internet requires a culture of accountability[192]. I do expect to see cultural differences affecting the work of Research Webs very significantly.

Bantz suggested some resolutions to the four empirical difference factors. His tactics for dealing with the language facility differential are designed for synchronous communications situations, but include one very usable in asynchronous communication: restating concepts in native languages[193]. Such restatement could find a natural place in a DocReview of a document. "Off-line" conversations between bilingual members and a member that may have language difficulties would be most helpful. Members should be sensitive to language differentials and should avoid colloquialisms and metaphors that may not convey meaning to non-native speakers. The Cultural Norm of work norms[194] does not have as great an impact on asynchronous proceedings as it does on synchronous environments. Nevertheless, all members should be forthcoming about when they work and when they rest. Tactics for managing Status Differences[195] are centered about making every member aware of the status of all the members and how that status might affect group communication. Fortunately asynchronous communication reduces the effects of status differential.

There is also the very important question of the differential behavior between synchronous and asynchronous social interaction. The absence of turn-taking conflict in asynchronous interaction certainly must blunt the power of status. It has been shown that e-mail weakens the power of social status[196]. The ability to reflect at length on one's communication and the communication of others certainly reduces the power of the native reader over non-native readers: this in stark contrast to the power of native speakers in face-to-face argument[197].

Conflict resolution presents major problems. Cultures that have a high level of respect for authority may abdicate their positions in the face of high status. Bantz observes that the behavior of members who are open and direct may introduce social difficulties when interacting with members who are oblique and indirect[198]. DeMente points out several ways how Japanese salarymen defer to authority and to the group[199]. In the Arab culture language use is marked by indirectness and elaborateness that may frustrate those from Anglo-European cultures[200].

The cultures of the communicants are important because the cultures determine the weekly cycle of activity and modify that cycle by mandating holidays determined by local religions, regional customs and national histories. The culture of the communicants also modifies the diurnal cycle by setting the length of the workday and by inserting customs such as extended mid-day mealtimes. The physical location of the communicants is important because human beings synchronize their activities to the position of the sun in the local sky. So the physical geography of synchronous communication largely determines the diurnal cycle of the collaborators, and its human geography studies the cultural modification of the diurnal cycle, the weekly cycle of the business activity and the annual cultural cycle of holidays.

2.3 A Methodology for Framing a Collaborative Research Process

The purpose of this section is to show how the Research Web (RW) can facilitate most aspects of the research process. To do this we must bring some order to the bewildering diversity of research as practiced. The VNS (Validity Network Schema)[201] provides a complete general description of process flow for an idealized research project. It is this ideal research project that we use to demonstrate the utility of the RW.

The VNS. a multi-perspective framework for understanding the inner nature of the research process, is one of the three foundation concepts in the conceptual framework for this dissertation. Below we will examine how the Research Web environment can facilitate the research effort from the VNS perspectives of: *stages*. or the temporal progress of the research: *paths*. or the conduct of research leading to a specific product: and *domains*, the basic epistemic thrust of the researchers.

2.3.1 VNS: An abstraction of an ideal research process

Research in practice is approached from a bewildering array of models. Each discipline has its own models for reports. and its own set of preferred models. a recipe. Research by recipe takes the researcher's mind away from the meaning of the research and replaces it with a set of tasks. VNS. in its ethereal abstraction, leads the research team to results by method rather than by task performance. VNS is well suited to any size of research team since the conduct of research must suit the behavioral nature of the individual team members. Unless the team is composed of "renaissance scholars." less knowledgable persons must join hands with others to explore each of the several approaches to the research. VNS depends on knowledge building from multiple points of view. and the RW organizes that knowledge.

The ideal research team needs three kinds of knowledge specialists: theoreticians, empiricists, and methodologists. Each of the team members is expected to team with members from the other specialties in order to produce new knowledge, or products. The interdisciplinary nature of many research issues suggests that scholars from disciplines outside the primary discipline can contribute to the knowledge building[202 203]. There are a number of functional roles to be fulfilled in the RW. These roles can last for the lifetime of the RW, a facilitator is always needed to reduce the cognitive load on the researchers; or they might be of short duration, as the need for a very specialized statistician for analysis of experimental results. The team members can move between roles, or researchers may serve on the team for the duration of only a well-defined task. While the RW is not a management scheme, it is an organizational shell flexible enough to adapt to changes in leadership, retirement, loss of interest, and other perturbations.

One role is pervasive: the role of collaborator. Every researcher must be, or become, a collaborator. Colleagues from other disciplines may be asked to participate, as a contributor or collaborator, in information gathering, evaluation of products, or document review. The role of author will persist only for the time needed to produce the document or research report. Authors of research essays may be asked to manage a team of contributing authors, and then be responsible for hosting a collaborative dialog leading to a succession of refining editions of the essay. The role of scientific leader (PI) may rotate, or may be shared. The role of facilitator is tangential to the research goals, but must be filled with a person, or persons, who have an interest in the research topic, and above all a willingness to serve the research team. The facilitator should teach members of the team how to use software that they might find useful. The facilitator should also train his or her replacement well in advance of departure. The role of critic is essential to maintain the quality of the RW. Criticism of essays is the engine of refinement. No document, reference or definition is exempt from criticism.

Due to the size of the RW team and the large volume of information and knowledge brought to bear on the research issue, there is a correspondingly large body of organized knowledge produced. The body of knowledge, the RW repository, can be easily used to develop multiple hypotheses, and thus will ultimately produce a stream of research results until the issue domain is well known. The RW is thus seen as an incubator of issue specific research. From this set of facts springs the necessity of long-term research. If the issue domain is dynamic, the RW might usefully persist for more than a lifetime.

The VNS applies throughout the range of RW applications between the small-scale single paper collaborations and the very large scale confederations of research efforts such as The Cochrane Collaboration[204], a very large organization devoted to meta-analyses of evidence-based medical studies, and the NCGIA (National Center for Geographic Information and Analysis), an incubator for diverse research efforts. Small-scale collaborations cannot afford the overhead involved in the RW, and confederations suffer from a low level of interdependency, a quality essential to participation[205]. Note that large-scale research confederations can include a set of independent RWs joined by a Web site that describes the purpose and emergent qualities of the confederation and provides an introduction and index into the Research Webs where the work is done.

2.3.2 The Research Domains

VNS divides all the knowledge and research effort in the issue domain into three domains: conceptual, substantive, and methodological. Each of these three domains attracts researchers with a preferential point of view, either theoretician, empiricist or methodologist, respectively. Of course no scholar can avoid taking part in all three points of view in the work toward an advanced degree. Still the preference remains, part of the personality that frequently becomes a hallmark of the scholar's reputation.

2.3.2.1 The Substantive Domain

The substantive domain contains a body of existing knowledge and new research designed to capture the observed nature of the objects and processes of the issue domain, the focal topic of a research project. It is the reality of the issue domain that exists prior to our research[206] and is the grounding for the theory and methodology, such as EAST2[207], that we might apply to our research. New observations made during the research will also find its way into the substantive domain. The substantive domain cannot simply be a repository of isolated information about the issue domain. It is so large that it needs to be indexed and organized. The organization is the function of the descriptive model. The descriptive model will describe all the objects in the issue domain and all the observed processes.

Empiricists work in the substantive domain. These researchers are primarily interested in discovering and describing the workings of some part of the issue domain. Their work includes the minute detail that others with a more grand view disparage as "stamp collecting," forgetting that grand visions are based on collections of observations. I think of naturalists like Linnaeus and Nikko Tinbergen, and the early astronomers such as Tycho Brahe and Charles Messier who built great catalogs as stereotypical empiricists: the observers, measurers, classifiers and catalogers. Brinberg and McGrath[208] add to that the system specialists and practitioners, perhaps the people that Funtowicz and Ravetz[209] call the "extended peer community," and those Donald Schön describes as professionals in his work on reflective practice[210]. This large group of people would include engineers, planners, nurses, educators, social workers and many other experts.

2.3.2.2 The Conceptual Domain

The conceptual domain abstracts the objects and processes of the focal topic, as described in the substantive domain. This abstraction characterizes the nature of the observed relationships and attempts to provide a causal explanation of why the issue domain works as it does. Each of those causal relationships, or mechanisms, becomes a hypothesis. The emergent explanations constitute the development of theory.

Theoreticians work in the conceptual domain. Basic science is practiced in this domain. Geographers such as Christaller and Lösch created central place theory in geography, and Wegener, a meteorologist, created the concept of "continental drift" that eventually became the theory of plate tectonics. The conceptual domain acts as a hypothesis mill, always turning up new research questions to examine by experiment. While scholarship is needed and practiced in all three domains, interest in the conceptual domain characterizes most scholars.

Theory can be appropriated as well as developed. A theory, EAST (Enhanced Adaptive Structuration Theory), was developed in 1996 to explain collaborative use of Geographic Information Systems for complex decision support processes[211]. EAST was then appropriated for a larger study in a more comprehensive study of participative GIS[212], and evolved into EAST2. Whether theory be appropriated or developed, new patterns from the substantive domain need to be incorporated into the conceptual domain. New patterns can lead to confirmation of theory, to extension of theory, or to correction of theory.

2.3.2.3 The Methodological Domain

The methodological domain contains all information regarding the treatment of the data gathered to support the study of a hypothesis. It will contain information regarding the operationalization of measurements, the measurement protocols, and the techniques to be employed to analyze the data to support or reject hypotheses. The nature of the variables, the operationalization chosen, and their relationships will determine the mode of treatment[213]. Very loosely, this can be referred to as the basis of research design[214].

Methodologists such as statisticians and experimentalists dominate the methodological domain. In the social sciences, measurement of a studied variable often requires selection of a surrogate that can be directly measured. These decisions, known as operationalization, comprise the auxiliary model[215], a model of the system that is actually measured. The RW documents the auxiliary model by making hypertextual links between descriptions of the operationalizations and the model of the system as described in the descriptive model and the explanatory models. The RW will contain several documents that describe the design of the experiment, the operationalization of variables and the analysis plan. The team members can place these documents in DocReview for local peer review.

The RW may, in mature sites, contain a simulation model of the issue domain. A simulation model can be started when the descriptive and explanatory models are sufficiently complete. The simulation model can be used for validation of the explanatory model. Since a simulation model is hierarchical, completed and validated submodels of the system may be published or placed on the RW's web site to be executed by anyone. A working simulation model will allow the research team to perform sensitivity analyses on the variables of the model. The sensitivity analysis will determine which variables contribute most to the variance of model output. Sensitivity analysis can also be used to evaluate determination of the relevance of mechanisms of submodels, in other words, can determine if certain elements can be removed from the model. The team can run scenarios that can examine unobserved situations and create plans for experiments to refine the model.

2.3.3 The Stages

VNS suggests that research studies have three stages: stage 1, a prestudy, or proposal phase; stage 2, a central research effort; and stage 3, making the research findings more robust. Stage 1 has well defined milestones to mark its progress: the proposal, receipt of funding, and completion of a research plan. Stage 2 has less conclusive milestones; research papers might be released during and after the central study. Stage 3 involves further generalization, limitation, reduction of uncertainty, or corroboration; it is actually never closed, though activity may be slight and publications few.

In research studies, activity in every stage is potentially perpetual, as information will continue to accrue (stage 1 or 2); study proposals will be made (stage 1) and executed (stage 2) for each line of research that might produce results; and corroborating or generalizing studies may be undertaken at any time to increase the validity and reliability of completed research (stage 3).

As one considers how the work of research is done in the VNS stages, the advantages of the RW will become apparent. One of the greatest advantages of a RW is that due to its size, the diversity of interests of the team members will be high, including methodologists, theoreticians and empirical researchers. Staffing levels may reach the point that there is a semi-permanent cadre of trained research assistants that may serve several research projects. Since a RW is organized around a rich issue domain, there can be a stream of research projects passing through, providing research positions for the diverse team. Once operating under full power, the RW will always provide research of interest to any specialty or research orientation.

The RW concept includes several repositories that can store and organize data, information and knowledge both new and old. Research Web Essays can describe the objects and processes of the issue domain. Annotated HyperBibliographies (AHB) can store references in an interactive annotatable format; and Annotated HyperGlossaries (AHG) can do the same for the vocabulary of the issue domain. Annotatable models make theory accessible to criticism at even the finest level. DocReview is the critical apparatus for most of the documents produced by the research team.

2.3.3.1 Stage 1

Stage 1 activity in a research project includes all activity from convening a research team to the completion of a research plan. Conducting research from within a Research Web provides enormous advantages. Convening a team is easier since members of the RW team are already interested and involved, perhaps only a few new members need be recruited. Gathering information is easier since there is already a knowledge base in place and the means to add new information is present in the RW infrastructure. Preparation of models of the project's focal topic is easier since a mature RW has models of the issue domain already in place.

The team is convened.

The initiators of the research initiative must first gather the core of the research team. What attracts researchers to a team? First, of course the problem itself, then the other team members, funding, and finally, how the team is to operate. The RW, with its infrastructure in place, can be a force in attracting members, especially members committed to collaboration. If the conveners have a paper outlining the nature of the research issue and the proposed products of the collaboration, then that paper can be presented as a Research Web Essay on RW web site. The invited scholars can mount this position paper in DocReview for annotation. This initial dialog not only informs, but also can be instrumental in setting the stage for the direction of the proposal.

The conveners can put other items on the RW that will inform and perhaps attract other scholars from their networks of scholars: personal web pages, and position papers outlining their personal connection with the proposed research issue. This material will show that the conveners are legitimate, have the power to attract funding and can provide an effective environment for collaboration[216]. The personal web pages should include the CV, but should also go beyond that to show how the research issue fits with their ongoing research interests.

Presenting the earliest efforts as a RW can show prospective collaborators that the conveners already have a collaborative environment in place. With a modest effort, all the web site and collaborative software can be put in place and a facilitator recruited. The content will naturally accumulate as conveners and new members present their thoughts in position papers. An Annotated HyperBibliography can be started with the works cited in the convener's position papers and the initial description of the research issue. Similarly, an Annotated HyperGlossary can be populated with the basic vocabulary of the issue domain. The facilitator and graduate assistants can perform these services.

Nothing succeeds like success, and a RW that is up and running is an impressive start. A section of the RW can be devoted to the description of the RW concept and how it will serve the research team. The RW, by its collaborative nature, is a powerful and demonstrable tool and may favorably influence the decision of the granting agency. In the event that the proposal fails, the work remains and can be revised and extended to make a better argument in the future. The RW can also function as a recruiting device to draw in new talent.

Data, information and knowledge are accumulated.

The research team will need to gather all data, information and knowledge relevant to the project's focal topic. While much basic material will naturally accumulate in the RW, what is most important is a plan for acquiring all the needed material. Part of that plan is building repositories for references (AHB), vocabulary (AHG) and organizing the knowledge (RW Essays). The descriptive model accumulates materials in VNS stage 1. Explanatory models may be initiated in stage 1, but will be finally realized late in stage 2. One of the greatest benefits of the RW is that the models, descriptive, explanatory and simulation, apply not only to the research project, but also to the entire issue domain.

Preliminary research hypotheses are developed.

The proposal must present some initial hypothesis in order to argue for funding. The research plan or proposal that the stage 1 team produces can suggest some hypotheses which are certain to be investigated.

The proposal or study plan is written.

The document is the RW's fundamental unit of knowledge representation. A proposal is a formalized document, a genre whose format is specified by the audience. A working copy of the proposal may be mounted on the RW site and made annotatable with DocReview. In that format every member of the team, and administrators from the department or college, may review and annotate the proposal at any time.

Putting the proposal in electronic format suitable for display on the WWW has a number of advantages. If the proposal states that it is available on the WWW, some referees might be inclined to access it on the web, and thus be tempted to explore links that effectively extend the page length restrictions of the proposal. Of course a web presentation can be much more attractive than a black and white laser print. Links to an

Annotated HyperBibliography or Annotated HyperGlossary might serve to demonstrate the effective use of modern technology by the team's conveners.

The RW web site is organized.

The RW web site's working area needs to be organized during the stage one. The organization should be patterned after one or more organizing principle. For research issues that have a strong locational principle, maps can be the organizing principle. Research issues that are dominated by a process should be organized around a diagram of the process. Some research issues are strongly organized by time, such as a history: for these organization by timeline is useful. Some research issues are strongly hierarchical as are some organizations, or classifications of organisms. These organizing principles will eventually become the foundations of the models describing and explaining the issue domain. The standardized infrastructure of the RW web site is discussed below in §3.5.2

It is very important to avoid structuring the RW site around artificial organization. The organizing principles must come from the issue domain, not around the team members or their institutions. If the team is multidisciplinary, the purpose of the RW is to bring the disciplinary material together: the disciplinary material should not divide the issue domain. Artificial boundaries divide and encourage parochialism.

2.3.3.2 Stage 2

Stage 2 is the central stage of the research effort. Knowledge of the issue domain is built by work directed toward three products. These three empirical products are: a set of hypotheses[217], a set of observations[218] and a study design[219]. Hypotheses will, along with the descriptive model, form the basis for the explanatory model. Observations will contribute directly to the descriptive model. Study designs will result in research experiments that will be used to support the research papers, or perhaps to become research papers on their own.

VNS provides several methods to help the research team insure that the research process produces complete coverage of the project's focal topic. In this stage, the principal method is called the matching process. This process is a collaborative process that compares patterns that emerge from three complementary points of view within the team. The patterns come from studying the issue while progressing along three different paths, discussed below. The congruence of patterns between these paths shows validity of the research by correspondence.

Essays and research papers are written.

Essays may be produced on any topic by the authoring teams or by individuals. Elements of the models, either objects or processes, will be described in *empirical* essays. Elements of the descriptive model may be fully described in essays that will then become targets for criticism by the research team and assembly points for further knowledge about the element. In a similar manner, hypotheses will become part of essays about the elements of the explanatory model. And perhaps when the research process is fairly mature, essays may, by operationalizing the descriptive and explanatory models, display the knowledge about the elements of a simulation model.

As knowledge grows, a set of *synthetic* essays will emerge. These essays will draw their knowledge base from the empirical essays on the elements of the models. They are the basis of published research papers. It is important to retain a working copy of the essay because it remains the definitive research document. If a research study is developed that shows promise for becoming an experimental protocol that might be repeated with other data, then a *methodological* essay will be a very useful, and publishable, product.

Modeling continues.

In stage 2 the descriptive model is largely completed. The explanatory model becomes the focus of theory-building for the research team. The simulation model may be started, though it will come into use only in stage three.

The information repositories are populated.

As the research progresses in stage 2, additional research literature will be identified. The vocabulary of the issue domain will emerge with alternative meanings and glosses. Glosses and alternative meanings will be quite common in interdisciplinary research projects. Experimental protocols, data (both raw data and reduced data), and metadata from the experiments need to be stored. Increasingly, granting agencies are insisting on the sharing of data. The National Science Foundation "expects PIs to share with other researchers, at no more than incremental cost and within a reasonable time, the data, samples, physical collections and other supporting materials created or gathered in the course of the work[220]."

2.2.3.3 Stage 3

> *Rather than spend[ing] valuable (and limited) resources generating new (and equally uncertain) information concerning the same focal problems, we urge researchers to spend more of their future time and effort pursuing robustness analysis as a means for reducing the uncertainty associated with the findings they already have.* --- Brinberg and McGrath[221]

Stage 3 is a mature state where the objectives of the team are to extend, generalize, and explore the limits of the issue domain. Reduction of uncertainty of the stage 2 results is the goal of stage 3 research. Uncertainty is reduced by three mechanisms: replication, convergence, and boundary search. Replication demonstrates the reliability of the results using the same methods. Convergence, or triangulation, uses maximally different experimental methods to demonstrate the robustness of the findings. Boundary search, or differentiation attempts to show some of the conditions that will produce results not explained by the theory.

Brinberg and McGrath make a strong case for Stage 3 research[222], pointing out that most research reports describe stage 2 studies and leave the difficult work of generalization to "future research." This future research is seldom done because one cannot build a reputation on replication of research. Certainly the value of determining the boundaries of theory and the building of robustness must be examined. Boundaries and nuances can be explored indefinitely, but certainly there are practical limits to the exploration. Senior researchers should design stage 3 studies, but can delegate the more routine work of execution. Given the importance of the socialization of students and junior researchers, some stage 3 studies might be assigned as exercises in legitimate peripheral participation. Certainly a well-conceived and executed series of studies that contribute to the robustness of the original published stage 2 findings would be publishable.

The stage 3 research is likely to add valuable detail to the descriptive and exploratory models. This sharpening of the empirical description of the issue domain and the theory of its operation is very important feedback that will be incorporated in the RW Essays as they are refined beyond the snapshot bounds of the published reports.

The simulation model can incorporate the stage 3 findings of boundaries. This information will improve the behavior of the model, perhaps to the point where the model can be used to develop hypotheses to chart the boundaries of the theory. Since studies are expensive, finding the best places to test will save resources. A well-developed simulation model can support uncertainty analysis and sensitivity analysis. As the goal of stage 3 research is the reduction of uncertainty, the simulation model is an essential prerequisite for the analyses that can accomplish uncertainty reduction.

2.3.4 The Study Paths

A Research Web will have a team that is capable of combining in many research projects, each potentially leading to research papers, as well as the larger collaboration to study the entire issue domain. VNS assumes that scholars prefer to work in one of the three broad areas of empirical description (empiricists), theory construction (theoreticians), or methodological examination (methodologists). VNS suggests that, in order to create the empirical products of the stage, the team engage in collaborations that combine empiricists, theoreticians and methodologists by pairing the interests to proceed along one of three paths, the *experimental*, the *theoretical* or the *empirical*, each leading to a different research product: a study plan, a set of hypotheses, and a set of observations.

As with all facets of the VNS, the flexibility of the schema neither demands nor precludes any form of team configuration, from one member to many. When I speak of a collaborator, I mean a person, or persons, acting in a role. In the social sciences, it is not unusual to have a single person acting in the roles of empiricist, theoretician and methodologist. More commonly, two people will share the three roles, and, of course, several people may share a single role.

2.4 Technology to Support Communication

Communication technologies fall into two pairs of categories: synchronous or asynchronous, and digital or analog (hardcopy). The research team is free to choose the technologies that suit its members. When choices are made, the communicator needs to consider the ability of the communication to be shared and the ability to be indexed and searched. Most of the older analog technologies are difficult to share (telephone calls, letters, conversations) and generally cannot be easily indexed and searched. Digital communication media are easy to share, copy, and search.

Most computer-mediated communication is asynchronous and digital, hence easy to share and search. Synchronous communication media have a special problem: recording. While analog copies may be made (tapes, CDs, etc.), the recordings are difficult to use and almost impossible to search. Conversations are an important and critical media; those that have content important to the team need to be transcribed to a digital format and summarized for asynchronous use.

2.4.1 Communication Modes

Communication is the glue that holds together all human social activity. In order to understand communication's importance to collaboration, we must investigate the communication process. The object of communication is to transfer a set of symbols, information, from one human mind to another. The elements of a model of communication contain five elements: the source, the transmitter, the channel (with its noise), the receiver, and the destination[223].

Problems in communication begin with the source. Human sources have limitations in their ability to formulate the communication. Does the person who is the source have knowledge of the symbols necessary to formulate the message? Often not. But is communication is necessary, and the source does the best it can. The human source also may consider its target and compose the message in symbols the target is likely to understand.

Transmission of the formulated symbolic message has a set of problems as well. The set of transmitters available to the source may be limited. If the source is mute, it cannot speak. If a person speaks, the symbols may not be well articulated or heavily accented. If the source is not equipped with suitable technology, it cannot write, or keyboard.

The communication channel may not be available, or it may degrade the message with noise. The Research Web depends on the Internet for its communication channel. The

Internet has essentially no noise, but is subject to variable rates of delivery and infrequent interruption of service. For speech, the air in the immediate environment is the communication channel. It is severely degraded with noise in some situations, such as large crowded lecture halls, or at social gatherings. Telephone channels are usually noise free, but are incapable of reproducing high frequency sound, thus persons with voices in higher ranges may be at a disadvantage.

An adequate receiver for the communication channel may not be available at the destination. The RW requires the availability of a WWW-capable workstation, with a display screen capable of rendering high-resolution graphics. FAX transmits only unacceptably low-resolution graphics and requires a special machine. Low-resolution cameras often used for synchronous teleconferencing cannot transmit either text of graphics, only faces or scenes.

The destination has difficulties just as does the source. Disabilities in hearing or in vision limit the ability of the destination from receiving information. Fortunately, the web browsers have the capability of displaying text in a user-selected size consistent with the reader's visual acuity. Language is often a problem, especially with speech. Some people who do not use English as their spoken language much prefer text for communication in English[224]. " ... foreign scientists occasionally had difficulties understanding oral English and considered text to be preferable, ...". They can reflect on the context of the text message, or consult translating dictionaries.

All these communication problems, as well as many psychological and sociological problems, are of great importance when designing and operating a Research Web collaboration. The systemic effects of synchronicity of asynchronicity dominate the utility of methods of communication. This section examines, with respect to the RW, the systemic advantages and disadvantages of both synchronous and asynchronous communication. Technology also has effects on utility, especially capacity and the ability of existing software to realize the potential of the communications methods. There are detailed examinations of the application of the major methods of communication within the RW environment.

Gaines has provided a model of the temporal structure of Internet communication[225]. There are four times involved in this model: the origination time (t1)-- the time from conception to becoming available to the recipient; the discovery time (t2) -- the time it takes the recipient to discover the message; the response time (t3) -- time taken to read, understand, prepare and send a response; and finally the response discovery time (t4) -- the time it takes the originator to discover the response. Many of the differences between communication modes are made clear by an analysis in Gaines' terms. This model shows the continuum of temporal behavior between synchronous and asynchronous communication and publication. Clearly reduction of the four temporal technological barriers will improve the efficiency of any communication. Such reductions should be implemented in any design or design revision to the tools of discourse.

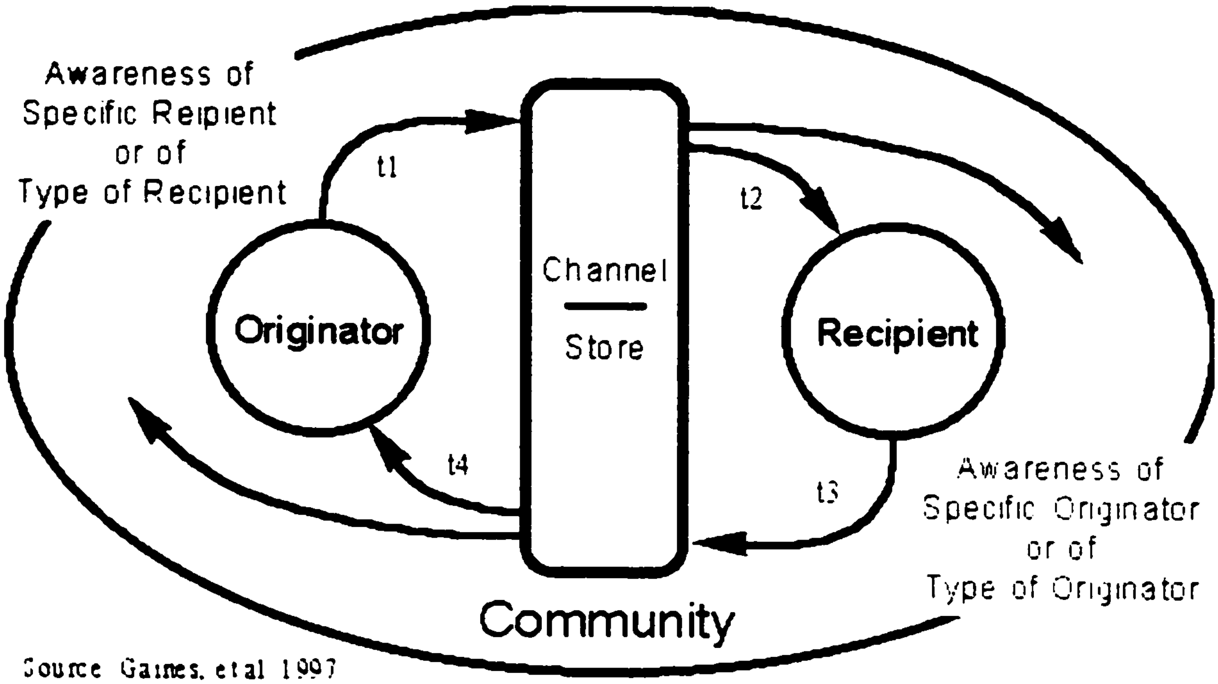


Figure III Punctuated Communication

T1 is the time that elapses between the time that the originator perceives the need to communicate and the time it takes for a message conveying the originator's thoughts to a place where the recipient(s) may receive it. I decompose t1 into three microcomponents: mental processes of the originator (t1a), including formulation of thoughts, reflection on those formulations, and consideration of alternatives: composition of the message (t1b), including selection of words, assembling the argument, and entering the message into the means of communication; and finally reflection, correction and transmission (t1c). T1a is inaccessible to RW technology, except that the RW makes the entire dialog about the issue domain accessible, perhaps assisting in message formulation. T1b can be improved by the use of alternative message entry. Some members may find voice recognition software useful. Use of a modern mailer program with spell checking will improve the quality of the message. T1c can be improved by selecting the fastest means of message transmission to the pickup point. E-mail can be quite slow compared to WWW page loading, so if the pickup point can be moved to a file that can be accessed by the WWW, T1c can be markedly improved. Many of the RW tools place communications directly into WWW files.

T2 is the time between delivery to the pickup point and the time that the recipient finds it. Bringing the recipient to the pickup point when the message arrives is the problem. Simply waiting for the recipient to call is the slowest method, and may actually prevent receipt of the message. Remember that the e-mail queue is not the only pickup point! Newsgroups are pickup points; the RW has many pickup points for annotations, essentially the web page of the document that is annotated. In the RW, as currently implemented, What'sNew (see §4.7) is a query facility that points the user to all pickup points for messages that have been issued in a certain time period. DocReview, the Annotated HyperBibliography and the Annotated HyperGlossary attempt to shorten the time to pickup by reminding the recipient of activity by e-mail notification. While this is an improvement over simply casting out the messages to the pickup point, things could be better. We are all familiar with "You Have Mail" and beeps when new mail is put in our inboxes; such instant (and hopefully unobtrusive) notification for all RW activity is a future design goal.

T3 and t4 are simply reiterations of t1 and t2. These temporal components are included in the model simply to illustrate "round trip" dialog. The RW does not often have this sort of conversational dialog; in Gaines' terms the RW is World Wide Web publication. t3 and t4 come into play in synchronous dialog.

2.4.1.1 The Time/Place Collaboration Matrix

Communication between humans may be classified in a two-by-two matrix based on time and place. The time values are "same time" and "different time", or synchronous and asynchronous. The place values are "same place" and "different place", or collocated and distributed. Collocated collaboration is by far the most common form of collaboration in business and classroom, due to the longstanding emphasis on the group in business and educational organizations. Distributed collaboration is a very common form of scientific collaboration, especially in academia.

The asynchronous distributed category contains the communication media most suited to the Research Web concept. While synchronous methods are deprecated, they certainly are not forbidden -- conversation is far too valuable to be discouraged. Collocation exists on several scales: in this work, collocation is considered face-to-face, not just at the same institution or city. Collocation is seldom universal in large teams, especially in academia.

Table III below is a compilation of classifications of communication media from several sources.[226,227,228,229]

Table III Collaboration Modes in Place and Time

	Same Time	Different Time
Same Place	**Conventional Meeting**	**Storyboard Meeting**
	Advantages:	*Advantages:*
	• face-to-face expressions • immediate response • helps building community	• scheduling is easy • respond anytime • leave-behind note
	Disadvantages:	*Disadvantages:*
	• scheduling is difficult • very high cost • power effects • frequent lack of record • isolates those unable to attend	• meeting takes longer
Different Place	**Conference call type meeting, Electronic Conferencing**	**Distributed meeting**
	Advantages:	*Advantages:*
	• no need to travel long distances • immediate response	• scheduling is convenient • no need to travel • submit response anytime • permanent record • reduced power effects
	Disadvantages:	*Disadvantages:*
	• meeting protocols are difficult to interpret to maintain meeting dynamics • limited personal perspective from participants • power effects • Turn-taking rules unclear	• meeting dynamics are different from normal meeting (a new "netiquette") • meeting is never over. lack of milestones • difficult to make decisions • what does non-response mean?

This space/time typology is rather primitive in its treatment of time. Most of the works cited above are discussed in a more technical treatise[230] that considers time in much more detail. using additional terms such as real-time. and concurrent. In their work. they define seven different meanings of synchronous. What is temporally important for our purposes is whether people must communicate information in scheduled session, or may communicate any time they wish.

Asynchronous distributed collaboration is collaboration among persons in different locations and/or at different times (see Table III above). This mode of collaboration is not popular for several reasons: first much of the technology that enables this sort of collaboration is new, hence not well understood or universally trusted; second, the software necessary to facilitate asynchronous collaboration is still primitive because, unsurprisingly, the intensely market-driven software industry is serving the perceived needs of conventional management by automating current methods rather than innovating; and finally, the current accepted model for collaboration is same time, same place - a well known comfortable, conventional, social activity. Each of the four spatio-temporal modes of collaboration have advantages and disadvantages[231,232,233], these need to be compared and contrasted in order to understand how they might all be brought to support collaboration in research within the issue domain.

This research is directed to the study and development of asynchronous distributed collaboration. My concentration on this mode of collaboration has been influenced by the general neglect of research in asynchronous distributed collaboration in favor of synchronous collocated collaboration, the most familiar mode of collaboration. Business and the academy have honed the tools supporting conventional synchronous collaboration to such a fine point that this form of collaboration has become culturally and economically accepted as the default collaborative behavior.

Realistically, asynchronous distributed collaboration must be facilitated by integration with the Internet, especially the WWW. While the tools employed must be designed to operate on the Internet, the real challenge is to not only facilitate collaboration, but to fully engage the collaborators to such a degree that the tools become genres of communication and information dissemination.[234,235,236,237,238]

Those wishing to categorize the myriad software programs offered to support collaborative applications can utilize a typology that extends the time-place matrix along another dimension: modality[239]. Modality is the combination of communication channels used -- document, audio, and video. This taxonomy is extensible. Nickerson's example includes nine types of collaborative application, but it cannot be universal since software necessarily is targeted toward the functional intentions of the collaborators. DocReview, for instance would be an application type called Document Annotation, a type not found in Nickerson's published typology.

Web-based tools are based on several simple core protocols that have collectively enabled the Internet revolution. These protocols are reliable software commodities that have two major advantages: they are free, and they are stable. Commercial companies are at a competitive disadvantage because they must charge for their products. To create competitive advantages they load minor enhancements on top of the capabilities of the commodities[240]. They are then able to market the products as "improvements" and at the same time undermine the strength of the protocols. Unfortunately, this marketing strategy works. The results are that there are many relatively inexperienced managers and users that accept the "more is better" philosophy. If these people consider how much training time is required to learn how to use these bloated products, perhaps they would see the advantages of simplicity.

Developers can resist these strategies by keeping their products simple and easy to learn. Complexity may be hidden by linking to more advanced features. The facile may become curious and investigate capabilities beyond the basic set. The tools developed for the RW adhere to the concept of hiding complexity and to the solid simple core of existing protocols.

2.4.1.2 Synchronous modes

The most amazing thing about synchronous communication is how *limiting* it is! Every synchronous method revolves about the concept of meeting person to person. Technology has freed us to some extent by allowing us to communicate over distance by telephone and then by television and ultimately, over the Internet. Yet the synchronous methods are, for some purposes, vastly superior to asynchronous means. Fortunately, we understand those purposes well, having used them personally from childhood and, as a society, since speech developed. What are the bases of the frequent superiority of synchronous communication? Rapid negotiation of meaning allows us to plan and learn. Speed of communication allows us to interact rapidly. Ease of communication in face-to-face encounters is undoubtedly the greatest advantage of synchronous communication. For purposes of social bonding, the maintenance of strong ties[241], and ceremony[242], synchronicity and collocation are essential. Temporary person-to-person contact, such as conferences or even phone calls, is often sufficient to maintain ties. Transfer of tacit or poorly expressed knowledge seems to be best accomplished with the strong social ties[243].

Given these advantages, what are the disadvantages? Time, space, power, and permanence. The principal problem is the very practical problem of coming together in time. Scheduling meeting times requires negotiation, unless done by decree. Disruption of personal planning schedules introduces psychological and economic costs. Though being together in time has been made less an onerous task due to the telephone and the Internet, travel is still often necessary to be together in space, be it a walk down the hallway or an intercontinental plane trip. Power effects are present, though often subtle. Synchronous communication always involves turn taking, and turns are controlled by power relationships. Certainly some power effects are positive, especially when decisions must be made. Yet when contributions are sought, power can stifle participation by triggering evaluation anxiety. The recording of synchronous communication is an immense problem. Most synchronous communication is never recorded. Transcriptions of meetings are extremely expensive and often almost impossible to read. Minutes are seldom accurate and never complete. Audio recordings are difficult to understand without personal knowledge of the speakers. Graphic images from whiteboards are almost never recorded in minutes.

The social effects of synchronous communication on team integrity are very important. Team research depends on unrestricted sharing of information. If the team has a geographically isolated individual, it is important for the better-connected members to keep the isolated member informed about any synchronous communications that have occurred within the synchronously connected group. Failure to recognize the vulnerability of the isolated individual is very likely to result in the withdrawal of that member. In a distributed team with multiperson nodes, meetings at each node seem to be inevitable. Failure to share the proceedings of such meetings destroys the integrity of the team. Meetings are the natural enemy of distributed teams -- they should be avoided whenever possible, and recorded and shared whenever they do occur. The socio-psychological phenomena of *the outsider* and *us versus them* exist to some extent in all human organizations.

2.4.1.3 Asynchronous modes

While synchronous communication is based on speech acts, asynchronous communication is based on message passing. The message is recorded with a device on some medium, is transported by some mechanism, and is then displayed by another device, or in the case of physical messages, often read directly. In most communication, the devices are computer workstations, the medium is electronic and the transport mechanism is the Internet. The address is usually a computer with e-mail software.

Messages can be sent at any time to anyone or in e-mail, to a group known at the destination address. The sender must compose the message carefully since there is no possibility of quickly negotiating the meaning of the message (though the workstation might complain about spelling and grammar). The time it takes to transmit the message on the Internet is almost negligible. With postal messaging the transmission time is measured in days to weeks. The recipient may pick up the message in seconds, or leave the message idle for weeks. In the RW some messages are posted on the RW's web site and the recipients are notified by e-mail that a message waits. Notification of "messages waiting" and changes in the intellectual content of the RW is an important issue.

Only information can be transmitted on the Internet. Uses remain for asynchronous methods such as postal services to transmit physical items. Voice mail and phone answering machines are useful for very time-sensitive messages. Legal documents requiring signatures are still bound to physical documents, though that is changing rapidly. Large datasets are still transmitted by CD-ROM and tape, but both those applications will soon be shifted to electronic means as technology improves.

The change from atoms to bits is irrevocable and unstoppable.
— Nicholas Negroponte[244]

2.4.2 Computer-Mediated Communication

Computer-mediated communication (CMC) is communication that has, regardless of source, been transformed into a potentially permanent digital record. All communication in a RW is CMC. Because the contents of the RW are all CMC recorded in digital format, they are permanent and may be recalled at any time. In addition to being permanent, they may also be modified. Modification must, of course, be managed responsibly.

CMC can be divided into two major categories with enormously different properties: synchronous, which takes place nearly simultaneously; and asynchronous, which is stored on receipt by the computer, and served up to the client later, or on request. Gaines has provided a model of the temporal structure of Internet communication[245]. In practice almost all CMC is asynchronous because the inevitable delays caused by transmission, storage and forwarding are disruptive to the smooth flow of communication seen in synchronous communication. At best, synchronous CMC approaches the jerky character of a long-distance phone call that uses satellite links.

The important differences between synchronous and asynchronous CMC lie not so much in their behavior, but in their psychological, sociological and institutional effects. The RW deprecates synchronous communication because such communication usually goes unrecorded. Similarly it has little use for synchronous CMC because of scheduling difficulties and a decidedly anti-democratic power differential.

It is important to note that the RW does not preclude the use of conventional communication media, synchronous or asynchronous -- it simply insists that the members have the discipline to record those communications in digital format. Meeting minutes and memoranda of communication summarizing important conversations have a very important role to play in the RW. If an important finding is shared between two individuals, the proper way to manage such a message is to send a message to the entire team, thus not only informing every member, but also placing the finding in the permanent searchable message archives.

The principal advantages of asynchronous communication are the temporal decoupling of communicants and the permanent recording of every message. The principal disadvantage is the need to carefully compose the message, an act that takes considerable time when compared to speech. Careful composition is essential because the recipient does not have recourse to rapid verification of his understanding of the terms used and the thrust of the message. The advantage lies with the recipients who are not interrupted by the arrival of synchronous communication, and have time to reflect on the message before replying. The "democratic" nature of e-mail burdens the powerful that now may find it necessary to compose a message on the keyboard instead of using the telephone.

2.4.2.1 Dialog

Dialog is the heart of collaboration. Dialog within a group assumes that there is a common ground, in our context a shared interest in the issue domain of the Research Web. The group attempts to accumulate knowledge by adding to the common ground through contributions. The principal means of adding to the common ground is unilateral action; contributing the right utterance at the right time[246].

Since the beginning of human communication, the building of shared understanding has been enabled by dialog. Before writing, conversation and story telling were the means of sharing knowledge. These forms of dialog are synchronous, and continue in use today. The introduction of writing, and its industrial counterpart, printing, introduced asynchronous dialog. When writing began to record knowledge, the first recorded dialogues were marginal notes to religious texts, and recorded dialogs and debates. In modern times, technology has introduced new media for both synchronous and asynchronous dialog.

Modern synchronous methods basically augment speech while asynchronous methods augment writing. Dialog in either of these families of media depends on interactivity. While interactivity in speech is as old as the human race, interactivity with asynchronous methods is relatively new, beginning with message passing and industrialized with the initiation of modern postal services. Synchronous methods of communication have been a constant target of technology and have recently been epitomized by broadband teleconferencing. The introduction of the Internet and services such as the WWW has produced a vast improvement in asynchronous methods, now providing speed that rivals synchronous methods at near-vanishing monetary cost.

We examine now the different natures of dialog in synchronous and asynchronous methods. Natural dialog, or face-to-face speech in pairs or small groups, is characterized by several social conventions: presentation, acceptance, evidence of understanding, and turn taking[247]. We can differentiate synchronous and asynchronous dialog by taking a close look at each of these conventions.

Presentation is the initial contribution by one of the team members. In speech, this is usually a sentence and seldom more than a paragraph, a set of a few related sentences. In the RW, presentation is usually longer, from an e-mail message of a few sentences to a complete essay of several thousand words. The reason for such a vast range of sizes is that the contributions of the team are submitted *en Toto* as a complete argument for the consideration of the team members. This mode of contribution is necessary because piecewise acceptance is impossible in asynchronous communication. Also speech is generally conducted in pairs or small groups while asynchronous communication in the RW is always a one or few-to-many transaction. Dialog in very large cognitive chunks can best be effective when the presentation is permanently recorded so working memory is not overwhelmed.

Presentation in speech is impaired by clarity of speech, ambient noise, and poor hearing[248]. From a theoretical communication standpoint much of speech and written communication share equally in problems of symbol selection and interpretation[249] (encoding, decoding) since words are symbols common to both. Written presentations have a much lower susceptibility to errors of transmission. While speech is aided by inflection and gesture, writing may also be inflected with alternative character fonts or underlining. Since speech is ephemeral, understanding diminishes with time; writing does not have that problem as the reader can return to reflect on the words. The issue of size of the contribution presented is more difficult. Speech is a serial process, while presentation of a large written contribution is a parallel process that presents several propositions at the same time. Readers can select from these propositions in a parallel manner by screening and then evaluate the selected proposition in a serial manner by reading.

Acceptance is the process of ensuring understanding between communicants. In speech, the turnaround time is very short, so a constant stream of presentations and acceptances can be interchanged efficiently. Among communicants known to each other, gestures often serve effectively as acceptance. Should acceptance be refused, repair transactions will be initiated immediately. In asynchronous communication, gestures are absent and turnaround time is highly variable and often long, so alternation of presentation and acceptance is impossible. Asynchronous collaboration in the RW depends on three mechanisms to monitor acceptance of a contribution: first, implied acceptance; second, the existence of a common language; and finally, responsibility of members to review contributions.

Acceptance in asynchronous presentation is implied by silence. Note that there is no conditional acceptance by silence; any response, other than praise, is a request to modify or clarify the presentation. Implicit acceptance is, however, not unequivocal because people are usually reluctant to challenge statements unless they are easily refuted. When it is important to be certain of approval, poll the team[250].

The existence of a common language is assumed in both speech and writing; but the RW has the advantage of having an integral glossary of terms. In a series of speech dialogs the meaning of a term can drift, because the context of each meeting is different. The asynchronous dialog in the RW has an interactive glossary so the team can have a recorded dialog about any term.

Reviewing presentations is required both in speech and in asynchronous presentation, but this process is subject to many more damaging power effects in speech. Review (as acceptance) requires evaluation, criticism, and sometimes the admission of ignorance. Face-to-face criticism, especially in a group situation is difficult for many people. It is widely held that power effects are diminished in asynchronous communication[251,252,253,254]. In an asynchronous situation, the reviewer has the opportunity to communicate off the record with peers or with the presenter, thus avoiding embarrassment. Review responsibility is implied in speech, but is more explicit in review of asynchronous contributions. Hiding disinterest behind nods of acceptance is common in speech; but its equivalent in asynchronous dialog, silence, is almost an admission of inattention. This is so because in large asynchronous contributions, there is obviously little likelihood of total concurrence.

In speech the commonest form of contribution is turn taking. Each turn is a collective act consisting of two participatory phases: presentation and acceptance. The median length of these contributions is 9 to 13 words[255]. Each turn adds to the common ground. Obviously, turns must be taken in a synchronous mode with very short pauses between phases. Turn taking in this sense is clearly impossible in an asynchronous environment.

So, what is the equivalent to a turn in the asynchronous environment of the Research Web? Another speech act is the assertion, which is an autonomous act, not a participatory act. Assertions, *unless rejected*, become part of the common ground. Thus in the asynchronous environment, turns consist of assertions (autonomous contributions) in written form, and the frequently lengthy exchanges of commentary (participatory contributions) required to repair the original assertion. In the Research Web, most contributions are understood to be plastic, and each contribution, or work object, has an owner who is responsible for making repairs based on commentary. Contributions in the RW are all autonomous, and vary in size from a complete RW Essay down to a brief comment attached to an assertion.

The apparently different natures of synchronous and asynchronous dialog are resolved by having a common end: adding to the common ground. Synchronous dialog quickly adds to common ground in very small units. Asynchronous dialog adds to the common ground either rapidly or slowly depending on the size of the assertion. Adding a reference to the Annotated HyperBibliography is unlikely to require repair, so adds to the common ground quickly; on the other hand, asynchronous dialog on a large RW Essay may last the life of the RW effort.

2.4.2.2 Criticism

> *"... Critiques pose problems and puzzles that have the potential to stimulate pathbreaking research. Critiques suggest novel directions and let newcomers know that there is a place for them in the solution of current problems. Critiques keep researchers from becoming complacent. ... The best way to advance knowledge, it follows, is to foment a constant stream of criticism and response. ..."*
>
> --- Marshall Scott Poole[256]

Critical annotation of documents is a practice fundamental to scholarly activity. Popper has argued that criticism is the basis of rationality in science[257]. Miller, in his book on critical rationalism, suggests that all science be accepted, if falsifiable, until it is proven false[258]. Justificationism, on the other hand, suggests that the better approach is to justify the hypotheses before the science is accepted. This is the approach taken by the RW, that criticism is a positive force for construction of science from the very beginning of work.

Critical social theory [of Horkheimer, Adorno, Fromm, and Marcuse] states that reason and critique are inseparable, and that researchers using this approach must collaborate with those affected by the research and must open the research to public debate and critical reflection[259]. The RW fulfills these requirements and also opens the way to action science through participative design and execution. Action research has been practiced with the RW's tools through the collaborative development of a metadata collection system[260].

Criticism can take substantial forms such as disagreement, clarifications, alternative explanations, and addition of information; or trivial forms such as grammatical or orthographical corrections. In the RW, all knowledge presented is in the form of a document, and the major documents all have a critical apparatus, or means of criticizing. RW Essays and other lengthy documents such as position papers and informative introductions may be presented in DocReview (see §4.3). The Annotated HyperBibliography and Annotated HyperGlossary have built in annotation capabilities for each entry.

The environment that encompasses the Research Web and the team must support the concepts of fairness and competence in order to ensure that criticism can operate properly. The Ideal Speech Situation (see Table IV, below) described by Habermas as modified by Webler fulfills the conditions of fairness and competence required for the RW[261]. Webler's rules are designed for public participation and are therefore designed for a less elite membership. See the author's notes for application to the RW environment.

Table IV Criticism Insured by the Competent Ideal Speech Situation

Rule	Fairness	Competence
1. Every potential discourse participant must meet minimal societal standards for cognitive and linguistic competence	Anyone may participate (a)	Minimal standards for cognitive and lingual competence (b)
2. Every discourse participant must have access to the knowledge needed to make validity claims and criticize others'.	Assert validity claims (c)	Access to the knowledge (d)
3. Speakers must verify the results of any attempt to translate expressive claims.	Challenge validity claims (e)	Consensually-approved translation scheme (f)
4. Judgments about conflicting validity claims must be made using the most reliable methodological techniques available.	Influence final determinations of validity (g)	Most reliable methodological techniques available (h)

— from Webler 1995[262]

Author's notes applying the situation to the Research Web environment
(a) Anyone on the research team plus invited guests.
(b) Standards must be relaxed to allow participation of junior members.
(c) A major responsibility. If research is viewed as argumentation, then validity must be established.
(d) Every part of the team RW must be open (exception is authoring team working areas). Tacit knowledge should be made explicit.
(e) See (c).
(f) Members may query any other member to clarify a document.
(g) This condition is met by leaving all documents open to criticism.
(h) Support software should be improved by participatory design.

Each member of the research team has the duty to review and criticize every document that lies within the member's area of interest. The member is expected to be responsible for the accuracy of the commentary, and should provide references to literature where known. Criticism should be attributed to the critic as a matter of responsibility. In asynchronous dialog, presentations are assertions; and criticism of assertions is the participatory mechanism that provides information to repair the presentation. The owner of the presentation is charged with editing the presentation from time to time and representing it as a new assertion. This cycle of presentation, criticism, editing and representation is the engine of refinement of the assertions that constitute the common ground of the research team.

2.5 A Conceptual Framework for Research Collaboration

The conceptual framework (see figure IV, below) has three mutually supporting legs: the first is the philosophy of realism, which provides the backing for the use of models in theory building. The second leg is the methodology of the VNS that, with its tripartite domain organization, provides a practical locus for the models proposed by realism. The third leg of the conceptual framework is the Research Web, the interactive environment that provides a home for models that realism proposes, and the support for the activities of the three domains of the VNS methodology. The Research Web, examined in detail in Chapter 4, is the repository for all team documents and the knowledgebase that the team assembles. The Research Web enables several fundamental functions in document management including criticism and successive refinement.

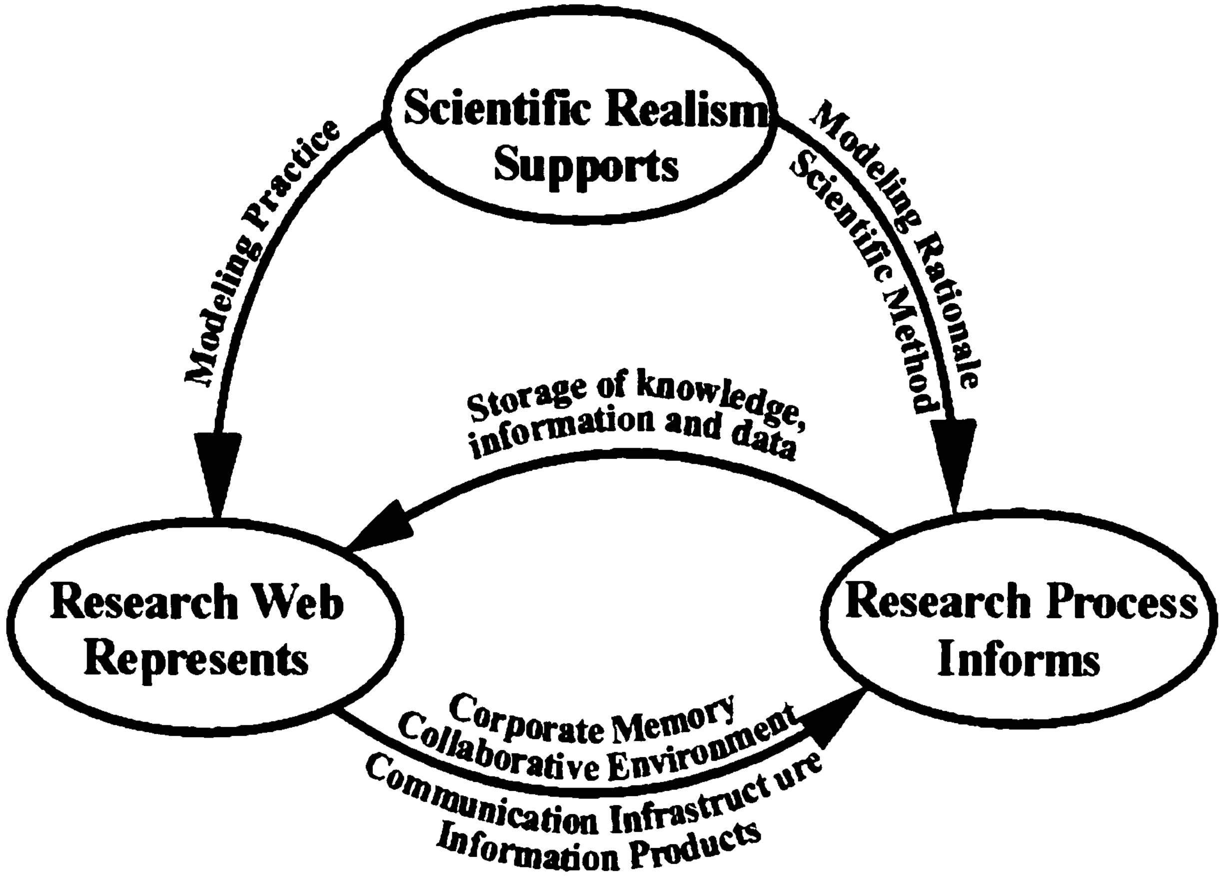


Figure IV Conceptual Framework

Notes to Chapter 2

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Chapter 3 --- The Research Web

The Research Web (RW) is a social, intellectual, and technological structure devoted to collaborative study of a single-issue domain. The research team uses a set of WWW-based programs designed as a basic tool set for collaboration within the prototypical research project: a widely dispersed, large-scale, long-term scientific collaborative research project. The selection of the WWW as a vehicle for collaboration follows substantial projects of large corporations, for instance NYNEX[1]. Since the universal characteristic is WWW compatibility, additional tools can be added at will to suit the needs of the individual Research Web. The basic tool set of the RW consists of: augmented hypertextual essays, the Research Web Essays; an integrated bibliographic information service, the Annotated HyperBibliography; and an integrated lexicographic tool, the Annotated HyperGlossary. These three productions, plus the tools that support them give the team a means to develop knowledge that is available at a click, and is all annotatable.

The work in this dissertation was begun very early in the history of the WWW[2] and the tools can expect to be eclipsed by new products in time. An example of services that are being created is the CrossRef initiative, designed to facilitate online interpublisher linking of article references to their full texts[3]. As a creation of a consortium of publishers, CrossRef is designed to augment their own online journals, not private creations. When mature and largely freed of excessive commercial interest, the tools developed by this initiative may migrate to the scholarly community; and can be expected to replace the HyperBibliography, but the annotation feature will likely never be incorporated into CrossRef tools. Keeping the team's criticism private and accessible will likely be the one of the last features added in large-scale development for collaborative software. The RW's critical apparatus is likely to be the lasting legacy of this work.

3.1 The Concept

The Research Web (RW) is the central concept in this research. The RW can present information and conclusions in a way that cannot be done in conventional literature. A Research Web is the electronic embodiment of the intellectual capital of the network of excellence which develops about an issue domain, the phenomenon being investigated. It is both a social organization and a WWW site that disseminates information, provides communication facilities and an infrastructure for collaborative interaction. A RW can be viewed as a domain-specific information repository (§3.2.2) and a network of communication channels connecting the collaborators and perhaps sponsors, stakeholders and interested members of the public. This view is compatible with the model of science as a distributed artificial intelligence network. Thagard[4,5] considers scientists to be nodes in a network connected by communication links. Other links connect the nodes with information repositories (research articles, journals, libraries, web sites). The entire scientific enterprise can be seen as a dense network of scientists (active nodes) and recorded knowledge (passive nodes). The links between the nodes of this network are directional, dynamic and of variable strength. The membership can vary as interests wax and wane or death intervenes, but the cyber-place remains with its knowledge base intact and growing. Ideas, hypotheses, findings, discussions and publications are spun out of the Research Web as portions of the issue domain are transformed into well-structured problems.

A RW network of collaborators adds a layer of specialized interconnection to the existing scientific network. The existing 'web of science' is largely composed of links that are socially frail, weak links[6], consisting of awareness and occasional short-term communication. Strong links, links of deep collaboration and friendship, are usually restricted to a small set of single paper collaborators, or to spatially collocated scholars at the same University or department. A RW strengthens existing communication links, usually weak links, or creates direct linkages, strong links, where none existed before. The tools associated with the RW promote interaction and facilitate additions and refinements to the knowledge repository of the RW web site. Since the RW is freely available to the research team, it also strengthens the scientific knowledge and intellectual power of the nodes, the individual scientists. It has been found that once a strong tie exists, it can be sustained through computer-mediated communication[7].

Recognition of a problem creates a need to define the system containing the problem, the issue domain. The issue domain is the body of knowledge, given and earned, together with landmarks and possible gaps, surrounding the problem that initiated the research effort. The goal of the RW is to develop comprehensive knowledge about the issue domain. The issue domain has physical, spatial, temporal and cultural components. Knowledge about the issue domain necessarily must precede problem understanding, structuring, and solution. In order to understand the issue itself, and to provide knowledge sufficient to solve the problem, significant research and exposition is necessary. The exposition takes the form of essays that are placed in an information repository. The essays may initially be taken from position statements, but will evolve into canonical documents presenting the knowledge of the research team and their intellectual support. The RW will have a library of literature representing new knowledge and representations of existing literature, bibliographies of relevant literature with annotations on that literature, databases, and models of the issue domain and its components. The research web will augment the institutional memory of the collaboration by permanently recording essays by the participants, building models, recording the dialog, and maintaining a corporate bibliography and glossary.

The character of the collaborative environment created by the RW is marked by opportunity to access all research materials, and to interact with most research material through critical annotation. Access and opportunity to interact are available anytime from any modestly equipped workstation. All dialog except private e-mail is recorded and indexed, as it almost always adds value by increasing the depth of knowledge. Informal communication among the team members is enabled by e-mail and a team listserver. The listserver is a mailing list with a searchable archive. Tools suitable for these components are widely available. Though the mode of interaction is primarily asynchronous, there are provisions to capture synchronous meetings and dialog in the form of meeting minutes and telephone conversation records. Capture of the synchronous record is the weakest part of the system as it depends on members taking the time to transcribe dialog from speech to text.

3.1.1 Defining the Issue Domain

All inquiries must have a beginning. The thought is articulated by a champion and then elaborated by a core group of researchers who come together to create a proposal. For them the proposal has two purposes, first to gather researchers to support the effort, and second to attract other scholars to the research effort. This core, the conveners, establishes, legitimizes, and guides the collaborative alliance[8]. Here, proposal means: a document that explains what the topic of the research is, the scope, purposes, and organization.

Such a proposal may not be a formal proposal submitted to a funding agency, but may be a manifesto presented to professional colleagues. The purpose of this proposal is to gather support. The support needed is the promise of collaboration from colleagues, the promise of cooperation from organizations that can provide resources such as money, labor, and facilities. Grant proposals to fund discrete detailed research efforts may be coordinated by the conveners or an executive committee. Such grant proposals must include some support for the RW, perhaps as management overhead.

Some proposals and grants assemble rather loosely associated groups together under an umbrella title under the assumption that each group's research will inform the others. In practice such taxonomic collectives[9] (united by classification only) almost never come together in meaningful collaboration. The Consortium for Risk Evaluation with Stakeholder Participation (CRESP) is an example of this type of organization. This large organization, funded by the Department of Energy, has operated from 1994 to the present. Originally, it established eight separate task groups that were interdisciplinary and distributed in space. While each of the task groups produced scholarly products. the mandated collaboration between groups was almost totally absent. Such groups need to establish a Web site for the umbrella organization, which may be responsible for generating reports and maintaining a public WWW presence. This web site can refer to Research Webs established for each of the substantive groups. Each group should have an independent RW with its own issue domain.

Like any human artifact. the issue domain must be designed. There are two critical aspects of this design: circumscription and conceptualization. Circumscription defines the scope of the Research Web. If the scope is too large. then the efforts will be too diffuse to gather a critical mass of researchers around related projects[10]. If too small. then the intellectual content will soon be exhausted. It is best to err on the side of a smaller than optimum scope. as the scope can easily be enlarged.

The process of issue domain circumscription is realized in modeling as a process of simplification and resolution. making the usually fuzzy boundary better defined. The process of issue domain circumscription is realized in modeling as a process of simplification and resolution. making the usually fuzzy boundary better defined. Simplification is a process of distinguishing parts of the topic. defining them and their relationship to the core domain. If the distinguished parts are not essential to the core issue domain. then they may be severed from the issue domain[11]. This severance defines a portion of the boundary of the issue domain. The organizing principle may be further clarified by the production of a context diagram that shows the boundaries of the issue domain. Logically. this operation is the differentiation of types within a supertype[12]. The process of simplification does *not* include the dismissal of minor contributions to complexity: it consists of a careful paring away of entire regions of investigation that lie outside to the issue domain.

Conceptualization of the issue domain is the process of identifying topics within the issue domain boundary. The property of interdependency must be maintained so the team collaborates on the basis of clear relationships rather than vague associations. Management may coordinate these tasks to maintain interdependence as portions of the domain become known territory. New topics may be added as objects and processes are discovered, provided they meet the requirement of interdependence. Topics that expand on previously identified topics are clearly related in a "drilling down" descent into detail.

The design of the issue domain will be revised as research progresses. Finding and describing the fuzzy boundaries of the issue domain is an ongoing exercise carried out in several ways: arguments carried on in regard to the qualitative models can carry a philosophical component; the simulation model can be used for probing boundaries by examining the sensitivity of the model to variables; and entire areas of issue domains may be severed and abandoned, or may be assigned to RWs working on associated domains.

> *The strength of any great system shines most brightly in the light of limits that give sharp and clear definition to the large, but not infinite, domain of its legitimate action.* — Stephen Jay Gould[13]

3.1.2 Determining the Audiences

Above all, the principal audience is the research team. The RW Essays are designed to become canonical documents and are addressed to scholars familiar with the issue domain. Works that derive from the essays will use language and arguments that are designed for a different audience. The granting agency and cooperating institutions might be offered the ability to audit the progress of the RW by viewing it, or through periodic progress reports. Sustaining grants may be more likely if the granting agency has access to the RW as well as obligatory reports and published papers. The RW may have a partition that allows public access to some information and to documents specially designed for public use. A similar partition may be set up to allow temporary access to professional colleagues outside the team. Parts of the RW may also be used in academic instruction.

3.1.3 Defining the Vocabulary

Identification of the objects and processes in the issue domain leads to the description and formalization of the language of discourse for the domain. In the context of a multidisciplinary issue domain words may take on multiple meanings[14]. Rachel and Woolgar report an extraordinary constellation of meanings and implications for the term 'technical'[15]. The author once sat through three hours of meetings devoted to defining the meaning of 'hazard.' Meanings of terms need to be articulated by collaboratively developing a glossary. The glossary must be a dynamic document that can be annotated at will by members of the research team; thus the glossary becomes an Annotated HyperGlossary. Glossary entries can be referenced in any RW essay, or other HTML document, and displayed in popup windows without leaving the essay.

Interactive software is necessary to develop the glossary and to display the information assembled. The program designed to assist in the assembly of the glossary is called Lexicon (§4.8). A geographic analog of the glossary, an Annotated HyperGazetteer, could provide the important ability to define describe and display regions, features and linear objects of interest in the issue domain. These features might be dynamically displayed on maps from the gazetteer, or be referenced from maps to the gazetteer.

3.2 Five Aspects of a Research Web

The Research Web is designed to be a vehicle for research collaboration, information dissemination, and model building. Five prominent aspects of the Research Web have emerged. These aspects serve to validate the design and explain how the RW works.

- The Research Web may be considered as an application of Critical Social Theory, the philosophical school that is concerned with finding alternatives that offer better solutions to problems of existing social conditions. In our context, "normal science" is an existing social condition, and participatory science is the alternative we are exploring.

- The RW can be considered as an information product, one that manages data, information and knowledge in a manner that makes access, contribution, refinement, and criticism as easy as possible for every user of the RW.
- The RW is also designed to transform data and information into knowledge, and to transform existing knowledge and tacit knowledge into new or augmented knowledge. These transformations must necessarily involve managing the flow of information and facilitating the work of team members in the creation of new shared knowledge. Processes within the RW make the work of the team more structured, visible and simple.
- The RW can also be seen as a set of formalisms, most borrowed from sources familiar to the team. These formalisms are genres borrowed or built to suit the issue domain. As genres, the formalisms are also boundary objects that serve to provide common structures for interdisciplinary research.
- The research process can be viewed as a process of informal argumentation. By using the RW to make the structure of arguments more clear, the quality of the arguments can be enhanced. Criticism is an integral part of this process. Organization of the argument has been demonstrated in many products and papers.

3.2.1 The Research Web as an Application of Critical Social Theory

The Frankfurt School developed critical social theory, or critical theory, in the mid 20th century. The principal thinkers associated with the School are Adorno, Horkheimer, Marcuse, Fromm, Benjamin, and later Habermas. The primary goal of critical social theory is to find "alternatives to existing social conditions which more adequately address human desires."[16]. The social condition we seek to find an alternative for is the current environment for development of scientific knowledge and its publication. We can apply the basic principles of the Theory and then appeal to Habermas' Ideal Speech Situation to show how the Research Web meshes with this tradition.

The Frankfurt School proposed a revision to Marxism that put forth five basic assumptions[17]. Here is the list of assumptions and how the RW works with them:

1. *People have the power to change their world.*

People have the power to change their world for the better because it is of their making, that is, the *status quo* is socially constructed. This principle leads to a general critical examination of institutional and personal power. Changing the *status quo* requires alteration of authority and custom. In the Research Web, the adoption of new distribution technology, the WWW, is a challenge to the scientific publishing system[18]. This challenge is now recognized as an inevitable force in the restructuring of the scientific publication system[19]. No one knows what direction it will take, but certainly it will be a long evolutionary process. Another institutional power that resists change is the academic environment. Some of the customs of academia operate to discourage long-term cumulative research, especially interdisciplinary research. The format of the publishing system does not have the means to publish small contributions. These barriers are discussed elsewhere (§2.2.5).

Publishing knowledge in the RW Essay format provides knowledge in a format that is linked directly to other knowledge as hypertextual sidebars. The integral critical apparatus (DocReview) opens the essay to criticism by readers. The art of footnoting may be revived by the hyperdocument format of the RW Essay, as the footnotes are unobtrusive marginal notes displayed in small windows. Ease of revision allows the RW Essay to have a dynamic nature, reflecting accumulated criticism and newly found knowledge. Older versions of the Essay are stored in easily retrievable DocReview archives.

2. *Knowledge of the world is value laden.*

If all knowledge is value-laden, then we must criticize the values in order to strip the knowledge of assumptions. Language itself is often value-laden. The RW attacks the assumptions of tacit knowledge by means of criticism through DocReviews of expressions of knowledge such as position papers and RW Essays. Jargon or specialized meanings are criticized by the annotation of definitions carried in the Annotated HyperGlossary. Research articles that provide an overly discipline oriented view of a topic may be criticized in the Annotated HyperBibliography.

3. *Reason and critique are inseparable.*

Kant, Popper and many others have noted the inseparability of reason and criticism; indeed Popper's demands of falsifiability may be demonstrated by critical annotation. The quality of dialog is augmented by criticism in a framework of argumentation (see §3.2.5).

4. *Theory and practice must be interconnected.*

The schism between practice and theory is an artificial division made perhaps by the academic tendency toward specialization. Today the division is being healed by practical concepts such as participatory design and action research. Participation of stakeholders in research of all kinds (especially environmental and management) is now accepted as the nature of "post-normal science"[20] in the face of risk and uncertainty.

Tools from the RW have been used in an exercise in participatory design of a user oriented software system to collect and distribute environmental metadata[21]. Opening of the documents of the RW site to annotation by colleagues, students and stakeholders is part of a democratizing process called legitimate peripheral participation[22]. Inviting these formerly excluded people to join the research enhances interdisciplinarity, socialization, and political inclusion.

5. Reason and critique must be reflexive in practice.

In the RW reason is expressed in documents that invite criticism. The reflexive nature of collaborative research practice is characterized by the constant feedback loop between documents and annotations to those documents. The RW Essay is the best example of this looping: Each version of the document accumulates, in the document's DocReview, annotations that require a response. Every response is either incorporated in a new version of the document or is rebutted with an explanation. The criticism and rebuttals form a part of the argumentation about the topic. This reflexive process surrounding a document is called successive refinement in this dissertation.

Changing the conduct of a social process, in our case research, requires that the validity of our findings and the resulting changes must be examined reflexively. The conceptual framework of this dissertation suggests that Brinberg and McGrath's VNS (validity network schema) be applied to organize the research. VNS recognizes the existence of constant feedback between research domains and between research phases. This solid approach coupled with the RW's many affordances for reflexive criticism insures that validity is always under review. This quest for reflexivity is the basis for action research and participatory design[23,24].

3.2.2 The Research Web as an Information Product

The Research Web (RW) is an information product, software that manages data, information and knowledge. An information product is a complex of hardware, software, procedures and data that is designed to serve a particular purpose for a set of audiences. The purpose of the RW is to provide an environment to investigate the nature of a phenomenon, the *issue domain*, using scholarly processes. The audiences are: the research team composed of scholars, collaborators, and research assistants; stakeholders, the people and organizations who are affected by the research; the sponsors of the research, those organizations and individuals who provide the resources for the research; and finally, perhaps, the public, composed of students and interested parties who may benefit from learning about the phenomenon under investigation.

A RW closely follows the architecture of information products defined by Meyer and Zack[25] (See Figure I, below). It contains three major abstract divisions: a *product family*, documents presented on demand to the information consumers; a *repository*, the information store for the RW; and a *refinery*, which contains the means (software and management processes) to manage and add value to the information in the repository. The repository is a database, whose architecture can assume a structure most suited to produce the product family. The product family consists of several document types carefully designed to serve the needs of the research team. The refinery is the heart of the RW. It serves five major functions: *acquisition*, the accumulation of information about the issue domain; *refinement*, the processes used to add value and quality to the information; *storage and retrieval*, the means to manipulate the repository's data; distribution, the means of taking the products to the information consumer; and *presentation*, the means of displaying the information to the consumer.

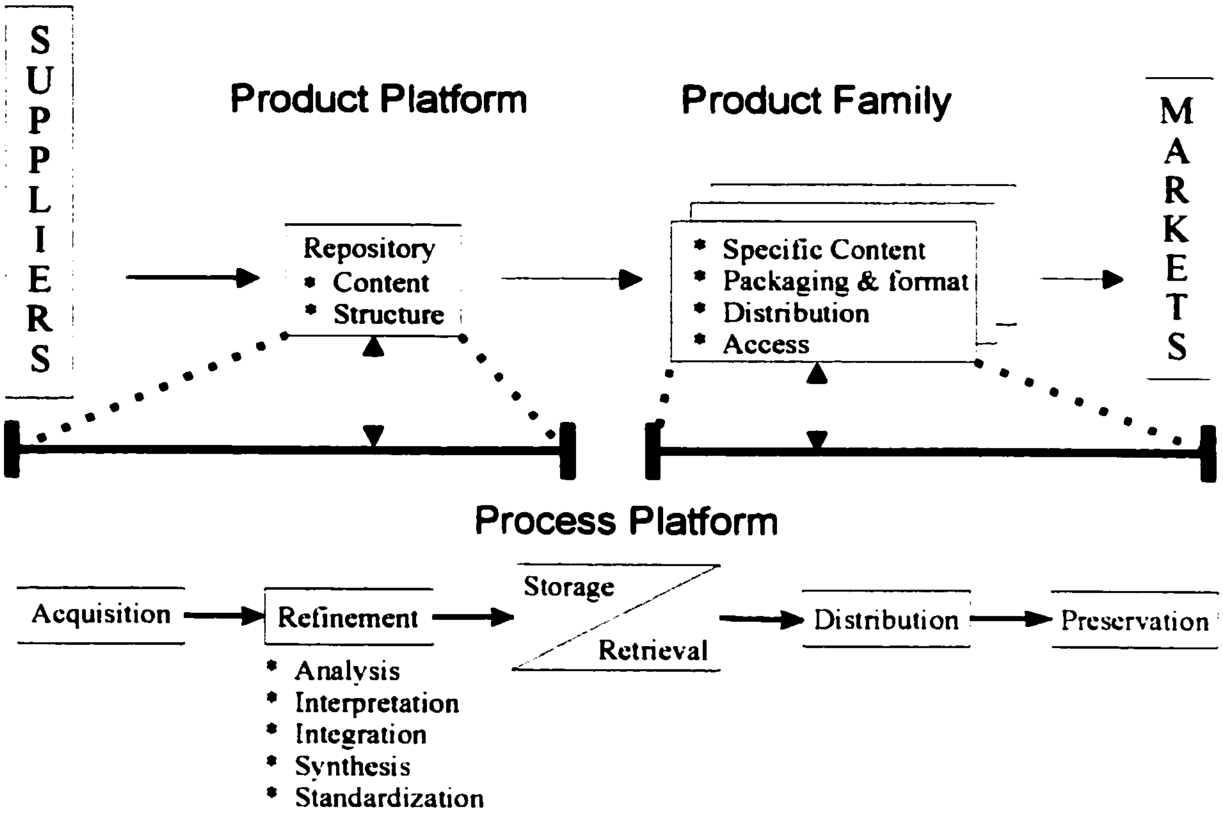


Figure I The Architecture of Information Products

Given the basic assumption that the RW exists in an environment established by the Internet and WWW. some of the processes outlined by Meyer and Zack fall out or are modified (see Figure II. below). The Internet manages the distribution process. That assignment of responsibility constrains the information system (RW) to limit its information to files structures compatible with the WWW. That restriction of file types also limits the product family to WWW compatible file types and their printed representations. The user must be equipped with a modern personal computer and an Internet connection. The Internet browser wholly manages the presentation process. That assignment forces the user to assume the responsibility of installing a browser on his or her personal machine. The user must also acquire the training required to use the browser and personal machine. The storage and retrieval process becomes a distributed system. with files stored in any server machine connected to the Internet.

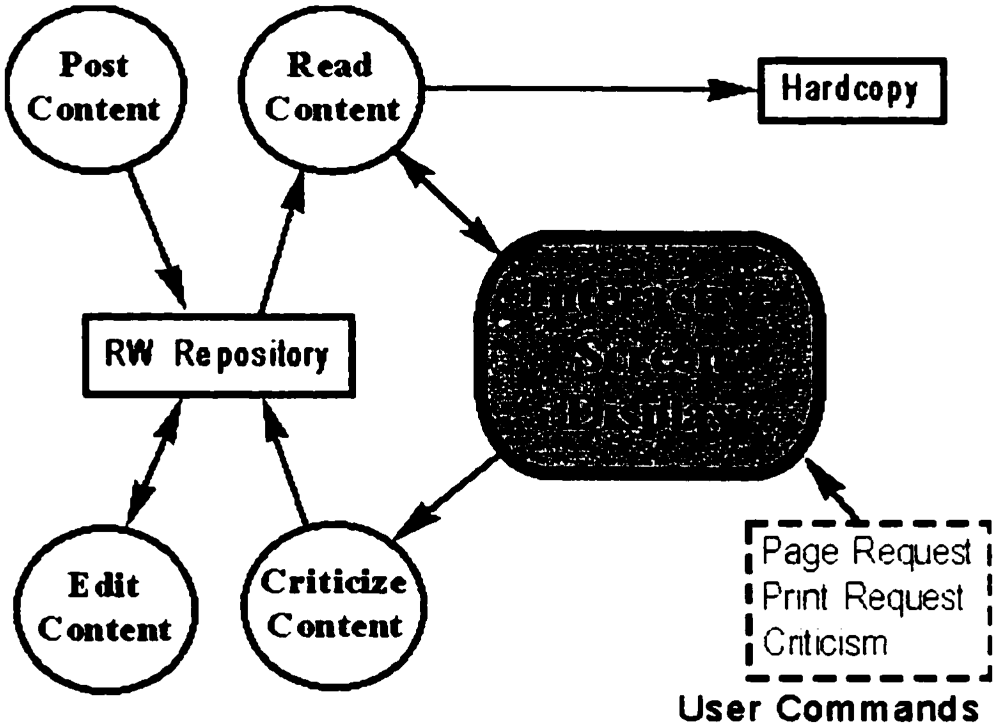
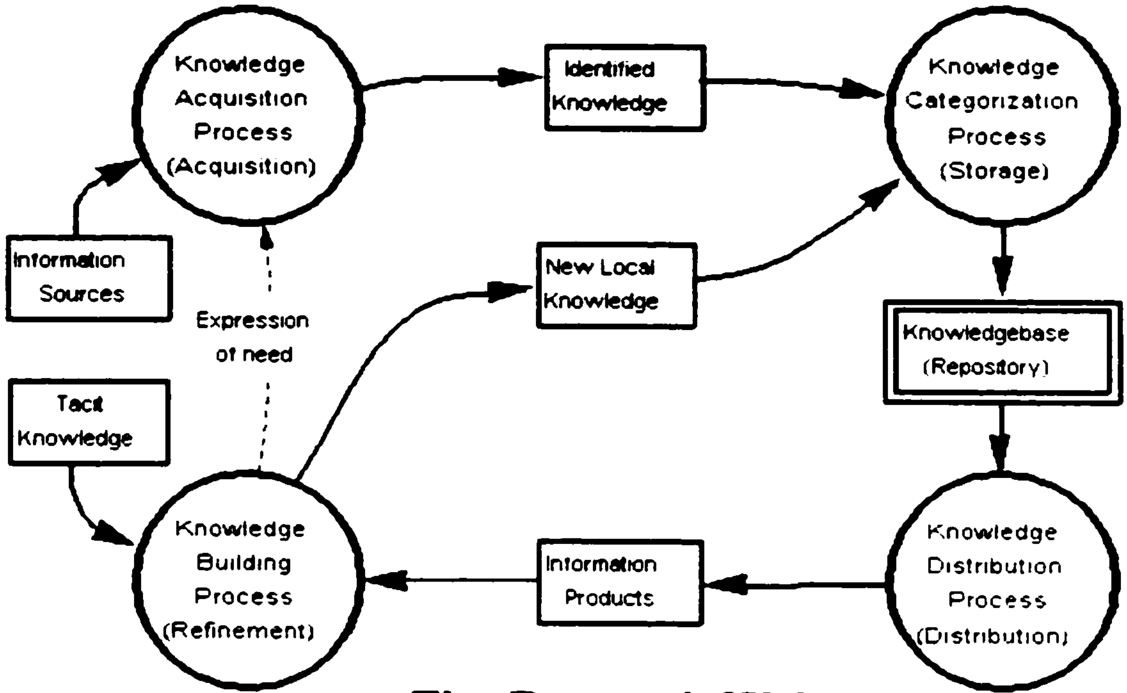


Figure II Information Flow in a Research Web

The process platform of the RW architecture is thus simplified to acquisition process. criticism process, and editing process. The acquisition process and editing process are human-centric processes managed by the author, scientific leader, and facilitator. The criticism process is managed by the user and by software on the server machine. The criticism process and editing process together constitute the refinement process of the Meyer and Zack architecture. The product platform is simplified to the repository and a combined distribution and presentation process managed by the browser under the direction of the user through an interactive screen display.

3.2.3 The Research Web as a Knowledge Transformation Process



The Research Web:
A Knowledge Transformation Process

Figure III

Abstracting from the Meyer and Zack architecture. it can be seen that the RW is an Information Product constructed to support a knowledge transformation process (see Figure III above). The research team can. from two types of input (Information Sources. and Tacit Knowledge) produce the ultimate output (Information Products) through three intermediates: Identified Knowledge. New Local Knowledge and the Information Products of the RW. Four interlinked processes support this transformation:

- The Knowledge Acquisition Process. based on the expression of need from the research team. identifies knowledge from existing sources. This process starts with conventional searching techniques, but requires that the knowledge or reference to the knowledge be converted to digital format.

- The Knowledge Categorization Process accepts identified knowledge and new local knowledge and characterizes it for placement in the Knowledge Repository, a database for knowledge accumulated by the RW. This process constructs and maintains the knowledgebase and designs the RW Web site.
- The Knowledge Distribution Process converts knowledge from the knowledge repository into information products of many genres that can be used by anyone, but especially the research team. This process is entirely automated.
- The Knowledge Building Process is a place of most intense collaboration, where the research team couples its members' tacit knowledge with the information products extracted from the knowledge repository to synthesize the most precious product: New Local Knowledge.

3.2.4 The Research Web as a Genre System

> *"... a genre system, when enacted by participants, structures or choreographs multi-party interactions within and across communities. It serves as an interaction template which participants draw on in engaging with each other across media, time, and space."* — Orlikowsi and Yates[26]

In order to design a good set of tools to facilitate collaboration, great attention must be given to the genres of communication currently in use by similar organizations. Each established form of communication is a genre[27,28,29]. These genres must be compatible and mutually supportive in order to be successful. Such a group of genres form a genre system[30] (see Table I, below).

Our genre system is composed of genres developed for general use in the RW environment, and specialized genres appropriated by the research team. The genres may be adapted to the peculiar demands of the issue domain. It is possible that a genre might be designed specifically for an issue domain-specific purpose, for instance a species list for a biological or ecological issue domain.

Table I The Genre System of the Research Web

GenreName	Function	Description	Reference
Models	Provides a synoptic overview of a process or set of objects. May serve as a clickable index to discussions of its constituent parts or submodels.	A tabular presentation of the characteristics of objects and how the characteristics may be operationalized. Or a graphic presentation usually consisting of nodes and links (bubbles and arrows) showing the relationship of its components. Or a computer simulation of the system or a portion of the system.	§3.2.4.2.1 §3.3 §3.5.2.4.1
RW Essay	a treatise, usually scholarly	A highly augmented annotatable HTML document with hypertextual links to bibliographic information, definitions, notes, and related documents.	§3.4 §3.5.2.4.2
DocReview	a critical apparatus	A suite of programs that allows the user to make annotations to predefined segments of text and graphics, and allows those comments to be read by any user.	§4.3 §3.4.2

Table I (continued)

Annotated Hyper-Bibliography	provides bibliographic information	A hybrid software system that allows the user to input data in a PBM (personal bibliographic manager) then utilize that data in an annotated bibliography and in popup windows in RW essays. Supports user annotation.	§4.4 §3.4.4.1
Annotated Hyper-Glossary	provides definitions and technical commentary	Definitions appear on a web page that allows the user to comment or add a gloss to the definition.	§4.5 §3.4.4.1
Discussions	Provides a venue for threaded discussions of a topic.	WWW site that allows annotation of an initial topic statement, and allows annotations of the annotations indefinitely	§3.5.2.2.4 §4.2.5
FAQ	answers commonly asked questions	A WWW page listing frequently asked questions with answers	§3.2.4.3
Personal Home Page	Introduces a team member to peers.	A WWW page that provides links to interests, CV, and publications.	§3.2.4.4
Topical Home Page	Introduces a major topic in the web site.	A WWW page that briefly describes a topic and provides links to more information.	§3.2.4.4
What's New	Informs the members of revisions or additions	A WWW page that allows the user to click directly to new or revised documents	§4.7
Listserver	Allows members to message the entire team.	E-mail lists for general discussion, contains an archive of past messages.	§4.1.3
Calendar	scheduling	A page that lists scheduled events	§4.2.4

Each genre selected or designed must also be modified to conform to the demands of the electronic environment. Hypertext alone will force numerous adaptations. International teams will need to consider cultural preferences and taboos.

3.2.4.1 The Essay Genre

Agre says that the designer of a new genre needs to work with the existing forms used in the activity, but then do more[31]. The Research web essay does more by placing the essay's annotation in context: there is no need to thumb through dictionaries and bibliographies, or to flip to a section of endnotes. All that information may be had at a click.

Scholarly annotation includes a wide variety of supplemental information: information on sources, clarification of obscure statements, references to related works, alternative meanings, definitions, glosses, editorial notes, etc. Over the centuries of representation of knowledge in codex form rules have evolved for the treatment of such information, with occasional revisions due to minor changes in technology, or changing fashion. With the introduction of hypertext and the WWW, those rules can now be challenged. A web page is not a codex document; it is a scroll. With the power of hypertext and the ability of the web browsers to create new pages, the rules can be reinterpreted to great advantage. In particular the editorial rule of "clean text," the minimization of interruption of the reader's view of the primary text, can be applied even more stringently. The RW Essay is a genre inviting application of new rules for annotation.

Every genre is a template for social action[32]; in this case the social action is the transmission of knowledge. The RW Essay gives the reader the ability to criticize the content of the essay, the language used, and the quality of the references. In other words the RW Essay not only informs, but also contains its own critical apparatus. Criticism is a major method of creating knowledge, and the best way to provide a research team with the means to participate in that creation. In the RW, commentary is a form of scholarly dialog. Commentary in the RW Essay is clearly secondary text. the essay's content is not altered until the author or authoring team chooses to incorporate or disregard the commentary in a new edition.

The Research Web Essay is a very highly augmented Web page. Like any other web page (a very well known genre). it reacts to clicks on hot spots on the page. The clicks pop up new windows displaying well-established features of scholarly literature[33]. Features implemented include marginal notes. sidebars (see alsoes). bibliographic information (including full text if available). glossary definitions (and discussion). a link to a means to annotate the essay (DocReview), and general notes (analogous to sticky notes).

These features are available to those that use the computer to read the material. Footnotes and references both have return links to the text. If the reader is curious as to where in the text an author is cited. all that needs to be done is to click on a return link icon (there is one for each time the work is cited). As a service to those who wish to have hard copy of the essay. footnotes. glossary of terms. and references for the essay are printed following the text of the essay. The printed essay is of course badly disabled by loss of the hypertext links.

3.2.4.2 The Model Genres

> *"... the function of a model is to form the basis of a theory. and a theory is invented to explain a phenomenon."* — Rom Harré[34]

The RW. in order to present a theory about the phenomenon under investigation must represent all the expressed models of the issue domain. and should discuss the unexpressed mental models as well. Mental models are the filters by which we interpret the reality we perceive[35]. Our mental models are constructed on observations and learning which lead to a set of hypothetical generative mechanisms[36] that account for our experiences.

Mental models are naturally unexpressed, and therefore become expressed as their description takes shape. I cannot imagine a description of a mental model being anything other than an evocative work of prose or art that shows the coherent nature of a set of ideas and their interactions. The closest formal genre that might fit would be an essay. This essay is bound to be intensely personal and full of conjecture and very weakly supported theory. It would very likely need to be kept private, as part of a notebook or a journal. An edited version would be very helpful as a basis for beginning the collaboration. The edited version would be a position paper, perhaps published in the RW on the team's biosketch page.

Since all but the smallest, or atomic, models contain submodels[37], larger models such as the descriptive, explanatory, and simulation models must be hierarchical. Those hierarchical structures are naturally expressible in hypertext documents. The models are process models, models of objects known as type or class definitions, and diagrams showing the relationships between objects (entity-relationship diagrams). All these models can be backed with dictionaries and catalogs.

The descriptive model forms a very large portion of the RW. It will contain a series of essays, organized hierarchically, that captures the nature of the phenomenon. As the essays are refined through criticism, they will uncover more detail giving the description breadth and depth. Each essay will produce two products: models and essays of details uncovered in the parent essay. Models take many forms, usually diagrammatic, but often textual. Submodels developed in the descriptive model are: process models that describe the temporal progress of actions; type descriptions, that list and describe the objects and processes that the objects participate in; entity-relationship diagrams that describe how the objects are related; and catalogs and dictionaries giving definitions of the terms used in all the models. In realist terms, each essay will deal with objects at its level and the emergent qualities of that level. Models are the glue that holds the essays together.

The explanatory model will be hierarchical and will resemble the descriptive model in form. The nature of the essays and models will be quite different, as they will deal with hypothetical causes and must describe the basis for experiments to support or reject the hypotheses. The essays produced for the explanatory model will be much more abstract than those of the descriptive model. The explanatory model must go beyond the description of the phenomenon in operation to the reasons why the phenomenon operates as it does. Causal models require the identification and elucidation of the mechanisms that presumably cause the observed behavior of the phenomenon, its objects and processes. The explanatory model expresses both hypotheses and theory. Those hypotheses will be examined in experiments, and the theory will be expressed in the simulation model.

The simulation model is ultimately represented by a computer program. That representation is, by itself, inadequate because of the incomprehensible detail and rapidly changing content and computational recipes (algorithms). The ruling representation for the simulation model is the description of the design. The design description captures the scientific intent of the model, leaving its implementation to the technicians. The design description is a model, usually graphic, that are defined as finite state machines[38], or petri nets[39,40].

3.2.4.2.1 Representation of the Models

Models have been inaccessible to many social scientists due to poor modeling practices and the cloaking of explanatory and simulation modeling in mathematical notation. The mathematical notation frequently alienates those inclined to be a bit skeptical about the applicability of mathematics to the human issues in our lives. The RW makes modeling accessible to human geographers, sociologists and other social scientists by a restructuring and expansion of the usual modeling processes. The Research Web is designed to make knowledge as models easy to accumulate and access.

The Source Model is an unexpressed but very important model that cannot be represented symbolically. There are *sentential* models[41] that form part of the bridge from the Source Model to the Descriptive Model and to the Explanatory Model. Sentential models are often simply collections of textually expressed knowledge. The RW Essay may be considered a sentential model. The Simulation Model is expressed in a computer language algorithm that is inaccessible to non-specialists. but it is modeled in a variety of expressed models.

The Descriptive Model is a suite of models of the objects of the issue domain. and models of the processes that relate the objects within the issue domain and to the rest of the world. The models of objects are maps of their attributes and the top-down hierarchies of related objects[42]. Our descriptive models are composed of lists of objects. their attributes. and the values that their attributes can assume. including much of the information found in the auxiliary model (see Table II. below). For instance. operationalization information can be added to each attribute and process: for instance an attribute such as a person's age can be operationalized in several different ways: by date of birth. by common designation (years). by developmental age (zygote. fetus. postmenopausal ...). by life stage (infant. child adolescent ...). and others. Each of the operationalizations has characteristics such as data type (integer. real ...). value range. precision. and of course a description. Processes may include several alternatives.

Object models are usually presented in tabular format. For each characteristic of the object (attribute) there is a row; and for each property of the attribute there is a column. In the RW. tables are presented in web pages. and each cell in the table may be annotated by using DocReview. Object models may be extended to include operationalizing details such as how measurements are made and with which protocol.

Process models are usually presented as node-and-link diagrams. In the RW. the diagram may be image-mapped so that each element. node or link. can be annotated. Clicking an element will display a document that fully describes the element. In complex processes. a node may be expanded into a sub-model. Clicking such a node can link directly to the sub-model. or the submodel can be part of a document. The documents referred to in a process model are annotatable in DocReview.

Relationship models are presented as node-and-link diagrams. In the RW. the diagram is image-mapped. Clicking a node. which is always an object. refers the reader to the object models for that object. Clicking a link will display a document that describes the link. These documents are annotatable in DocReview.

Table II

Extension of the Descriptive Object Class Diagram into the Auxiliary Model

Physical Body

Attributes	Operation-alization	Description	Data Type	Values/Range	Precision	Notes
Age	Common	The number of units of time that have passed since birth.	Integer	Units: weeks, Months, Years	minus 0 to plus 1 Unit	In Japan, people are assumed to be one year old at birth.
	DOB	The date of birth.	Abstract: Year of birth; month of birth; day of birth.	month: 1-12; day: 1-31	one day	In Moslem culture, years date from the Hegira (AD 622).
	Developmental	Stages of life marked by physical milestones and characteristics.	Nominal	Zygote, blastula, embryo, fetus, neonate, infant, child, adolescent, adult	fuzzy	
	Gestational	The age of a fetus since presumed conception	Integer	weeks	plus or minus 2 weeks	There are many clinical proced-ures often used in combination.
	Life Stage	Stages of a model life in a given culture.	Nominal	Infant, child, adolescent, student, married, retired, senescent	fuzzy	Could be elab-orated with any milestone, or rite of passage (e.g. bar mitzva, confirmation, divorce, promotion).
Sex	Reported	The sex that the Person assumes in life.	Binary	Male, Female		
	Preferential	The sexual roles that a person assumes.	Nominal	Female, Male, Lesbian, Gay, Bisexual, Asexual, Chaste		
	Chromosomal	The makeup of the sex chromosomes.	Nominal	XX, XY, XXY, XXXY		

|← Auxiliary Model → → → →

The process models of the RW are almost always directed graphs, or node and link models, backed with RW Essays describing the operation of the process. These models generally have text labels on nodes, which may be circles or boxes, and links that are lines connecting the nodes. The lines representing the links may be augmented with arrowheads or other devices to indicate the directional character of the link. Mathematical models can be qualitatively transformed into graphs for better understanding: input, process, and output.

The hypertextual nature of the RW allows us to use each model as an index to its component parts, both nodes and links. The models are realized as "image maps." In an image map, each element, node or link, is invisibly surrounded with a "hot spot" area that may be clicked on the computer display. When the element is clicked information about the element is "popped up" in a new window. That new window may contain a submodel, or a textual explanation of the element. It should be noted that the label associated with the element is simply a *sign*, and the element has to be clicked to obtain the information about the element.

Hierarchical hypertextual models have the monumental advantage of allowing the reader to request explanation of any element of a model in increasing detail, perhaps even until the element is irreducible. This ability to "drill down" allows exploration of just those parts of the model that interest the reader. This type of modeling has been employed for several years in maps as "hypermaps"[43].

So, we have foundation models expressed in simple graphics and plain natural language. This organization allows the presentation of the model to be quite simple, since the labels simply suggest the information about the element. The brevity also allows extremely complex models to be reduced to an absolute minimum of complexity. Burying the information about a sign in a subsidiary document is called information hiding. One great advantage to information hiding is that, for the novice, the signs become links to knowledge; and for the expert, the signs become knowledge.

3.2.4.2.2 The Process of Modeling in the Research Web

All modeling in the RW starts with an exhaustive analysis of the objects and processes operating within the issue domain. This analysis is referred to a system analysis, and it is the basis for all modeling that follows. System analysis is not only accessible to the social scientist, but in fact is their strength. Any scientist who has described a social phenomenon, from migration to learning, has engaged in system analysis. The system analysis performed by the social scientists resides in the repositories we call the descriptive and explanatory models.

Description of prototypes, description of the data, and description of behavior is the heart of social science. The team may start by describing the objects and processes captured in the Annotated HyperGlossary. Objects are described in annotatable tables with hyperlinks to associated essays and other informative documents. Empirically observed processes are described in node and link diagrams that may be incorporated in RW essays.

Explanation is theory-building based on description and probable causal mechanisms connected through abduction. The explanatory model will include abstract objects and processes based on the real objects and processes of the descriptive model. As causal hypotheses are developed, they can be assembled in the explanatory model. The explanatory model will be the source of experimental hypotheses that will be examined in the later stages of work. The experiments of the past and those performed in the course of the research provide inductive proof of the theory.

When the system analysis and explanatory modeling has reached sufficient maturity or detail, then simulation modeling can start. It is at this point that operationalization takes place. Operationalization is normally considered part of experimental design, but it is also a set of instructions for simulation modelers. The descriptive and explanatory models through operationalization form the auxiliary model, and the auxiliary model informs the experiment and the simulation model. Social scientists who choose to involve themselves with simulation modeling and computer programs may certainly do so, but can also defer to computer scientists or hired programmers.

Whoever does the simulation modeling must be held responsible for firmly linking the programming with the descriptive, explanatory and auxiliary models. Programmers are well known for disdaining commentary linking their procedural code to the reasoning of the analysts who have designed the theory. The team must not allow failure to maintain the chain of reasoning to degrade the modeling effort. If the simulation modelers are puzzled by the foundation models, then they must bring this to the attention of the social scientists, for such puzzles are feedback pointing to weakness in the foundation models.

Throughout the modeling process, new knowledge and criticism will surface. This new material will require the expansion and revision of the models and essays that formed the basis for the new material. Change will constantly ripple through the models and essays, requiring a steady stream of revision. Management of this process will determine the quality of the work of the team.

3.2.4.3 The FAQ Genre

The FAQ (Frequently Asked Questions) was created early in the history of the Internet, probably as a defense from repetitious questions from newcomers to open discussion groups. Defense from the naive was the true motive, but service to the learner is a fortuitous and more important outgrowth. It is the nature of members of a group to bully newcomers who have naive questions, so not only was the discussion burdened with the questions, but also from many rude responses from the group members. Customs have now developed to control this behavior: members now send private e-mail messages to the "offender" suggesting how to get to the FAQ.

The FAQ begins as a compendium of naive questions and answers to them, but soon actually becomes an index to succinct topics of group knowledge covering the entire nonspecialized issue domain[44]. FAQs are the place to go if one needs a quick and correct answer on a topic. There are even Indexes to FAQs or "FAQ on FAQs" (see http://usenet.umr.edu/faqs/).

The fully developed genre organizes the information in a very carefully designed hierarchical index, perhaps headed with a "top ten" set of questions. Each section of the FAQ then simply contains a set of questions with answers. There may be several answers to a given question and there may be hypertextual links to more complete discussions of the question. The FAQ frequently contains a search engine so the user can rapidly view the knowledge relating to a set of keywords. The FAQ usually contains an introduction to the community of interest, including listserves, appropriate canonical documents and URL references.

In an interdisciplinary Research Web, the FAQ might contain background knowledge from each of the specialties. Many of the questions regarding terminology will be discussed in the Annotated HyperGlossary, and principal references in the Annotated HyperBibliography. Since the RW's working area is usually closed to the public, the FAQ is often not required there, but if there is a large public partition, a FAQ can be a real service.

3.2.4.4 The Home Page Genre

The home page is an index page[45] for a project (topical home page or THP), or the personal home page (PHP), a narrative of self-evaluation[46], of the account owner. The home page is a new genre created as an outcome of technology and may be considered the first truly digital genre[47]. It came into existence with the WWW, made necessary to navigate the structure of the web site. Every file system needs a "root" directory containing any number of files and subdirectories. Located at the root, the home page will provide the information necessary to navigate the web site.

Any team has the need to know each of the members. Social as well as informative purposes are served by the personal home page. Personal interests and expansive descriptions of research interests provide a window to view the personality of the subject. Dillon and Gushrowski[48] found that at least half of their experimental subjects agreed on each of ten features that should appear on the PHP: a title, an e-mail address, an update date, a table of contents, a create date, external hypertext links (perhaps research project pages), a welcome message, from one to four graphics, photographs, and a brief bio (for academics, a CV or a link to a full CV). As time passes, the PHP has become an increasingly stable genre. The personal home pages of the team members must be linked from an index page (see §3.5.2.2.1). The index page (a topical home page, see below) might include a brief description of the position that each person fills on the team. The PHP should be linked by URL, as it can be stored on any WWW server. The facilitator can assist any member in preparation of a PHP.

The home page for the RW, a THP[49], is basically an index to the other major topical pages in the site. The content of this page is devoted to an introduction to the issue domain of the team's research. As a navigation device, this page should provide one click access to major sections of the site, such as the index to Research Web Essays, and to frequently used pages such as "What's New" and the MailRoom. The site needs separate

THPs for each partition implemented: public, the working area, and the guest partition. A topical home page has not only links to subtopics, but also introductions to them. The topical home page can introduce and subject in the logical hierarchy of the site. In a strongly hierarchical issue domain, the connections of the topical home pages may be shown in a diagram, the organizing model, with each link and node in the diagram or model serving as a clickable link to other pages. These "clickable images" are a powerful navigation tool.

3.2.4.5 The Meeting Minutes Genre

Groups will find it necessary to meet synchronously from time to time. In these meetings, members discuss important issues and make decisions that may affect other members. Minutes of these meetings need to be recorded and opened to annotation. The attendees of the meeting need to see that the minutes are both complete and correct. The minutes then can be archived and become a searchable part of the team's research record.

In the RW, meeting minutes have evolved into an interactive genre that to date has been a very successful application of this research. After the scribe renders the minutes in an electronic format, the minutes are forwarded to the facilitator who mounts the minutes in DocReview (§4.3). Each item in the minutes is made into a separate review segment. The facilitator then sends a notification of the posting of the DocReview to all attendees. The attendees can review the minutes item by item at their convenience any time well before the next meeting. Objections, corrections, elisions, and amplifications become DocReview comments, visible to all immediately.

Just before the next meeting, the meeting chair may print out the DocReview from the WWW in a format that interleaves comments after the review segment (the "on-the-bus" format). Copies are distributed to the attendees along with the agenda. The first item on the meeting agenda is the correction of the previous meeting's minutes. The attendees discuss the recommended substantive changes and the scribe notes the dispositions. The last item on the agenda is usually discussion of outstanding action items. The action items are tagged with the date assigned and are carried over until completed or removed. Like all items in the DocReview the action items may be annotated.

After the meeting, the facilitator will correct the old minutes, archive the DocReview (thus preserving the annotations), and post the minutes to the web site. The approved minutes may then be e-mailed to a distribution list. The archived minutes are then linked from an index page for all meeting minutes. The minutes are searchable documents.

3.2.5 The Research Web as Argumentation

> *"Rhetorically, the creation of knowledge is a task beginning with self-persuasion and ending with the persuasion of others."* ---- Alan Gross[50]

All knowledge is socially constructed. This is especially true of social science. The body of knowledge in every discipline is the result of an ongoing multilogue between all scholars, present and past, who have contributed to the literature. The multilogue can be expressed as argumentation.

Realist philosophy recognizes that hypothetico-empirical proofs will seldom be found in social science due to the open system nature of human society. Rather than depending on certainty to establish validity, as is possible in closed systems sometimes seen in the natural sciences, validity in social science is established by other standards such as relevance, cogency, and truth[51]. All these standards may be judged by the principle of practical adequacy[52], or by the degree to which the model of the system resembles the system itself, verisimilitude[53].

Practical adequacy and the measurement of verisimilitude are arrived at by a process of social interchange. This interchange, at present, takes place formally in the literature. The rules of interaction are designed to insure that scholars present rebuttals or confirmation in published papers. Classically, each paper must present a complete valid argument rather than an attack or confirmation of a single small point, though disagreements are frequently noted *en passant* in the review of literature. Discussion of minute points is seldom published because such communications do not meet the minimum publishable unit requirements. Argumentation on a single point or subsection of a published paper is carried on in often unindexed minutia such as Discussions, Technical Communications, and Letters to the Editor, or remains unpublished. The RW can have a much more intense and rapid social interchange of any item regardless of importance.

Scientific arguments, both regular (supportive) and critical, have a very clear structure[54]. Eisenhart and Borko propose that following Dunn and others, research, especially action research in education, can be considered a form of argumentation[55]. Dunn suggests that knowledge and practice can, through a process of reasoned argument and debate, be successfully advanced[56]. He uses the metaphor of jurisprudence as a process model. Gross also refers to courtroom argumentation[57]. Representation of adversarial positions held in conflict over environmental impacts of chemical weapons disposal by argumentation has been demonstrated by Liebow, et.al.[58]. Both Dunn and Liebow suggest using the Toulmin method of argumentation. Toulmin's typology of the elements of argumentation includes claims, grounds, warrants, backing, qualifiers and possible rebuttals[59].

3.2.5.1 Argumentation Capabilities in the Research Web.

Information contributed to the argument is collected as a byproduct of normal operations of the Research Web. Submission of e-mail. DocReview comments. HyperBibliography comments, HyperGlossary comments, discussion forums. meeting minutes. and above all RW Essays provide the elements of argumentation. A formal argumentation structure may be built by using a web-based tool. The Landscape of Reason. after which the structural layout may be directly manipulated. This tool presents the argument in a hierarchical hypertextual format that may be read by anyone on the WWW. Construction of the argument is an intellectual edifice built by organizing information extracted from the contributions of the team. Additions. deletions or revisions are to be managed by the facilitator. but may be opened for direct user manipulation in technologically facile teams.

In the RW Essay. each review segment may be critically annotated publicly thus directly contributing to not only content but to the valuation of adequacy. Such public argumentation approaches Habermas' Ideal Speech Situation much better than current practices of scientific peer review[60]. The quality of references and the accuracy of the vocabulary of the issue domain can be argued in the Annotated HyperBibliography and Annotated HyperGlossary.

The Annotated HyperBibliography supports argumentation by allowing public evaluation of the references used as backing for an element in the argument. Commentary contributed to the AHB can point out other works that amplify. conflict. or rebut the cited work. Appropriate comments can be incorporated in the formal argumentation structure.

The vocabulary of the RW's issue domain is defined in the Annotated HyperGlossary. The annotation capabilities of this tool allow the users to gloss each definition. and discuss the phrasing of that definition. Should an alternative meaning emerge. that new definition may be added just as dictionaries carry alternative meanings. Hypertextual links to the proper alternative definition can be made from the RW Essays.

E-mail of course has been used for decades in dialog and will continue to do so as it is a completely general critical tool. In the RW, specific e-mail messages can be directly cited by reference. In the Landscape of Reason, a summary of the major point will be entered, but there will be a hypertextual link directly to the message.

3.2.5.2 Measurement of Quality of Argumentation

Progress in research is directly proportional to quality of argumentation. There are two forms of assessing the rationality of a discussion: material rationality or procedural rationality. Material rationality is a measure of the acceptability of the contributions to the argument; this is of course specific to the topic, and thus inaccessible to general methods of evaluation. Procedural rationality, how the dialog is conducted, is accessible on a general level, as rules for the dialog can be expressed. Pröpper has devised such a set[61] (see Table III, below).

Table III A Model Procedure for Discussion

1. A committed attitude

1.1 One is committed to the objective of the discussion.
1.2 One is committed to the things one has said and implied therewith
1.3 One is committed to the arguments being solid

2. Accountability

2.1 Every participant in a discussion supports his or her statements with the help of arguments, when other participants (may be expected to) demand this, unless he or she gives plausible reasons justifying a refusal.

Table III (continued)

2.2 When one doubts the arguments relating to the point of view of another participant in the discussion, one may only challenge these if one gives counterarguments.

3. Consistency

The participants in a discussion act and speak in a consistent way.

3.1 The participants in a discussion are not allowed to contradict themselves.
3.2 The participants in a discussion are consequent.

4. Relevancy

4.1 The arguments one gives, and the information accompanying them, must be relevant.
4.2 When making a statement that (apparently) does not refer to the statements and arguments which are the subject of the discussion, one has to state one's reasons for making this statement, if other participants (may be likely to) expect this.

5. Objectivity

The participants in a discussion adopt an objective attitude.

5.1 One is not allowed to prevaricate.
5.2 One is not allowed to ascribe to another person points of view that one does not support.
5. 3 The points of view held must not be tendentious due to ambiguity.
5.4 The participants in a discussion are not allowed to present their own contribution(s) to the discussion tendentiously, by means of incorrect or incomplete information.
5.5 One should not become personal.

6. Openness

The participants in a discussion must see to it that the discussion is open to others and to their contributions.

6.1 It must be possible for everyone (to the same extent) to take part in the discussion.
6.2 The participants in a discussion are allowed to raise any point of view and advance any information they consider relevant for the defense or challenge of a certain point of view.
6.3 One is allowed to challenge any statement brought by another participant to the discussion to justify or refute the expression of an opinion.
6.4 The participants in a discussion are to provide as much information as necessary (for the aim of the discussion at that moment).

— **Pröpper (1993, 82)**

In the RW there are two major tools that express argumentation: The Landscape of Reason, and DocReview. All contributions to a discussion in the Landscape of Reason are likely to be valid elements of argument. In DocReview, many annotations may not contribute to the content of the argument, but to the form of the document. DocReview annotations need to be screened to remove the contributions that do not contribute to the content of the argument. Once the contributions have been weeded, they can be analyzed or coded. After coding, several evaluative measures can be extracted using methods developed by Pröpper[62].

The purpose of evaluation is to determine the effectiveness of an enterprise. The effectiveness is a combination of many factors, principally the quality of the team members, the quality of the tools, and the quality of the assembled body of evidence. While the expense of performing such evaluation may be far beyond the resources available, it may very well be useful in some cases. Comparisons in the effectiveness of different tools may be of interest. Given a large body of participation, the effectiveness of individual members or teams could be measured. In a very large scale RW, such a study may benefit both the conduct of the research, but also contribute to research about the RW concept.

3.3 Models as an Organizing Principle for Navigation

The organization of the team's working area must be driven by the nature of the issue domain as represented by the organizing framework, a model. To organize the working section by any other method is a grave error. In a distributed RW, to organize the working area by location is to invite provincialism and competition. To organize by disciplines in a multidisciplinary team is bound to fragment the team and stultify any attempt at interdisciplinary research. Organizing by individual or authoring team is likely to encourage elitism and competition rather than teamwork.

The organizing principle of the Research Web's web site is a model that provides a framework for the pieces of the research effort. This model, the most abstract of the models, is the top level of a hierarchy of submodels. Every object in the issue domain will have to be securely placed within one of the submodels of the model of the organizing principle. The organizing model is a device that allows the user to navigate content on the basis of hierarchy of level of abstraction. This content-driven organization may be supplemented by any number of indices organized on other bases, even alphabetical.

A good organizing model uses a dominant metaphor of the issue domain. For instance, the process of plate tectonics is made abundantly clear by using maps showing the location of spreading centers, transform faults, triple points, hot spots and subduction zones. Sections across a plate relate the cycle of crust generation, plate collision, plate motion and consumption. Migration can be described with behavioral diagrams showing how an individual or family makes a decision to move and then resettles. A lifecycle timeline can be used to show the times of life when migration is more or less likely.

The conveners of the Research Web must have a conception of both the character and scope of the issue domain from the beginning. The character of the issue domain is the target of the research. The character of the issue domain is described in a model, the descriptive model; and the theory behind the behavior of the issue domain is described in an explanatory model. After the work begins, the issue domain must continue to be described and circumscribed. Defining the scope of the issue domain and its relationship to other domains is an essential and ongoing activity.

There is a definite granularity of the models used in the RW. The organizing model is very coarse, with each element being very general. The descriptive models of the issue domain are fine grained, incorporating many attributes of each object, some of which may seem inconsequential out of the context that identified them. As the modeling of the issue domain progresses, its granularity will grow finer as attributes and subprocesses are added; and will also grow coarser with the creation of supertypes that are the embedding context of previously defined types of objects. Eventually the hierarchy of models will connect the organizational model with the finest element of the described objects and processes.

The modeling hierarchy has both breadth and depth. Depth increases the detail of the objects into finer and more specialized components. A Research Web can grow in breadth, or scope, first by incorporation of topics that lie in the fuzzy boundary circumscribing the issue domain, or by making the organizational principle a submodel of a larger type of object, a great expansion of the issue domain. Breadth increases the diversity of a type of objects, for instance adding a new species to an existing genera, or adding a new land classification boundary to the existing ways of dividing the earth. Projects undertaken within a Research Web generally illuminate only a small part of a submodel of the organizing model. The knowledge created or gathered in the research process is incorporated into the modeling hierarchy as it is found. It may be that the research illuminates a section of the hierarchy that is not well defined, and will not be well-connected to the model. Finding the connections to the model will be a theory-building exercise. Poole cites the problem of unconnected theories in group communication theory[63].

> *Each of these [series of studies] has produced a "minitheory" of the phenomenon under study, and some of these are ingenious and useful. However, for the most part, these efforts do not attempt to tie into a larger theory and therefor remain isolated findings.* — Marshall Scott Poole[64]

In the descriptive model, the objects of the issue domain are described and related. The relationships in the descriptive model are process models created from observation and past research. Tacit knowledge is made explicit and myths and conjecture may also be included in the descriptive model, as part of personal, cultural or disciplinary knowledge (which is not necessarily true).

Explanatory models are attempts to uncover the causes of the observed behavior and form of the objects. Theory is created in the explanatory model. Explanatory models are likely to follow the form of the descriptive model. Processes are explained, and then elaborated by showing how behavior is affected by the state of the system. In attempting to discover and demonstrate cause, the explanatory model may extend into domains not described in the descriptive model. In the building of an explanatory model, theory may uncover new organizing principles that must be incorporated into an expanded descriptive model.

The simulation model is derived from both the descriptive and explanatory models. The theoretical processes that drive the behavioral model of the system must come from the explanatory model. The simulation model's objects are defined by the object's nature as specified in the descriptive model. The simulation model has several potential uses within the RW. It is a powerful means of validating work in the methodological domain. Behavioral experiments may be designed with the simulation model. In a well-developed simulation model the boundaries of the issue domain may be explored through sensitivity analysis.

3.3.1 The Descriptive model

The Descriptive Model (DM) is the model around which the substantive domain of the research is developed. This is where the team will define all the real objects it discovers in the issue domain. There are three main types of models within the DM: object models, process models, and relationship models. The object models define the attributes of each object. The process models define how the objects behave. The relationship models describe how the objects are associated with each other and with the processes.

The DM also may contain data on the objects and processes. While the models describe the characteristics of a class of objects, the data contains information about actual instances of the class. This data becomes the basis for establishing the verisimilitude of the explanatory model with reality. The DM will contain the data in datasets, and each dataset will have elaborate metadata connected to it. The metadata is the quality control for the dataset; if one is to trust the data, one must do so on the basis of the metadata. Metadata therefore is carried in a document or set of documents that are annotatable. If a member of the research team detects a deficiency in the metadata, it is noted and efforts may be made to bolster the quality of the metadata by further research. Sadly, most scientific data is not made public, but even worse, and more often, no metadata such as protocols are attached to the data.

The bulk of the remainder of the DM is a collection of documents comprising what Harré calls a sentential model[65]. The sentential model is a collection of sentences, or facts (subject to discussion), that are documented in RW essays, e-mail, annotations, on-line text, etc. The sentential model is the basis for argumentation about the DM and the elements of the model refer to them for provenance.

3.3.2 The Explanatory Model

The purpose of the Explanatory Model (EM) is to explain actions within the issue domain. For every process model in the Descriptive Model (DM) there should be a corresponding process model in the EM. The EM shows how a hypothetical generative mechanism accounts for the behavior shown in the DM. The EM will include many elements of theory from the literature of the discipline. In the light of the DM and derived EM, the existing scholarly literature may come under criticism, or may be reinforced.

While an EM's process model is based on the corresponding DM process model, the EM process model will be much more complex. In the DM, it is observed that two nodes are connected by a link; it is the job of the EM to explain how the link works. In practice, it may be that there is more than one mechanism associated with a link. For instance, in the DM for family migration behavior, there might be a link between two nodes called "Active Information Gathering" and "Decision Making." The corresponding link in the EM describes *why* a family unit that is actively gathering information with respect to relocation will convene a meeting to discuss their migration. There may be many reasons for this change in behavior: one member of the family may have found a critical piece of information that might cause migration to go forward, or to decide not to migrate; some external event such as a legal status change might force a decision. The EM will have to become a directed multigraph; it will have multiple links between the nodes, each representing a different mechanism.

The EM's object models will be identical to the object models in the DM, though the research into mechanisms will likely make some additions to the characteristics of the object necessary. An example of a characteristic that may be added to an object "Dependent Child" in the migration model is student status. If a child is going to graduate from high school, the child might leave the family to go to a University or to take a job. The theory-building that takes place in the construction of an EM may create the need for a new, likely abstract, object that must defined in a new object model.

The hypertextual nature of the models will clearly aid the reader by having an explanatory document available by clicking each link and node. The merits of the explanation can be argued through a DocReview until it is well described. The theory represented by the EM needs to be associated with explanatory documents, with inference links, in order to justify propositions with a foundation of qualitative statements[66]. Harré refers to this set of qualitative statements as a sentential model[67].

One of the principal functions of the EM is to provide the basis for hypothesis formation. The hypothesis statement can hypertextually refer to any link or node explanatory document. When an experiment is designed to investigate the hypothesis it too can refer to the explanatory documents, object models, process models and link and node explanatory documents. In addition to those references, each term in the experimental protocol can be discussed in a document that argues the operationalization of the term. Such references constitute an auxiliary model[68].

The EM will be modeled in general system terms. Since the issue domain does not, and cannot, include all of reality, the EM of the issue domain will necessarily be an open system model[69]. The establishment of the boundaries of the issue domain was discussed above (see §3.1.1). If the modelers identify and describe the interfaces with the world external to the issue domain, the *embedding system* to Brinberg and McGrath[70], then the EM will be extensible in future research. We should keep in mind that the principal functions of the EM are to express theory and provide the basis for a simulation model. Theory need not be expressed mathematically, and indeed should not be if the mathematics purporting to describe the operation of the issue domain should constrict or misdirect thinking about the issue domain[71].

3.3.3 The Simulation Model

A simulation model (SM) has five major components:

- an environment

  The initial condition of the system a specified by the modeler, a collection of objects that populate the system, with their attributes assigned. The environment's creation is a major effort.

- a script

  A temporal series of external events that cause changes in the system by triggering actions affecting the objects in the system. The system is also perturbed by internal events caused by the behavior of the objects. The script normally asks for periodic reports of the state of specified objects in the system, this data may drive animations or be encapsulated in graphs.

- an algorithm

Effectively the explanatory model expressed as a computer program.

- a timekeeper

A clock that causes events from the scripts to be presented to the algorithm.

- a reporting mechanism

A program that accepts reporting requests from the script, or from the algorithm, to examine the current state of a set of system objects of interest, or state of a process.

The simulation model (SM) has several potential uses within the RW. It is a powerful means of validating work in the methodological domain. Behavioral experiments may be designed with the simulation model. In a well-developed SM the boundaries of the issue domain may be explored through sensitivity analysis.

3.3.3.1 Validation in the Simulation Model

The proposed simulation model is a disaggregated, discrete event model that may be run with an infinite number of scenarios, each a different combination of environment and script. There will be stochastic variables in the model in order to express uncertainty, and perhaps alternative processes that depend on the situation or state of the model at any time. Running the model many, perhaps thousands of times, using the same scenario will demonstrate robustness if the outcomes remain consistent.

The behavior of the model is profoundly affected by the processes defined in the explanatory model. These processes (algorithms) may be altered in order to establish the sensitivity of outcomes to variations in the processes. These variations represent new hypotheses and may suggest changes to the explanatory model. There may be hundreds of variables in a mature simulation model. Each variable may be examined to see its effect on the simulation. When the effects begin to depart from expected behavior, a limit of applicability of that variable is reached. Understanding the limits of the model allow the team to examine the more carefully in order to revise the explanatory model to increase the robustness of the simulation model.

3.3.3.2 Hypothesis Investigation in the Simulation Model

Hypotheses generated to extend the explanatory model must be examined by experiment in order to prove their validity. The hypothesis may be examined in the simulation model prior to design of the experiment. If the hypothesis is shown to produce expected or reasonable behavior, then the very expensive experiment may proceed with confidence.

3.4 The Essays

The Research Web Essays are the working documents that bear directly on the research effort. Most of the facilities in the RW are dedicated to the support of the production of the essays. They include essays that are organizing documents that link the site's research efforts together, giving an abstract overview of the research topic. The hierarchical nature of the RW demands a cognitive chunking of knowledge. Essays high in abstraction serve as expositions of the character of the topic, any emergent qualities the topic has, and as introductions to more detailed essays on the component objects of the topic of the essay. Essays that discuss the detailed research findings are the nascent research papers of the team. After publication of the research papers, the essays may remain on the site and be further refined as research continues. These essays form the canon of the team.

The RW has tools for annotation and criticism available to both the writer and reader of the essays. The HyperDocument format allows the author to introduce marginal information with popup hypertext windows. The author may use notes, sidebars, definitions and glosses, and literature citations. The RW has several methods of commentary and annotation available to the reader: of the text and notes with DocReview, of the vocabulary with the Annotated HyperGlossary, and of the citations either through DocReview or the Annotated HyperBibliography.

3.4.1 Essays as a Communication Genre

The first duty of an essay is to communicate knowledge. RW essays are presented in a communication genre called the HyperDocument. The effectivity of the essay in communicating the knowledge itself is dependent on the writing skills of the author. The HyperDocument format contributes to the effectivity by allowing collaborators other than the author to contribute to the effectivity of the document by annotation using DocReview. Efficient communication, on the other hand, depends on the visual presentation of the knowledge. The essays may be viewed in two media: the screen and in printed hardcopy versions. Viewed on the screen, the HyperDocument format provides formal hypertextual augmentations, which vastly improve the efficiency of the presentation. Since hardcopy format is frequently utilized as a communication medium, despite its loss of hypertextuality, it is critical that the hardcopy presentation of the essay is no less efficient than familiar paper-based scholarly documents. The printed hyperdocuments have appended glossary terms and bibliographic references.

What qualifies the RW essay as a communication genre? In recent years the communications genre has come to mean a typified social action[72]. The social action that the essay satisfies is that of communication of scientific knowledge. The existing genre is the scientific research paper. A design goal for the RW essay as printed in hardcopy is to conform to the scientific research paper genre. The appearance of the essay as viewed on the computer screen is nearly identical to the hardcopy version. Any scholar will be quite familiar with the format of the essay. A communication genre must be a stable well-defined but flexible formalism[73]. The HyperDocument format structural definition is presented below.

Hypertext and interactivity make the behavior of the essay a truly different genre. On the computer screen the user sees two colors of hypertext links: standard blue links are navigational links that allow the reader to jump to different parts of the same document; and gray links call up new "popup" windows with bibliographic information, definitions, footnotes, or "sidebars" which are related web pages, often other RW essays. The essay may be annotated by clicking a gray link, "Annotations in DocReview" at the top of the essay. Citations and footnotes have always had the clear meaning, "Go elsewhere for more information." The HyperDocument format makes the task of obtaining the information a simple mouse click. The HyperDocument qualifies as a communication genre because it is also a genre that takes advantage of the WWW as a "remedial medium"[74] that overcomes some of the limitations of a pre-existing medium.

3.4.2 Essays as Work Objects

Essays are the textual representation of knowledge in the RW. As objects in the issue domain are discovered, they are abstracted, analyzed, and expressed as topics of essays. These topics are contained in a hierarchy of abstraction familiar to all, in texts, as a table of contents. Perhaps an even more accurate metaphor would be a classification of knowledge as in library cataloging. Scholars in any specialty are adept at creating such hierarchies. The work of the RW goes forward in large part by identifying essay topics, writing the essays, refining them through criticism, and finally making them into canonical documents. Essays will also form the basis of professional papers and reports. The essay as work object is a target for the tasks of writing, criticizing, and editing.

Each essay must become a conscription device[75] that attracts a following of authors and critics among the team members. Once the essay becomes a conscription device, it then becomes a unit of work that can be scheduled and managed. The essay will have a place and function within the RW. If an identified essay topic does not attract participation, then there is reason to question the importance of the topic of the essay. Alternatively, it is possible that the topic is not of interest to, or within the realm of expertise of, the existing team. In that case, the research team needs to be enlarged to include an expert on the topic.

3.4.3 Essays as Canonical Documents

The destiny of the RW essay is to become a canonical document for the given topic. As canon, it must incorporate the extant knowledge from the scientific community and to that add the new shared knowledge that the research team creates in its collaboration. A document does not become canonical overnight. There is a progression from rough drafts to a professional essay, then on through a successive refinement process that depends on DocReview (see §4.3), the critical apparatus, to collect criticism from collaborators. Each refinement carries the added knowledge from criticism of the previous draft. Commentary from DocReview can be incorporated as new text, as new footnotes or sidebars, as glosses for the HyperGlossary or notes in the HyperBibliography, or may be discarded or folded into existing footnotes.

The RW essays are the principal scientific documents generated by the RW. They form the basis for scientific papers, the repository of knowledge, and through attached annotation, the consensus and argumentation surrounding the topic. At any given time the essays hold the latest and presumably best scholarly thinking about the topic. In other words the essays form the *canon* of the RW team.

These canonical documents are in the opinion of some the only documents worthy of annotation[76]. The annotator has been designated by the community to perform the annotation. Annotations of these documents are original scholarship in that they expand, point out shortcomings, provide support, and most of all provide a meeting place for the scholarly community. The very pedantic points of scholarship vis-à-vis annotation such as those made by the authors writing in *Annotation and Its Texts*[77] are important guides but are perhaps a bit too restrictive for an environment as flexible and dynamic as the RW essay. The path of scholarly endeavor between a good second draft and a canonical document is a long and difficult road! As the quality of the document rises, so must the quality of the commentary. While we aspire to produce canon, scientific philosophy demands that our work be shrouded in skepticism and contingency.

3.4.4 The Integrated Structure of Essays

The Research Web Essay embodies the new knowledge created by the research team. The design of this document type was directed toward the creation of a strong boundary object[78] and conscription device[79]. To create a boundary object requires that the essay fill these needs: flexibility for the entire team, strength for specialists, and a well-defined media genre. To become a conscription device, the essay must attract participation and facilitate participation through ease of use.

Flexibility is assured by the hypermedia format of the WWW. The essay can incorporate any document that is compatible with the WWW. Specialists can present their interpretations in their own language within sidebars or footnotes. The HyperDocument format of the essay is defined below. Participation is encouraged by not only the intellectual content of the essay, but in the ready access to the intellectual provenance of the material through links, sidebars, notes and citations. Aside from the content, the principal attraction to the essay is in the ability to annotate by using the built-in DocReview of the essay. Ease of use is assured by the single click navigation characteristic of WWW applications.

Research Web Essays have three major functions to perform: they must function as: a *Communication Genre*, a *Work Object*, and a *Canonical Document*. In order to fulfill all the functions, there must be a number of features that perform each requirement without interfering with other functional requirements. Functions of a Communication Genre are fulfilled by having a formalized structure familiar to all members of the team. Each essay is a WWW page, HTML augmented by JavaScript. Functions of a Work Object are fulfilled by designing the WWW page to receive additional information in the form of insertions or commentary. DocReview provides the ability to insert text or commentary at points designated by the author. The functions of a canonical document are to provide a specialized document that provides the highest quality of information on the topic. The quality of the content is initially the responsibility of the author, but after initial release the entire team shares responsibility. Canonical quality will demand documentation of sources (HyperBibliography citations), expansion of some points (notes and footnotes), references to closely related topics (sidebars), and explanation of terms used in the text (Annotated HyperGlossary). Since canonical documents accrue greater stature through annotation. DocReview serves as a means to incorporate criticism

3.4.4.1 The HyperDocument Format

The format of the scientific research paper is by no means standard. It has varied through time and varies today by discipline and journal. The common features have been: a reference section and citations to that section; footnotes for amplification of statements. or for citations; cross-references to other parts of the text. especially in dictionaries and encyclopedias; and definitions of terms. usually referring to a footnote or glossary of terms. The printed hardcopy of the RW essay has citations. numbered footnotes. marked words indicating a glossary entry. and underlined cross-references. At the end of the essay are Appendices for References. Notes. and a Glossary of terms. So. in static terms. the RW essay is a familiar genre. Its dynamic behavior on the computer screen is vastly different.

The electronic representation of the essays may include graphics and even sound as well as text. Hypertext links to other parts of the same essay may be used to make reading more efficient. It may be advantageous to provide a graphic image that has "hotspots" which are hypertext links. Links to return the viewer to the start of the essay are often included (top of page). If the essay has footnotes or a reference list. then there are "reverse links" which allow the user to jump to the point in the text where the reference is cited. or to the source of the footnote. Cross-references to related RW essays or offsite web pages may be "popped up" in new windows (sidebars). Literature citations can be clicked to obtain annotatable bibliographic information and abstracts (Annotated HyperBibliography). Definitions and glosses of terms can be popped up in new windows (Annotated HyperGlossary). See Figure IV below for the HyperDocument definition.

- Header
- Title (mandatory) -- Necessary for citation by others.
- Author byline (if attribution is unclear)
- Link to Instructions on reading (optional) -- Those unfamiliar with the genre need some help.
- Link to the DocReview of the essay (mandatory) -- Open annotation is a central principle of the Research Web. DocReview is the critical apparatus for the research team.
- Links to Appendices (optional) -- People often wish to scan the references before reading the body of the document.
- Navigation Links (optional) -- Next page in sequence, previous page, table of contents, etc.
- Body
- Table of Contents (optional for short essays) -- Very useful for navigation and summarizing.
- Text (mandatory)
- Sidebars (if appropriate) -- Popup windows for extensive cross-reference. May be other essays or external web pages.
- Footnotes (if appropriate) -- Small popup windows with conventional footnote functionality augmented with the multimedia functionality of the WWW.
- Sticky Notes (if appropriate) -- Small popup windows for ephemeral notes or graphics, generally for collaborative or coordination purposes. They do not appear in the hardcopy version.
- Citations (if appropriate) -- Small popup windows with conventional bibliographic citations with further links to abstracts and full text if available. The bibliographic entry may be annotated. Full bibliographic information is provided in the References section of the Appendices.
- Glossary references (if appropriate) -- Small popup windows with definitions and glosses of terms. The glossary entries may be annotated. A glossary of terms appears in the Appendices listing the definitions of all terms referenced.
- Top of page links (optional for short essays) -- Useful for navigation, provides the reader with a path back to the Table of Contents.
- Footer
    - Information about essay, perhaps including acknowledgements
    - Title (mandatory)
    - URL (mandatory)
    - Date written (mandatory)
    - Last revised (mandatory)
    - E-mail contact address (mandatory) -- This contact is for technical help, reporting of broken hypertext links, etc.
- References section (if citations are present) -- All works cited are listed in this section with hypertext links back to the text every place they are cited.
- Glossary of Terms (if glossary is referenced) -- All terms referenced from the glossary are listed.
- Endnotes (if footnotes are present) -- Endnotes are a listing of the footnotes with hypertext links back to their origin in the text. Essential for the hardcopy version.

Figure IV The HyperDocument Format

The HyperDocuments utilize only well established capabilities of the WWW. In order to reach participants who may not have the latest features in their web browsers. only capabilities that have been available for well over a year are utilized.

3.4.4.2 High Performance Scholarship

Douglas Engelbart has been designing and developing hypertextual documentation systems for decades[80]. His work by far predated the Internet and was restrained by the technology of the time. His most successful systems were deployed in the defense industry and were implemented for private networks. Englebart has established the Bootstrap Alliance to develop the concept of the HyperDocument within a much larger system of collaboration that. when used in the scholarly environment. he calls *High Performance Scholarship.*

Engelbart's Open Hyperdocument System[81] incorporates many of the features of the work described in this dissertation. but is "big-time computing" designed for a much wider (perhaps universal) application and is a work in progress. The Research Web is very tightly targeted on research and is consequently a much smaller system. As currently publicly envisioned. criticism is not integral to the Open Hyperdocument System.

3.5 Web Site Architecture

The RW web site is the information system for the research team's work: its data repositories. organizing models. social interchange. and research products. The web site is hypertextual and can thus present information and conclusions in a way that cannot be done in conventional literature. All pages in the web site are in WWW pages. thus are accessible to the team members through their web browsers. Since the WWW is a distributed network. the web site may be physically distributed among several servers. Such distribution may be the result of donated resources. software availability. performance. or need for server access. The fact that the site is physically distributed will have no effect on the users.

3.5.1 Functional Partitions

The RW web site may be divided into four logical partitions: an optional public presentation partition, an optional guest partition, the facilitator's work area, and a private team working area – a work-in-progress site[82]. Each of these partitions has its purpose and corresponding access restrictions. The public partition corresponds to a standard *Internet* site; the private team working area to an *intranet*; and the guest partition to an *extranet*. There is a rich literature to consult in each of these areas.

If the team has a need to inform the public, the sponsor, or their institutions about the research, then they should open a public partition. Its function is to inform the public about the work the team is doing, to advertise the support of the sponsors, and to recruit new members to the collaboration. While the conveners of the RW will have made an effort to attract scholars known to them, there may be isolated scholars, or scholars in allied disciplines who may wish to contribute[83]. Hypertext links to public resources can be provided to give the users more information about the general research area or about the sponsors.

The guest partition is set aside to allow temporary access to interactive materials such as DocReviews. An interdisciplinary team will, on occasion, want to call on colleagues from the larger research communities for advice or for review of materials. This partition might also be used for semi-public participation in design of questionnaires or software tools, or for participation in experiments. The guest partition must be password protected, and should not be indexed for the search engines, as drafts need protection from unauthorized quotation and poaching. The password should be changed after each period of use. The guest partition has no links to other partitions, but the private working area may link to the documents in the guest partition.

The facilitator's partition is necessary to provide a place for the facilitator to design, develop and test software, particularly the programming that enables the team's interactivity. The facilitator may need permission to enter several of a web site's servers if the web site is distributed. This work site is also used to prepare the documents developed by the team for interactive use. Content contributed by the team members is usually not directly usable on the WWW. Typically, this material is formatted for a word processor. It will need to have hypertext links added, and it will be reformatted to take advantage of the many annotation methods available to the RW essays. Graphics may need to be edited and perhaps converted to a format compatible with the WWW. All this work needs to be tested in a protected area before it is installed on the web site. There is little reason for other team members to have access to the facilitator's partition, so it should be protected simply to prevent inadvertent damage.

The private working area is the center of Research Web activity. All communications are archived here. All research references are accessed here. Documents are displayed. Models are built and presented. Questions are addressed to the team. Definitions are offered and debated. Under the assumption of privacy, team members frequently make tentative statements that cannot be public. The private working partition contains the intellectual property of the entire research team, and may contain commercially valuable content as well. Works in progress must be protected for priority claims and poaching.

3.5.2 The Team's Private Working Area

The Research Web's scholarly activity will take place in the team's private working area. This partition, an intranet, is designed to serve the needs of the team for their roles as collaborators, contributors, critics, and coordinators. As much work as possible is to be offloaded to the facilitator so the researchers can concentrate on the intellectual content. The team members may contribute documents through the facilitator, and may directly contribute annotation to documents through DocReviews of those documents.

Collaborators may also contribute references for the annotated HyperBibliography through the facilitator. Annotations to the references may be directly contributed through the Annotated HyperBibliography. Definitions of terms may be contributed for the Annotated HyperGlossary through the facilitator. Annotations on the definitions may be contributed directly through the Annotated HyperGlossary.

Since the RW is highly interactive, it is vulnerable to the graffiti and abuse of vandals. While, in general, scholars behave ethically and are far too busy to poach on the team's research, such activity is not unknown. A team password will be assigned and changed from time to time or whenever unwanted participation is detected.

3.5.2.1 Home Page and Internal Links

The Home Page is the principal entry point into the private working area. From that page the user should be presented with several links: to the infrastructural pages; to the public and guest partitions, if present; to a list of indices; to a site search engine; to the models, if present; and to the research web's intellectual content. In order to provide meaningful content in addition to navigational links, the home page is a good place for a mission statement. Proficient users will soon develop their own bookmarks to navigate directly to those portions of the web site they use most often. Nevertheless, the home page is a necessary part of the architecture, a root of the hierarchy of pages, the default connection from the outside world.

3.5.2.2 Infrastructural Pages

Infrastructural pages are web pages that are designed to introduce the team members to each other, to provide information about team activity, and to provide links to services designed to facilitate individual and group work. In a large RW web site, there may be a need to have an index page for these pages; but in the beginning these links may be made directly from the home page.

3.5.2.2.1 Introductory Material

The current sponsors of the research should be identified on a "Sponsor's Page" as a matter of courtesy. This page will also inform the team members who have supported the RW in the past as well as the present. Work that has been developed or contributed without support should be featured as well, just to identify the altruism of those members.

The team members always have a need to know about their colleagues: background, publications, and positions[84]. Members will likely have personal home pages that can be referenced from a "Team Members" page; if not, the facilitator will be able to help them develop one. The personal home page needs, at a minimum, the member's CV. Much of this material may be directly employed in research grant proposals, so it should be kept current.

Of critical importance is a position paper that describes each member's relationship with the RW's issue domain. Questions that need to be addressed are the expertise that the member brings to the team, the research questions that the member is particularly interested in, and the opinions that the member currently holds in regard to the issue domain. A discussion of research interests could include a number of suggested essays that the team could build. These suggestions will help the team develop an overall research plan. Suggesting an essay is the first step in authoring team formation and turf marking. Opinions and conjectures are important, as they are the basis for hypothesis formation. They will of course be heavily qualified by the member and should be read with great latitude by the others.

These position papers will be DocReviewed and will then serve as a basis for initial team interactivity. Questions may be asked and knowledge and opinions offered. Certainly, the position papers may be archived and reissued as new editions when the member's positions are refined.

Current associates such as research assistants, postdoctoral fellows, and staff members should be introduced with biosketches and personal home page references. Close interdisciplinary associates that may have contributed to the research products may be mentioned here as well. Past associates may be remembered for their service in a "Personae Emeriti" page.

3.5.2.2.2 Services

What's New (see §4.7) is a tool that allows the team member to survey the activity on the web site since a given date. What's New provides a listing of new documents, RW essays, annotations made by members through DocReview, the Annotated HyperGlossary, and the Annotated HyperBibliography. The listing is in HTML so the page can be searched in the browser for name of contributor or keyword.

Calendar software may be placed on the site in order to coordinate any synchronous events that the team may take part in. Periodic all-team meetings may be part of the management plan. Authoring teams may gather synchronously in person, or on the WWW, in order to discuss issues that cannot be resolved well online. Conferences that may interest individual team members may be listed on the calendar. Deadlines for work objects or critical reviews may be entered in the calendar.

MailRoom (see §4.1.2) is a tool designed to capture e-mail that should be shared with the team. Typically, the sender types in the e-mail addresses of the recipients and sends the e-mail on its way. Such mail is usually not archived at the RW web site unless the sender includes the e-mail address of the site's archive. MailRoom is a web-based tool available to the user at a click. The user can select any member of the team, or any group of addresses that the facilitator has created for MailRoom. The message may be automatically copied to the sender, and will automatically be sent to the RW site's e-mail archive. While MailRoom may seem to be unnecessary, experience shows that a great deal of mail traffic is lost when the sender fails to include the site archive as an addressee.

The *FAQ* (Frequently Asked Questions) is, just as the name implies, a list of questions that users have often asked. Many of these questions are generic technical questions regarding the use of tools, the installation of software, or navigation of a RW web site. Other questions may be specific to the issue domain. An FAQ will often serve as supplemental introductory information to the team members, especially at the beginning of operation.

3.5.2.2.3 Minutes, Reports and Plans

Even in a RW experienced in working asynchronously, there will be a constant background flux of synchronous activity: face-to-face meetings, telephone calls, electronic chat sessions or teleconferences. This activity will be lost to the team unless the dialog is captured. Face-to-face meetings must be summarized in a good set of minutes. One very successful application of DocReview has been the review of minutes. After review and editing, the minutes can be stored and indexed as a web page. Important telephone calls that bear upon the research effort should be captured in a telecon record that is stored and indexed. Electronic chat sessions can use tools that produce a transcript, provided that the input is keyboarded. That transcript may be abridged and edited to produce an excellent record. If the chat session is audible, then it should be treated as a face-to-face meeting. Teleconferencing should be treated as a face-to-face meeting.

From time to time team leaders or authoring groups may wish to issue progress reports. Quarterly or annual reports are often requested by granting agencies. These reports should be indexed and mounted on the web site. Publicly circulated reports from other research groups may be mirrored, with permission, or referenced on the web site.

Some tasks may be so complex that they require a plan. The leadership of the RW should maintain a plan for guiding the efforts of the RW. This plan will establish the scope of the issue domain, enumerate research topics, and suggest funding proposals. If a research team follows a methodology similar to VNS (see §2.3), then a research plan is a required document. The entire team should review the research plan in order to capitalize on the experience of others. Experimental protocols can benefit from publication, as they can be reviewed by team members in DocReview, and can serve as templates for other protocols.

3.5.2.2.4 Discussion Groups and Discussion Archives

There are two major discussion tools currently in service: the e-mail listserver and the electronic discussion forum. The listserver is considered a necessary feature in any RW. The listserver is a general-purpose group electronic mailing list that allows the team to engage in a dialog on a one-to- many level. The listserver is an informal tool that works admirably for proposing informal discussions, carrying out those discussions and, importantly, for asking questions of the "Does anyone know about ... ?" variety. Since there may be a sizable flux of information transfer by this means. it is important to archive the messages and to store them in a searchable archive that is accessible from the WWW.

The electronic discussion forum (see §4.2.5) is a popular tool in some web-based communities. Most of these tools have built-in archiving facilities that produce searchable, web-based documents. Should the team choose to use this tool. they should be aware that they seldom are successful because the RW team usually does not have the size to raise a critical mass for this type of tool. The tree-structured format of these forums may not be intuitive to some users.

3.5.2.3 Searching

The web site should have the capability of searching every HTML document. Since archived documents are in HTML. the search engine will find e-mail and DocReview comments. The search engine will identify the documents containing the keyword(s). Then the user can go to the document at a click. and go directly to any word or phrase by using the browser's "Edit. Find in Page" feature.

3.5.2.4 Scholarly Content

The scholarly content of the RW site is contained in models. essays. reports. bibliographies and glossaries. There will be pages designed to introduce the content and pages designed to help the user navigate among the pages. While each RW site will be unique. there are several common characteristics. The first of these is the presence of an organizing model.

The organizing model is a diagram whose purpose is to provide a unifying synoptic view of the entire issue domain. The diagram may be a map. a hierarchical network. a process diagram, a timeline, or any other visual representation of the issue domain. It is important to represent all major topics in the issue domain, even if much of the issue domain is unrepresented by intellectual content, as it will be at the beginning. The organizing diagram's function is to provide a logical organization of the potential topics that may be investigated over the life of the RW. The diagram is usually prepared as a clickable "image map" that allows the user to link to a submodel of every entity in the diagram.

Another common characteristic of every RW site is the Annotated HyperBibliography (AHB)(see §4.4). There is no research that exists without an intellectual foundation contained in the literature of the issue domain. The literature of the issue domain will cross-disciplinary boundaries and will be far more extensive than the literature supporting a single research effort designed to produce a research report for publication. Team supplied annotations to the references will add value to the references. The AHB will support all the RW essays and research reports produced within the Research Web.

Each issue domain has its own vocabulary: very specific meanings applied to widely used words. These special meanings are called glosses, and reside in the Annotated HyperGlossary (AHG)(see §4.5). The AHG may contain several definitions of important terms. Each of these terms has its own entry and may be specifically referenced from any document in the RW.

3.5.2.4.1 Models

At the intellectual heart of the RW lie the models of the issue domain. These models collectively describe, explain, and demonstrate the theory behind the issue domain that has been synthesized by the research team. The scholarly content only exists to describe the objects and processes of the issue domain or to explain its operation. The models are likely to be presented in graphic format in order to show order in a temporal sense or spatial adjacency. The elements of these graphic presentations may serve as index pointers to subsections of the model, or to textual explanations. In the WWW environment these links are all "clickable." It is likely that, within the RW, the ultimate element of the graphic model is fully described in a RW essay. All models are hierarchical, so a top-level model contains elements that may be further decomposed to any level of specificity necessary. Every element in the models will eventually be described in a Research Web Essay. In practice there is a lower limit of size that an essay might be, so there will be more than one level of the modeling hierarchy described in most essays.

There are, in the mature RW, four models that need to be built and represented on the WWW: the descriptive, the explanatory, the simulation and the auxiliary models. Every element of each of these models must be presented in a DocReview or PicReview in order for the team to review their work. If criticism uncovers a need for redesign rather than a simple correction, then a team member skilled in model design should analyze the changes and present a proposal for editing every model affected.

If a decision is made to develop simulation models, the informal models must be supplemented with formal models. The formal models may use a well-developed modeling technique, such as Unified Modeling Language (UML)[85], or a combination of techniques. Before the team embarks on construction of formal models the magnitude of the effort must be recognized, and resources will need to be obtained. Simulation modeling and the formal modeling that precedes it will require technical assistance for model design and for the programming of the simulation model itself. It is likely that the facilitator may be able to perform some of the modeling work.

The design of a simulation model will generate a considerable amount of documentation. most of which represents a design proposal that the team needs to review. Much of the design work is based in operationalization of the variable used in the model. This operationalization forms a parallel model called the auxiliary model[86]. The auxiliary model supports experiment design and simulation modeling.

3.5.2.4.2 Research Web Essays

RW Essays (see §3.4) are essays about objects and processes in the issue domain: they are presented as highly augmented HTML pages with hypertextual annotation that includes bibliographic references. definitions of terms. reader commentary. marginal notes. images. and cross-references. The essays serve several purposes: as working documents of the authoring team: as the basis for publications: as the descriptions of models of objects and processes in the issue domain: and finally as "living documents" that allow a continuing incremental refinement of an essay. All RW essays are annotatable through DocReview: so. through scholarly criticism and occasional editing. the essays may remain the active contemporary authority on a topic.

The RW Essay presents a narrative about part of the issue domain that contains description. theory and the intellectual argumentation backing the theory. It is a verbal representation of the formal model. With abundant means of annotation. the narrative can present a scholarly argument that is much more accessible than the paper-based research article.

3.5.2.4.3 Data Resources

Many RWs will be able to draw from data sources on the WWW. Typical data would be: census data. maps. physical constants. chemical characteristics. dictionaries. gazetteers.

classic works of literature and history, encyclopedias, and many others. Team members are likely to be aware of these public sources, and may also know of private sources that are available by request. Bibliographies, even annotated bibliographies, are rather common. These data sources can be made available through a "jump page" that assembles the team's collective knowledge.

Data developed by the research team should be displayed in raw and reduced forms on the web site as part of the RW Essay that reports an experiment. Experienced statisticians may be able to contribute observations through a DocReview of the data. If the conditions of a research grant require public disclosure of data, these data may be mounted in the public presentation partition, and referenced in the team's private working area.

Links to related sites are a fairly standard but naïve feature of web sites. The Research Web should occupy a unique position in the WWW, the only site dedicated to scholarly research into the issue domain. If the RW does not soon surpass every related site in quality, it was founded in territory perhaps too well investigated. In general, only very specialized high quality sites should be referenced. Care should be taken to link to such external sites through new windows, as in the "sidebar" feature of the Research Web Essay. This strategy reduces the likelihood of digression as the RW's web site remains displayed.

3.5.2.4.4 Authoring Partitions

A team that is authoring a research web essay, especially one that is destined for publication in the scholarly literature, is likely to feel a need for privacy even within the research team. There are three fears driving the need for privacy: the first is the necessity of presenting a quality product to one's peers: the second is premature quotation: and the third is recognition of the existence of competition and its fortunately rare agent—poaching. A special partition for the purpose of authoring can shield the authoring team from unwelcome and premature access.

When a team is formed to build a RW essay, that essay topic is already known to the team and most likely the majority of scholars within the discipline. The authoring team has little to fear from publishing an outline of the paper within the RW itself. That outline could benefit from the criticism and encouragement of the entire team. A DocReview of the outline might improve the scope of the essay, find holes in the proposed research plan, and offer fresh ideas and examples. Once that DocReview has served its purpose, the authoring team might have the facilitator set up a passworded partition within the RW working area. That partition would then be doubly passworded from the outside world, and the team could work in private until the essay has progressed to a polished draft. The draft may be registered with a digital notary site[87] in order to establish priority. The draft may then be moved to the working area, and perhaps the guest partition, for a final presubmission DocReview of the RW team peers, and invited peers.

3.5.3 Information Design

As in all design, one must focus on the user first, and often almost exclusively. There are several overall design issues that apply exclusively to the "look and feel" of the site. First, remember that the audience is at the site for information, not entertainment. There is a *laissez faire* attitude about the WWW, and its tools allow anything to go. You can do anything, so start by remembering your customer. Follow good design practices; apply the advice of Nielsen[88] for page design, Strunk and White[89] for composition and Tufte[90] for graphics. Keeping it simple is best. Never use gratuitous graphics! Do not use animation unless it contributes intellectual content. Never use frames! Never use backgrounds where not essential! Never use web site building tools that restrict typefaces and sizes; let the visually impaired user select the face and size in the browser! Design for operation with browsers that are at least two years old so even users with older browsers can use the site[91]. Do not require browser plug-ins that are not absolutely necessary.

3.6 The Research Team

Research Web team members fill fluid roles. Members of a team that is operating well help each other by not only fulfilling their roles, but also helping others fill their own roles. Roles may be shared, be vacant, or be transferred from member to member. Members may operate in several roles every day. There are several specific functional roles, discussed below, for members within the Research Web and four abstract styles[92] common to team members in general. In addition to the roles discussed in this section, all team members must participate actively. The participative behavior is discussed in §2.2.4.

There may be people who are connected to the team without being a part of it. Those people may be overseers or employed staff. Overseers are those who have an interest in seeing the team succeed; they may be part of the granting agency, host organizations, or stakeholders. Staff members are those that support the team in maintaining the team's environment. Staff members may be on contract to the team, or they may be employees of cooperating institutions. Both overseers and staff should operate in the role of cooperator, people who assist the team without joining the scholarly effort.

3.6.1 Abstract Roles (Styles)

The literature in organizational behavior and small group behavior abounds with descriptions of team membership style and recipes for success. Parker[93] lists four that are used by Austin and Baldwin[94] as a framework for discussion of the characteristics of effective team members. Most team members will exhibit, from time to time, all of these styles: contributor, collaborator, communicator and challenger.

The contributor[95] is primarily a content provider who shares information with other members. In the RW, all team members should exhibit this style. The contributor will provide input to RW Essays and models, and will contribute content by annotating other's essays and commenting on resources and the vocabulary of the enterprise (see §2.2.4.6.1).

The collaborator[96] is a goal-directed, group-oriented team member. Collaborators are willing to forgo some individual rewards for the benefit of the team and other team members. The collaborator sees the goals of RW team as having validity in the long term, as opposed to more competitive members who will focus on authoring project tasks that will guarantee authorship rewards shared by a small number of authors. Role-sharing and collective honors were described in a research group that collaborated on 34 articles with every team member, as well as a consulting editor, listed as author[97]. An extreme example of collaboration was Bourbaki[98], a collaboration of from 10 to 20 mathematicians who published anonymously and collectively for several decades under the name Nicolas Bourbaki.

The communicator[99] is a person who works to support the team's work processes by helping to integrate new members, or to get the initial team to function as a team. Conflict settlement, consensus-building, encouragement and recognition are important functions of the communicator. Groups tend to have two leaders, one a task specialist and the other the maintenance specialist who specializes in conflict resolution[100]. The maintenance leader, a communicator, has been described as a "team mother" and is often a woman. Austin and Baldwin point out several gender differences in research and professional behavior that support that observation[101]. Communicators need to work on both the RW level and at the authoring project level.

The challenger[102] is the conscience of the team. The challenger is not afraid to question authority, or the state goals of the team. In the RW, this person can also operate on the project level within an authoring team. Fortunately, most researchers are well trained in critical thinking! To a great extent the challenger style is satisfied by members filling the critic functional role (see §2.2.4.6.7).

3.6.2 Functional Roles

The Research Web has a number of functional roles that are called into existence by the implementation of the concept. The RW will have *conveners* who start the activities that eventually result in a functioning RW. The RW must have a *scientific coordinator* to manage the business of research. A *facilitator* is required to run the technologically intensive environment, and to take as much unproductive load of the team members as possible. *Lead authors* will direct the research efforts of their teams, generating not only professional papers, but also feeding the knowledge generated into the models, essays, glossary, and bibliography. The *collaborator* is the central universal role, helping others on the team through criticism, questioning, and providing knowledge and information.

3.6.2.1 Convener

The conveners of the RW are scholars that are almost always well known to each other prior to the establishment of collaboration[103]. The functions of the conveners are to begin to define the issue domain, begin recruitment of additional members, write funding proposals, and to start building the RW's web site. The conveners must also bear the costs associated with those activities[104]. The conveners almost always become the PIs for the original projects within the RW, as a natural result of their professional status, and as an appropriate reward for their investment.

Wood and Gray, in discussing interorganizational problem-solving collaborations, have identified a number of characteristics that conveners need[105]. In their list, for our context, assume that stakeholder is defined as "an interested and qualified scholar." Qualities that the conveners collectively should have include:

1. "convening power, that is, the ability to induce stakeholders to participate."[106]

2. legitimacy among the stakeholders, who must perceive that the convener has the "authority to organize the domain" [107]
3. an unbiased, even-handed approach to the problem domain, to prevent the convener from losing credibility in the eyes of the stakeholders[108]
4. appreciative, envisioning, and processual skills, meaning that the convener must appreciate the potential value of collaborating," and must be able to "envision a purpose to organizing the domain: and establish a collaborative process and context[109]
5. the ability to identify all relevant stakeholders, who must have legitimacy and thus "be perceived by others to have the right and the capacity to participate" in the collaboration[110].

(Wood and Gray[111] -- page references to Gray 1989)

The convener also must be a technology champion. The Research Web is a technological environment that is quite foreign to most researchers. While few scholars would suggest that they are not in favor of collaboration, many are not aware of collaboration beyond cooperation of institutions or writing a research paper. Few are willing to pay the overhead in collaboration around an issue domain larger than the topic of a single research paper.

Being a technology champion requires a unique blend of personality characteristics, leadership behaviors, and influence tactics[112]. Of the characteristics describing technology champions, only two are likely to be possessed by young or unknown researchers: risk-taking and innovativeness. The other defining characteristics of political astuteness and charisma, and the ability to introduce innovations by "the articulation of a compelling vision of the innovation's potential" are seen more often in older researchers and administrators.

Since a small group is unlikely to harbor such a talented being, it would seem that a shared leadership that borrows abilities from those that possess them might have the needed characteristics. Those leaders in supporting roles, such as stakeholders, host department chairs, resource managers, sponsors, and attentive team members can contribute to the success of a collective technology champion. A team member who does not agree with any concept of the Research Web should raise the problematic issues in order to improve the concept. If all attempts to reconcile the member, then he or she should withdraw, or have the grace to suppress obstructive behavior.

> *They [technology champions] need* information *to evaluate, choose and sell an innovation:* material resources *to obtain the necessary information and to test and make transitions: and* political support *to guarantee both the availability of the material resources and, eventually rewards for successful innovations (or protection from sanctions, in case of failure).* — Beath[113]

3.6.2.2 Scientific Coordinator

The scientific coordinator is responsible for managing the conduct of research in the Research Web, defining the scope of the issue domain and determining the structure of the organizing model. MacArthur Research Network Chairs have referred to the position have referred to the position as the "key primary obligation" and a "second religion" [114]. The position of Scientific Coordinator has no way to be rewarded except by grant support. The Scientific Coordinator is responsible for maintaining the models and coordinating research, not writing papers. Unless the models themselves lead to research papers, there is no scholarly reward. The Scientific Coordinator's position is a collaborative and supportive role.

The research team cannot operate well without a leader. Since most of the team will be involved with the production of science in the form of specialized research papers, someone has to have an overall vision of where the team is going at any given time, someone who has "a knack for observing interconnectivity among the work of seemingly diverse scholars"[115]. This capability may result in much better collaboration among the team members, and occasionally from scholars from the outside who are known to the scientific coordinator.

The scientific coordinator may also act as an arbitrator to the authoring teams, especially when issues of authorship arise. As the models of the RW are developed, objects and processes that may become the topic of RW Essays and subsequent research publications. When these components of the issue domain are identified, scholars will immediately begin to lay claim to these pieces of turf. The scientific coordinator may be called upon to settle the makeup of authoring teams.

The Scientific Coordinator must be supported by the PIs and must support and direct the work of the facilitator. The scientific coordinator is also likely to be a project leader and lead author. By virtue of the oversight function of the position, the scientific coordinator is also likely to be one of the strongest critics on the team. Recruiting new members, both temporary and permanent is an activity that naturally falls on the scientific coordinator, though some of that duty is shared by the project leaders. Obtaining grant support is a duty that falls on the project leaders as well as the scientific coordinator, who fills the role of *grantsmaster*[116]. In the MacArthur Research Networks, the scientific coordinator (Network Chair) is also responsible for linking the team to the Foundation staff by integrating the Foundation appointed Network Administrator into the team[117].

3.6.2.3 Project Leader

The Project Leader is a principal investigator (PI) responsible for a research project within the issue domain. There may be several authoring teams within a project, and the lead authors must work closely with the project leader. The project leader must develop the model of the domain of the research project in order to illustrate the interdependencies of the work of the authoring teams. The project leader may be called upon to settle conflicts within authoring teams. The project leader is perhaps equivalent to the first line of management, while the scientific coordinator is the general manager, and the lead authors are supervisors.

The project leader will need to collaborate with those responsible for the development of the project's models that will merge with the models of the issue domain. There may be some reluctance from the project leader, and even more from the authoring teams, to engage in the modeling effort. Modeling may be seen to be a distraction from the main issue, which is, to the authoring team, to write scholarly content, first the essay and then the research report. Modeling should not be a retrospective activity; there should be co-evolution with the essay. The model should first inform the essay, and then the research for the essay will inform the model. If the conveners who wrote the grant proposal had the foresight to budget for staff personnel to develop models and to facilitate the collaboration, then the problems involved with modeling and technical support would vanish.

3.6.2.4 The Collaborator

The collaborator is one who engages in collaboration with the team members. While a collaborator may also engage in communication, coordination or cooperation, we consider here only the nature of the person engaged in collaboration, the *role* of collaborator. Thagard defines four kinds of collaborative relationships: *employer/employee*, *teacher/apprentice*, *peer similar* and *peer different*[118]. In the RW's research team, peer similar relationships dominate, but it is very important to support and encourage all kinds collaboration.

The employer/employee relationship is occasionally played by research assistants who are engaged in routine assignments. The facilitator, when managing technical matters, falls into an employer/employee relationship with the team members, especially with the scientific leader. An understanding of the necessary subordination and at least respectful deference marks the character of this relationship. While this is the weakest form of collaboration, it is true collaboration as both members realize that they are collectively contributing to the work of the research team.

Teacher/apprentice relationships arises when there exists an opportunity for an expert to pass knowledge on to a team member who is actively learning. This form of collaboration is especially valuable in the socialization of graduate students, postdoctoral fellows, and interdisciplinary colleagues. The principal mechanism of this socialization is *legitimate peripheral participation*[119]. The collaborator who is "teacher" has the responsibility to not only instruct, but to encourage the participation of the "apprentice." Both teacher and apprentice must be aware of the psychological and sociological barriers to collaboration presented by status differences. Collaborators must practice either courage or forbearance in this relationship.

Peer similar collaboration is the most common and productive form of collaboration. While the training of all peers will have been similar, it will by no means be identical, and indeed, among strongly specialized fields, may only overlap at the fundamental level. Those collaborating at this level have a responsibility to suppress competitive interdisciplinary tendencies when the topics are important to the research team. Collaboration among students has been observed to exhibit a full range of professional socialization[120].

Peer different collaboration is generally a teacher/teacher relationship. When trained scholars from different disciplines come together in a collaboration, they are expected to inform the team about the understanding of the research topic within their discipline. In the RW, collaborators from specialties outside the principal discipline of the research topic are likely to be encouraged to make their implicit knowledge explicit[121]. They might provide an essay that outlines their discipline-specific knowledge about the team's research topic. The collaborator should also contribute references to pertinent literature from her discipline. Peer different collaboration is often the most innovative collaboration since new perspectives are presented. Peers from other disciplines should contribute commentary on differences in vocabulary.

Jane Maienschein describes another collaborative relationship, *helping hands*, where a technical specialist may be asked to participate in order to perform duties the team cannot[122]. I view a helping hands collaborator as a specialized facilitator. Of course this category could also include an employee.

In dealings with the RW, each collaborator fills one or more of several identifiable roles: in dealing with RW content as a contributor or critic; in social promotion roles such as advocate, supporter, protector; and in structuring roles within discussions as moderator, facilitator, delimiter, synthesizer, interpreter, arbitrator, and reporter.

3.6.2.4.1 Responsibility for personal participation

Every collaborator must be aware that participation is necessary. Regardless of the status and role of the collaborator, some contributions are expected. The collaborator will have been informed of those expectations when invited to participate. Participation can take many forms: contribution of content, criticism, dialogue, or support and encouragement. Contributions can be made directly in the RW as contributions of essays or critical annotation in DocReviews, the Annotated HyperBibliography, and the Annotated HyperGlossary. Dialog in the form of e-mail or discussion forums is also a very important contribution. Rewards are of course contingent on participation. Free-riding is considered to be very poor form in the RW.

3.6.2.4.2 Team member

How does one become a team member? The conveners are certainly members, and are likely to occupy the positions of power and reward. As first on the scene, the conveners will likely include the scientific coordinator and the coordinators of the first papers to be produced. High stature peers are likely to be invited to join the team in order to strengthen its scientific knowledgebase. Other scholars are likely to be invited on the basis of their specialized knowledge, or known ability to collaborate. Each candidate must be given the expectations of the group, especially the understanding that some of the rewards must devolve from the individual to the group.

Every team needs to have the ability to select its members. The bases of selection include professional status, personality, apparent willingness to participate, and a statement of their intent. The statement of intent is essentially a position paper stating the goals the scholar has in dealing with the research team. These statements of intent should be posted in a section of the RW that introduces the team to the reader.

As a team member, one has access to all areas of the RW. There are two major exceptions to access, the first is the flux of inter-member e-mail that occurs outside the team listserver; and the second is access to drafts and DocReviews of works-in-progress that might be passworded by authoring teams. In any group there is always a necessary undercurrent of communication that best remains private. The need for protection of works-in-progress is sometimes made necessary due to the competitive aspects of scientific practice. In any case, the early drafts of papers are simply not suited to local peer review by DocReview: premature exposure to a draft of a paper can lead to "review fatigue" -- there are only a very limited number of times a reviewer is willing to study a paper.

Occasionally a member chooses to move on to other interests, or retires. It is clear to the scientific coordinator when a member's participation drops or vanishes. A short private communication will establish whether the member wants to remain active. If not, the member should be thanked for past contributions and removed from the distribution lists. If the dissolution of the relationship was acrimonious, then the password for the site might need to be changed.

3.6.2.4.3 Invited peer

Often a scholar will be invited to join the collaboration in order to provide learned criticism. Critics are always acknowledged, and occasionally invited to become authors. The question of authorship is intensely debated among the team. but should never include eminent scholars or administrator who do not directly contribute significant content. Peers may be invited to review a single paper by mounting the DocReview in the guest partition.

3.6.2.4.4 Member of scientific community (literature)

The scientific literature is the knowledgebase for any scientific work. A passive form of collaboration exists in the form of citation of published works. Citation is itself a considerable reward. as citation analysis is frequently used to measure the impact of a scientist's body of research. The references cited in a draft may contain peers who might consent to review the work. Being invited to review work that builds on your own is a pleasure. though not a responsibility. An invitation to review may be a scholar's first exposure to the RW. and might grow to a more fruitful relationship.

3.6.2.5 Lead Author

The lead author is responsible for directing the research leading to the production of a set of Research Web Essays on a topic identified by the team as part of the issue domain. There may be several essays involved. most leading to publications. At the beginning of the research project. the lead author will be responsible for managing the development of a model of the objects and processes involved. After the model has been established the lead author will supervise the incremental elaboration of the models as research progresses. The lead author is usually the project leader for a section of the RW and may also be a convener. Almost certainly he or she will be supported by a grant.

3.6.2.6 Facilitator

The Research Web Facilitator has many duties, but only one role. That role is to be the conscience of the team, monitoring quality of presentation and the degree of participation. While the facilitator is not an expert in the content of the research, s/he is facile in the process of collaboration[123]. The facilitator takes as his desired that which is desirable for the community; this includes the quality of the Web Site. There is not a perfect coincidence of desired and desirable within the community[124]; indeed there is a considerable tension corresponding to the conflict in the interests of the individual and those of the community. The facilitator serves the team directly by taking responsibility for transforming intellectual content into RW Essays and models. Technical training is another service that the facilitator provides[125,126].

*The facilitator works **with** the team, but **for** the leader.* -- Phillips and Phillips[127]

The literature on facilitators is dominated by meeting facilitation rather than mediation and facilitation for a long-term largely asynchronous group. In a work examining the facilitator of computer-supported meetings, Clawson, et.al. identify 16 dimensions[128]. Seven of these dimensions may be used for evaluating the effectivity of the RW's facilitator:

- Promotes ownership and encourages group responsibility.
- Demonstrates self-awareness and self-expression.
- Appropriately selects and prepares technology.
- Listens to, clarifies, and integrates information.
- Creates comfort with and promotes understanding of the technology and technology outputs.
- Creates and reinforces and open, positive, and participative environment.
- Understands technology and its capabilities.

3.6.3 Potential Rewards

RWs offer some opportunities to develop an enhanced reward system. These rewards are rewards designed to encourage collaborative activity. Some of them attempt to remediate some of the disincentives that are part of the existing academic environment.

1. Additional and follow-on grants

While none of the RWs studied survived to maturity, an argument can be made that one of the more important functions of the RW is to act as an incubator for grants. Funding agencies have, in their grant decisions, always leaned heavily on the record of scholarship of individual scholars. A RW provides proof of the existence of an active productive team of scholars endowed with long-term scholarly capital in the form of an elaborate model of the issue domain. This second source of knowledge is a form of intellectual capital not often seen.

2. Career enhancement

Authoring teams will be rewarded in the usual way. The scientific coordinator and facilitator have a new claim to make on their CV: management of a team of collaborators. The scientific coordinator can point to the management of a model of the issue domain that necessarily includes both determination of the boundaries of the issue domain with definition of adjacencies of other issues and a hierarchical decomposition of the issue domain itself. Of course the skills of recruitment, decision-making and coordination of authoring teams will demonstrate the ability to manage as well as contribute.

The facilitator will be able to point to the ability to work closely with a senior scientist, and the technical skills to design, acquire, and use software necessary to support a collaborative team of scholars. Since the facilitator is not initially likely to be familiar with the issue domain, great adaptability and learning skills must be applied simply to be able to engage in planning the RW web site and conversing with the team members.

3. Legitimate Peripheral Participation (LPP)

Graduate students and non-professional staff members can be socialized into the research team and can be introduced to scholarly research through the mechanism of LPP. Being asked to serve on a research team is a great event in the lives of most committed students. Learning how research is done is a necessary element in the education of anyone aspiring to a life in science.

4. Credit in tenure reviews

Scholars on a tenure or promotion track need to be able to convince a committee that they are worthy of appointment or promotion. The literature is replete with examples of lack of credit being given to any activity other than conventional scholarship, service and teaching. In a RW, one of the duties of the Scientific Coordinator is to inform every team member's academic department of the contributions that the member is making to the team's efforts. This is especially true when one considers that a member may contribute enormously to a modeling task or a literature review that does not directly produce a publication.

5. Acknowledgments

As a matter of policy in RWs, *every* contributor to a RW essay and any professional paper that results from such work will be acknowledged. In conventional scholarship acknowledgments have almost no standing at all, indeed some publishers refuse to publish acknowledgments. In the now-ascendant electronic journals and in self-published web pages, there is no such restriction. It will hopefully come to pass that acknowledgments will be given some greater status in the world of scholarship.

6. Awards or bonuses for exemplary service

This reward offers management to codify the desired collaborative behavior. Rewards of this nature have not only a conventional positive reinforcement component, but implied penalties as well. If awards are presented to half the team members, then it is obvious that the other half didn't perform well. There may be difficulties in applying grant money to such a program, though in an industrial or government setting it could be applied.

Notes to Chapter Three

[1] Girgensohn, Lee, and Schlueter 1996, 246

[2] WWW 1995

[3] Anon 2000

[4] Thagard 1997

[5] Thagard 1993

[6] Pickering and King 1992, 357

[7] Koku, Nazer and Wellman 2000

[8] (Wood and Gray 1991)

[9] Sayer, 1992, 250

[10] Poole 1994, 23

[11] Sterman 1991, 5

[12] Aronson, Harrè and Way 1995, 45

[13] Stephen Jay Gould 2000, 70

[14] Chen 1994

[15] Rachel and Woolgar 1995

[16] Ngwenyama 1991, 268

[17] ibid. 269

[18] Gaines 1996, 315

[19] Cronin and McKim 1996, 170

[20] Funtowicz and Ravetz, 1993

[21] Hendricksen 1998d

[22] Lave and Wenger 1991

[23] Wadsworth 1998

[24] Schön 1983

[25] Meyer and Zack 1996

[26] Orlikowsi and Yates 1998

[27] Orlikowski and Yates 1994

[28] Agre 1998

[29] Bazerman 1988

[30] Orlikowski and Yates 1998

[31] Agre 1998

[32] Orlikowski and Yates 1994, 542

[33] Cronin et.al. 1998. 1319

[34] Rom Harré (1970)

[35] Sterman 1991

[36] Harré 1978. 275

[37] Ziegler 1990. 29

[38] Hendricksen 1989

[39] Peterson 1977

[40] Benwell 1991

[41] Harré 1970

[42] Aronson. Way and Harré 1995. 36

[43] Milleret-Raffort 1995. 208

[44] Crowston and Williams 2000

[45] Furuta and Marshall 1996. 185

[46] Roberts 1998. 85

[47] Dillon and Gushrowski 2000

[48] Dillon and Gushrowski 2000. 204

[49] Crowston and Williams 2000. 208

[50] Alan Gross 1990. 3

[51] Dunn 1982

[52] Sayer 1992. 65

[53] Aronson. Harré and Way 1995. 12

[54] Toulmin. Rieke and Janik 1979. 249

[55] Eisenhart and Borko 1993

[56] Dunn 1982

[57] Gross 1990. 7

[58] Liebow. et.al. 1998

[59] Toulmin. Rieke. and Janik 1979. 25

[60] Gross 1990. 129

[61] Pröpper 1993

[62] ibid.

[63] Poole 1990. 239

[64] ibid.

[65] Harré 1970. 36

[66] Rao and Turoff 1990. 348

[67] Harré 1970, 36

[68] Blalock 1968

[69] Sterman 1991

[70] Brinberg and McGrath 1985, 32

[71] v. Bertalannfy 1968, 24

[72] Orlikowski and Yates 1998

[73] Orlikowski and Yates 1994

[74] Levinson 1997

[75] Henderson 1991

[76] Hanna 1991, 178

[77] Barney 1991

[78] Star and Griesemer 1989

[79] Henderson 1991

[80] Englebart 1995

[81] Englebart 1990

[82] Eaves 1997

[83] Cronin 1995, 228

[84] Furuta and Marshall 1996, 184

[85] Booch, Rumbaugh and Jacobsen 1999

[86] Blalock 1968

[87] Menkus 1995

[88] Nielsen 2000

[89] Strunk and White 1979, 66

[90] Tufte 1983

[91] Nielsen 2000, 36

[92] Parker 1990, 63

[93] Parker 1990

[94] Austin and Baldwin 1991, 54

[95] Parker 1990, 64

[96] Parker 1990, 69

[97] Shreeve et. al. 1986

[98] Halmos 1957

[99] Parker 1990, 75

[100] Weinberg 1971, 85

[101] Austin and Baldwin 1991, 74

[102] Parker 1990, 80

[103] Finholt and Olson 1997, 35

[104] Marwell and Oliver 1993, 34

[105] Wood and Gray 1991

[106] ibid., 71

[107] ibid., 71

[108] ibid., 72

[109] ibid., 72-73

[110] ibid., 121-122

[111] Wood and Gray 1991, 150

[112] Howell and Higgins 1991

[113] Beath 1991, 356

[114] Kahn 1993, 20

[115] Poole 1994, 26 quoting Hirokawa

[116] Poole 1994, 26

[117] Kahn 1993, 22

[118] Thagard 1997

[119] Lave and Wenger 1991

[120] Weedman 1998

[121] Crow, Levine and Nager 1992

[122] Maienschein 1993, 173

[123] Schuman 1996, 126

[124] Hofstede 1991

[125] Orlikowski 1993

[126] Bullen and Bennett 1990

[127] Phillips and Phillips 1993

[128] Clawson, et.al. 1993, 556

Chapter 4 --- The Tools of the Research Web

The tools discussed in this section are all software that the team may use in its daily work of the RW. The tools were appropriated from commercial or academic sources, where available and suitable; but the core tools were built by the author specifically for the Research Web. Frequently inadequate tools must be used out of necessity, due to limited resources, temporal and financial. No tool is perfect and no RW is static in its needs, so tools must be revised or new tools acquired in order to support the team.

Tools must meet several standards in order to be useful:

1) The tools should be familiar to operate, or transparent[1]. Difficult tools will be avoided by the team members, and will severely degrade the effectivity of the RW.

2) The tools should support a known or appropriated communication genre.

3) The tools should be priced reasonably.

4) The tools should be maintainable by the facilitator.

4.1 E-Mail

Email is the universal communications tool. It is a genre that is adopted from the familiar office memorandum[2]. The genre is very highly augmented in the Internet environment, including numerous very useful features such as hypertext links to web pages, personal message archiving systems and the ability to transmit files attached to the message. E-mail programs are abundant, reliable and employer or ISP provided, or free. The team members may use the program of their choice. In the RW e-mail is used for three primary purposes: private communication, team communication, and notification.

Private communication is frequently necessary to protect the social functioning of the team. Care should be taken to prevent the hiding of information that is of potential value to the team. If matters discussed may be of importance to the team avoid mixing in private material. Above all, avoid the corrosive tendency to store topical information for personal or subgroup advantage. If a private message is to be made public, all parties to the message should be consulted.

Team communication takes the form of management announcements, topical queries from individuals, responses to queries, perhaps requests for opinions on a hypothesis or proposal, and many others. The originator of messages addressed to the entire team should copy the message to the team's e-mail address. If the sender operates from the MailRoom, this is automatic. Notification e-mail is sent to team members when a new page is added, an existing page is modified, or when a comment is made in a DocReview, HyperBibliography card, or a HyperGlossary page (see What's New §4.7). Notification lists are customized to notify only those who wish to accept notification.

4.1.1 Searchable E-mail Archives

E-mail messages are a primary source of information for the team. Tacit knowledge often first becomes expressed to the team through e-mail. In order to utilize the data, information and knowledge content from this source, all messages must be indexed for full-text searching. The ability to examine the entire e-mail archive for messages on a single topic is a powerful tool. The search engine must display the message headers for all messages meeting the search query's specifications. These headers will contain links to the full text, which should highlight the keywords in the text.

In order to be archived, all team communication (except for notification messages) is copied to a team e-mail address. Any team member may also archive a private message simply by copying the message to the team e-mail address. A computer program may be activated automatically to reindex the archives on any schedule the team requires. Once a day indexing is a minimal requirement.

4.1.2 MailRoom

MailRoom is a program that allows the user to send mail from a web page. *MailRoom* gives the team members a single point from which they may send public e-mail to any team members, all members or members of authoring groups. The facilitator can set up group lists on request. All communication through the *MailRoom* is copied to the team's e-mail archive address for permanent recording. The advantage for users of *MailRoom* is that they know they are archiving their communication. They are also spared the necessity of maintaining addresses for all members, the many authoring subgroups, and the team's listserver.

MailRoom does not offer services such as attachment of files, blind cc, return receipt, etc that e-mail programs offer. If any of these services are deemed necessary the sender can always revert to private e-mail with a copy sent to the team's listserver.

4.1.3 Listserver

The RW has a team listserver that serves all members and the team's e-mail archive address. The listserver duplicates the MailRoom's send-to-all services, though there is no conflict between the two. The management of the site may find some reason for making the listserver open to a different set of people than the set of members listed in MailRoom. The listserver should have archiving and search capability, if not then MailRoom should be used exclusively.

Suitable listserver software with archiving and full text searching is expensive. Research teams can take advantage of institutional cooperation by utilizing the site license of one of the cooperating institutions. There is no reason for the RW to be sited at a single institution. The facilitator should have access to the listserver in order to correct or delete messages and to edit the address list of members.

4.2 The World Wide Web

The World-Wide Web (WWW) is both part of and the foundation of the infrastructure of the Research Web as currently designed. This WWW is a peculiar foundation, however; as a revolutionary and recent innovation it is very much a work in progress (Berners-Lee 1999). As time passes and more people use the WWW, the need for change exerts itself inexorably. As changes are incorporated, they open new ways for humans to interact with each other and with the machines that may be utilized from the WWW. The hardware environment also changes as entrepreneurs and research labs invent new machines that allow us to realize the powers of the web. At the time of writing, the most common environment for web users is the personal computer workstation plugged into the Internet with the wires and cables offering services of varying capacity. This environment will change, just as the WWW itself. Wireless access to the WWW will allow portable machines to display web pages anywhere in a variety of devices. One of the most promising devices is the wireless electronic book[3] that will eventually offer portability, access, freehand input of annotation, and all the power of the current PCs.

The software environment is changing even more rapidly than the hardware environment. Currently, there are a plethora of file types that can be read with web browsers, but most files are coded in HTML (HyperText Markup Language). HTML is a markup language that controls how the browser displays content. Access to databases cannot be done with HTML, but must be done with a very complex set of software installed on the server.

The introduction of XML (eXtensible Markup Language) allows several services to be added to the web page including access to databases and display of very exotic notations, such as complex mathematical notation[4]. Unlike HTML, XML programming will require real computer programming ability. This fact and the growing importance of other computer languages, like Java and JavaScript underscore the need for a technically qualified facilitator to manage the RW web site.

4.2.1 Browsers

There are two major browsers in use at the time of writing. Netscape Communicator and Microsoft Internet Explorer. All web pages must be tested for proper operation on both of these browsers. There are many other browsers available and team members may use the browser of their own choosing, but it should be made clear that other browsers may not work properly. The facilitator should design materials to operate in browsers at least two years old (Nielsen 2000). since some team members might not upgrade their browsers on a regular basis. Older browsers are generally quite capable of meeting the needs of the RW: most of the "improvements" offered by more recent versions are market-driven features of marginal value. Practice conservative design: just because some feature may be used does not mean it should be used!

4.2.2 CGI Programs

Interactive behavior of web pages. such as annotation facilities. requires the use of fill-out forms. Each form must be backed up with a computer program called a CGI script (Common Gateway Interface). These scripts are computer programs written in any one of many computer languages. The team members. except for the facilitator. are not exposed to these programs in any way. The CGI programs can perform many functions far beyond the capability of normal web pages. E-mail may be sent. databases may be accessed for data manipulation and computer programs of any complexity may be run on the server computer with a report of results returned to the client's browser.

4.2.3 Helpers, Plug-ins, and Other Programming

Special multimedia presentations such as audio, video, motion pictures, postscript displays, pdf displays, slide shows and others require that the browser be augmented with special programs. These programs are called plug-ins or helpers. Many documents, for instance, are displayed in a special format called PDF, display of these documents require that the Adobe Acrobat Reader be installed in the browser. While installation of such programs is very simple for those who have modest computer skills, some people simply do not have the time and inclination to install plug-ins. For this reason, the web site needs to use only the most essential plug-ins. Detailed instructions and help with installation must be offered to all team members when plug-ins are required.

4.2.4 Calendar

When there is a synchronous component to the operation of the Research Web, meetings can be set up with the use of a web-based calendaring system. Meetings are much more effective with an agenda, and the calendaring system allows negotiation of agenda items. A calendar may also provide a hypertext link to minutes of meetings just past. There are many free or inexpensive calendaring systems available the facilitator can set one up for the team in a couple of hours. Typically the calendar allows anyone to enter events on the system, but on an active site, the facilitator may want to manage the entry of information.

4.2.5 Discussion Groups

One of the Internet's most well-known and used pieces of software is the threaded discussion group[5, 6]. Discussion groups are likely to be a useful tool in any RW as they offer an informal free-form discussion; however, the success of discussion groups should not be assumed! There appears to be a critical mass effect in discussion groups. Palme suggests that the lower limit for success is 20 to 50 active participants[7]. There is an upper limit as well, established by excessive message traffic; but this is far beyond the likely membership of a research team. Developing a successful topic may require leadership in the form of gentle admonitions and occasional reminders often in the form of questions and summaries. Discussion forums allow very general discussions to mutate into a branching structure that is confusing to novices. Extensive discussions frequently lead to topic spread, and even topic loss—these shortcomings were the impetus to develop DocReview (see §4.3). DocReview is a very highly directed critical annotation tool that does not encourage discussion of comments.

4.2.6 Development Tools

Composition of content for the RW's web site can use two methods: conversion of word processor files, or direct editing in an HTML editor. Content prepared by scholars is almost certainly done with a word processor. The programs that convert word processor files to HTML do not produce HTML compliant with industry specifications. The files created by these conversion programs are bloated files full of unnecessary tags. Not only is the quality poor, but also the code produced is not compliant with practices designed to produce copy that can be read by visually impaired individuals who may be more comfortable with a larger type font. One company actually uses, as a marketing point, the fact that its product (DreamWeaver) weeds out unnecessary tags ("trash") from MicroSoft's Word HTML converter[8]. There are standalone programs that do a better job of conversion than the programs provided in the word processors. Both popular browsers have editors that produce HTML code. Nonetheless, the code from these simple HTML editors frequently needs to be corrected.

The tool used to correct faulty HTML is a plain text editor[9]. The advantage of a plain text editor is that it does not produce unwanted characters, as all word processors do. The code produced is ASCII characters. Should the facilitator be writing programming in Java, JavaScript, or CGI programs in Perl, such a plain text editor is essential as none of these languages tolerate the gratuitous characters inserted by word processors.

Programs that can produce and edit digital images are necessary for all but the simplest site. The facilitator needs a good assortment of graphic tools in order to create diagrams for the team, to convert from one format to another, to create "thumbnails", and to edit images. A tool to create image maps (hot spots) for diagrams and pictures is necessary. There are many tools in all these categories, for all budgets.

4.3 DocReview

The World-Wide Web (WWW) provides an interactive mode of operation. CGI scripts, that allow asynchronous distributed collaboration by means of critical review of documents. DocReview is web-based software that facilitates the review of documents by user annotation. The commentary is permanent and immediately available to the collaborative team. In the Research Web almost all documents are annotatable using either DocReview or an e-mail link.

Critical annotation of documents is a practice fundamental to scholarly activity. A product that uses a frame of reference familiar to the user's culture is more likely to be well received[10]. DocReview is designed to provide collaborators with a tool whose success is based on ease of use and familiarity[11]. A document presented for review with DocReview becomes a *boundary object*[12], a place in cognitive space where members of interdisciplinary teams can come together to share their knowledge about the document's content, and their opinions on its presentation as well. Critical review is an activity that attracts both learners and professors, thus DocReview also becomes a recruiting device for the collaboration, a *conscription device*[13].

An annotation program must satisfy several general design requirements to be successful. First the program has to be accessible and interactive. Both of these requirements are met by designing the tool to operate on the WWW. Second, the tool has to be easy to learn and use. The widely known behavior of the WWW largely satisfies this requirement. Ease of use, which includes learning the behavior of the tool, is aided by the tool's simplicity. DocReview uses links sparingly: in the latest version there are only two buttons used to go to additional services or more information, and two linking tags which are repeatedly used for reading and writing annotation on pre-selected segments of the document. Simple: click "W" to write, "R" to read. Finally, the behavior has to satisfy most annotation functions in a manner that closely follows customary "hard-copy" annotation.

How do people annotate hard copy? The first act of annotation is to fix the location of the comment. DocReview provides tags at convenient locations so the reviewer can click on a link that applies to a section of text (a paragraph or cognitive chunk), or to an embedded graphic or table cell. Wordsmithing (minor edits) usually applies to single words or phrases. Comments on grammar or errors in the content generally apply to sentences or paragraphs. Occasionally entire paragraphs or sections may be the subjects of annotation. The sponsor or editor of the DocReview must determine the segmentation to suit the anticipated annotation behavior of the users. Typically each paragraph is made a review segment, but the dense sentences of some scientific works may be made into individual review segments. Abstracts are often rich in such sentences. Often there are comments that apply to the entire document, or simply have no locational focus. DocReview has a dedicated area for making general comments.

Ease of use is critical. Collaborators have only a limited amount of cognitive energy available for the collaboration. That energy should be focused on the content of the collaboration, not on the technical environment and tools. The great advantage of using the WWW is its very simple interface. Any web-based tool should be careful not to add complexity to the environment. The tool will ideally be completely transparent, that is, *will look and behave just like any other web page.* If a reluctant user finds difficulties by having to learn a complex user interface, then that user is not likely to participate.

The existence of a permanent record of the critical dialog is very important to collaborators who reflect on the commentary again and again on their way to understanding[14]. DocReview permanently records the base document and all commentary. After the review has served its purpose it may easily be archived. All archived DocReviews are instantly available in read-only format. Besides performing the necessary recording function, this permanence encourages quality annotation. Knowing that your words are forever on the record sharpens the mind and cools the emotions.

Notification when annotations are posted is very important. DocReview has a feature which allows participants to request notification when comments are made on any particular DocReview. This feature is not only a service to the requester, but also acts as a stimulus to the collaboration itself since the notification messages tend to generate further participation from the requester. It is possible for a sponsor to sign up the entire research team on a mailing list for notification. The notification messages are designed to discourage off-the-record direct e-mail replies, so the requester must return to the DocReview in order to respond.

Collaboration must be encouraged at every opportunity. The knowledge that your participation or lack of collaboration is a matter of public record is a powerful incentive[15]. When the sponsor of the DocReview sends out an e-mail announcement of the review, everyone on the mailing list receiving the announcement knows who was invited to join the collaboration. Any social process creates its own in-group. If someone consistently fails to participate, they are soon perceived to be outside the group. Non-participants are unlikely to be included in any credits for the work.

Collaborators are psychologically motivated by many factors, not the least of which is vanity. We all want our colleagues to know that we are hard at work on the products of the collaboration. In addition to vanity there are mass and threshold effects. These effects suggest that social activity indicators should be included in any software intended for group use[16]. DocReview displays a message in its 'header' that tells the readers how many comments have been received, who the latest contributor was, and when the annotation was made. The sponsor of the review can often stimulate lagging participation by injecting a comment to "get things moving."

One of the strengths of asynchronous communication is its reflective nature. Recognizing the need for researchers to reflect on what they've read, and that the user's environment does not always include a computer connected to the WWW, DocReview provides a display option provided that inserts annotations into the document just below the appropriate review segment. This display, the "on-the-plane DocReview," can be printed, enabling the traveler to reflect on the document and its annotations while away from the office. Handwritten marginal notes can be keyed into the DocReview when the traveler returns to the Internet. DocReview soon may be enhanced to allow downloading a DocReview into a Palm Pilot, allowing comments to be uploaded to the server when the user returns to an office workstation.

Providing easy navigation to the services offered by the tool encourages use of any tool. All services beyond the basic commentary facility may be accessed in any DocReview by clicking a button marked "Special Features." An active collaboration may have many DocReviews in use at the same time. An index, which operates from a pull-down menu of active DocReviews, encourages navigation to any review at a click. A "What's New" feature provides the user with an itemized list of activity in any or all DocReviews on the site since any given date. Readers can get a complete activity log for the entire site by leaving the date open and selecting "All" from a pull-down menu of active DocReviews. The editor can see from the activity log who is contributing, and who isn't.

Users employing HTML in their commentary, or who cut and paste comments into the DocReview may use a preview feature to review the comment for typographical errors. After receiving the comment, as a polite gesture, DocReview thanks the contributor for each comment and offers to display all the comments made in the review segment just commented on. Notification of annotation to those who wished to be notified of changes is e-mailed by DocReview. The DocReview itself is updated immediately.

4.3.1 Universal Commenting Facility

In large research projects findings are often reported in essays or monographs. Position papers are frequently produced to clarify views on a topic. All these web documents, while finished, are, in a collaborative environment, always contingent and open to revision, correction, and qualification. DocReview has the ability to display the base document without review segment tags, the instruction headers and copyright notice. We can use this ability to give the editor the ability to present documents in plain form, but to offer the ability to comment on this same plain text. Clicking a "Read and Write Comments" link at the head of the page enables commenting. If you click that link the document is displayed on a new window in DocReview format ready for commenting. Each document then has a universal commenting facility.

4.3.2 Applying DocReview to Documents

Thought provoking messages or memoranda can be distributed on the WWW as DocReviews just as easily as through e-mail. The collaboration facilitator or other skilled staff member can manage the extra work of converting the memo to HTML. If cast in DocReview, all readers may comment on a common copy rather than engaging in a blizzard of repetitive and hard to follow e-mail replies (often not addressed to all recipients).

Specifications are documents that move interested parties toward the completion of a common task. Specifying the design and planning the completion of any large product is a rational and prudent action in any group activity. Several types of tasks are sufficiently complex to warrant description and design by specification: large documents, WWW sites, and software. Presentation of information on a large scale requires consideration of goals and means, audience, resources, information content and presentation. These requirements are quite similar in both text and hypertext. Software specifications are central to the successful production of useful programs. Both users and programmers use this common design document. Coming to a common understanding of functions and behavior of the software saves time and money. Having a permanent DocReview record of the dialog provides a necessary case history of this important phase of document or software development.

The writing task and annotation of drafts are key tasks in the final stages of most scholarly collaborations[17]. Drafts and outlines of professional papers may be reviewed with DocReview. Papers are usually far too long to be reviewed electronically as a single document but may easily be fragmented along the paper's logical divisions. The DocReview of a paper or other large work is entered through a DocReview of the Table of Contents of the work. The organization of the document in the large can be annotated in this DocReview, and each heading in the table can be made a link to a DocReview of that section of the work. In other words, there can be hypertextual organization within the DocReview itself. Collaborative grant proposals can be handled just as papers are.

In 1997 DocReview was used in the analysis of user evaluation questionnaires about an information collection and dissemination system. The questionnaire was presented on the WWW as a form with several free-form text inputs. Eight responses were received. These responses were blinded and redisplayed in DocReview to allow an analysis team to deconstruct the responses of each responder to determine what was causing the problems (or successes). These DocReviews were then used to create a document that summarized the analyses of the responses, question by question, and then recommended corrections to the design and presentation of the system. The recommendation document was itself mounted in DocReview to allow comments to be made on the recommendations. After the end of the review period and negotiations with the commenter, a report was issued detailing the changes to be made. The report was given to the software developers for implementation and letters were sent to the responders thanking them for their participation and detailing the changes made or not made in response to their comments.

While DocReview is an easy program to use, the work of the editor requires a modest knowledge of the server computer's operating system (UNIX) and HTML. Setting up the review segments in the base document requires some learning and practice. Furthermore there are some finer points of DocReview that are rarely used by an infrequent (or busy) editor. These skills are often not required in many of the collaborator's professional environment. We have found it almost imperative to have a technical person (collaboration facilitator) assigned to act as the editor for the entire team. The collaboration facilitator is called on often enough to stay "fresh" and on becoming familiar, by use, with the fine points can produce more effective DocReview installations.

4.3.2.1 Conversion of the Base Document

The document to be reviewed must first be converted to HTML. If the document was written in a WYSIWYG HTML editor such as Netscape Composer, then few if any modifications are necessary. Documents written in plain ASCII text may be converted to HTML manually or by first converting the to word processor files. Documents that are prepared in word processors may be converted to HTML with a converter provider in the word processor. The converted file is likely to contain many unnecessary tags that should be removed for clarity, compactness, and robustness. Dreamweaver makes a product that will clean up Word conversions[18]. The facilitator will act as editor for the mounting of DocReviews, so must be familiar with HTML and converters.

4.3.2.2 Tagging the Base Document

The base document HTML must now be tagged to identify the "review segments." A complete set of tagging instructions is available in the DocReview Editor's Guide. Review segments are sections of the document that may be individually annotated. There are two ways to tag review segments: use of existing HTML tags, or insertion of "special tags." For simple documents, a checkoff list may be used to select any or all of these elements to be designated as review segments: paragraphs, list elements, tables, and table cells. For more complex documents, using the "supplemental" special tag may also be used. The supplemental tag is a user-defined tag, defaulted to <rs> that will designate review segments. The supplemental tag is simply inserted wherever the editor wants to start a review segment. All review segments end at the start of the next review segment.

Other tags that may be used to make the review segments better defined are the "no tag" (<notag>) tag and "segment end" (<endseg> or <segend>) tags. The segment end tags are used to specify the ending of a review segment before the beginning of the next one. This is commonly encountered when the editor wants to leave section headings or quotations outside the review segment. The notag tag is used when the editor is using existing tags for review segments and wishes to declare that a particular review segment tag is to be disregarded. This allows a single review segment to include more than one paragraph or list element.

4.3.3 Managing the DocReviews

The management of the DocReview is done through a set of HTML form pages that may be called up from the "Managing the DocReviews" page. This page allows the editor to select, by button click, which of four operations (Create, Archive, Delete, Remove Comment) is to be performed.

4.3.3.1 Creating the DocReview

Once the base document has been converted and tagged, the creation of the DocReview is managed by filling out a form selected from the "Managing the DocReviews" page. The creation form contains many options that are explained through hypertext links from the form page.

Fields that must be filled out are:

- *HTML file name (the file name for the marked base document)*

The file must be located on the server where the DocReview programs can open it.

- *Review title (a short name for the review)*

In several places the DocReview program inserts a title for the DocReview. The purpose of the title is to differentiate between DocReviews in the index of DocReviews, not to describe the document under review. The length of the DocReview title is limited to sixty characters.

- *Review Nickname (the name of the directory for DocReview files)*

All the files for each document installation are kept in a single subdirectory. This directory needs to have a directory name for the URL that accesses the DocReview installation. The directory name has to be a unique legal directory name. In the case of UNIX machines this means some combination of upper and lower case letters, digits, and the underscore character. The program checks for this, so if your operating system accepts other characters, don't use them.

The DocReview "nickname" must be relative to the DocReview directory. Suppose you would like to create the nickname directory on the same level as the DocReview directory: in that case you should enter ".../Nickname" in the form. If the nickname directory is to be within the DocReview directory, then "Nickname" should be entered in the form.

- *Sponsor's Name (usually the author of the document)*

When the user submits a comment, the program sends an acknowledgment message. The sponsor's name is appended to the acknowledgment as a signature. If you wish to append a facsimile of your signature automatically to all acknowledgments, all you need to do is to create a scanned image of your signature and store it as "sig.gif" in the directory immediately above the DocReview directory.

If the editor accepts the standard default selections for the remaining fields, the DocReview may now be created by clicking the "CREATE DocReview INSTALLATION" button. But if the defaults need to be overridden, then the proper values may be entered in the fields provided for:

- *Review tags (default paragraphs and list elements)*

You may check off any or all of these elements to become review segments: paragraphs, list elements, tables and table cells.

- *Replacement review tag (default <rs>)*

The replacement review tag is simply a user-devised review tag that you may insert into the base document. You might make the tag <RS>, <FAKE>, <REPL> or any other non-standard HTML tag. You might need to place a review tag at a graphic, or at the document title. The replacement review tag allows you place a review tag anywhere in the document.

- *General Comments Allowed (default yes)*

Review segments allow the user to comment on a short section of the document, but frequently the user will want to comment on the entire document. This commentary may refer to the absence of some information, the general tone of the document, or perhaps even some general praise! Some documents may have special instructions such as a request for approval/disapproval, voting, a request for permanent annotations for an enterprise-wide annotated bibliography, or suggestions for entries in a glossary. The general comments section provides a place for special remarks. To add a general comments segment, accept the default (checked).

- *Suppress bolding of comments in the comment pages (default no)*

When the user clicks on the W tag of a review segment, the program pops up a page with a form to enter the commentary. In order to remind the user what is being criticized, the text of the review segment is written above the field for the comment. This text is normally presented in the bolded italic face. To eliminate this emphasis, accept the default value (checked).

Materials that benefit from eliminating the emphasis are review materials that contain bold face or italic text that provides meaning. Bibliographic materials are an example of material that projects meaning through typeface. Suppressing the program's emphasis allows the HTML tags for this material to function properly.

- *Log comment authors and their address (default yes)*

In order to automatically fill in the user's name and e-mail address in the comment form, DocReview's comment filing script creates cookies. These same cookies are also used to log the user's annotations in the log file (log.txt). If you check off this box, reading sessions will be logged using the cookie data, if not, the reading sessions will be logged anonymously. There is an ethical issue for you to decide. If you choose to log the reader's name and e-mail address do you need to inform the reader beforehand? Do you know all the readers?

- *Color of DocReview tags (default FF6508 -- orange)*

There are color accents throughout the DocReview pages, usually in the titles. If you don't care for the Insignia Orange color accent of the default setting you can change it by entering a six character hexadecimal code **RRGGBB**: where **RR** is the saturation of the red, **GG** is the green, and **BB** the blue.

- *Special Instructions to users (default blank)*

For most text documents the simple instructions in the header on how to read and write are sufficient. Special instructions might be in order for some documents. There might be a deadline for participation, say to reviewing meeting minutes that are to be published on a fixed schedule. Documents that accumulate new data in addition to commentary on existing data may refer the user to the general comments area to suggest new materials for the collection. You may use HTML in this field to provide emphasis, lists, or links.

- *Restrict writing of comments (default no)*

You may wish to restrict the ability to contribute comments to a select group, while leaving the review open for reading. If, for instance, you are reviewing a controversial document, open public commenting may dilute the comments of your reviewers or attract graffiti. If you wish to restrict both reading and writing, then simply use the .htaccess and .htpasswd methods of protection common to UNIX machines.

If you wish to restrict writing, enter a password of your choosing on this line. It is effective for this single document review. It is best to keep it short and in lower case. Be sure to notify your reviewers of the password. This can be done at the same time you announce the installation of the document for review.

- *List of people to notify of comments (default blank)*

If you are, as either a user or editor, involved in several reviews, it is quite burdensome to have to scan every DocReview installation to see if any comments have been made since last seen. DocReview can issue e-mail notification as comments are entered.

To notify someone, just enter the e-mail address(es) in the field provided. Separate the addresses by comma. Use no spaces! Addresses must be legally formatted, but the program cannot check to see if the legal addresses actually point to the right person. You may add names on this list, and add everyone on a separate list (see next item).

- *File name of comment notification list (default notificationlist.txt)*

To notify an entire list of people you must create a file of comma separated addresses. Use no spaces! Addresses must be legally formatted and correct because the program cannot check to see if the addresses actually point to the right person. Enter the file name (relative to the DocReview directory) in the form. The default file name is notificationlist.txt. You may add the names on this list, and add separate addresses (see item above). If notificationlist.txt is empty or nonexistent, no notifications are issued.

- *Name of directory for commonly used graphics (default .../graphics)*

In order for graphics to appear in the DocReview, the graphic files must appear in the nickname directory, which is created when you create the DocReview installation. Many graphics are used in several html pages and DocReviews. If you have copied every one of the commonly used graphic files into a single directory, the installation program will automatically create links from the nickname file to the common graphics directory. Specify the common graphics directory by entering the relative path from the DocReview directory to the common graphics directory. For example, if the common graphics directory is at the same level as the DocReview directory, and it is named "graphics" enter ".../graphics" in the input box.

After the form is filled out, the "CREATE DocReview INSTALLATION button is clicked and the computer creates the directory for the DocReview, creates the necessary files, and updates the list of active DocReviews. If there is a problem encountered, the computer sends back an explanation of what is wrong without making any changes to the files on the computer. The errors encountered are usually errors made by the editor in tagging, or providing a "nickname" directory that is illegal, or already exists. If the DocReview was successfully created, then the editor should carefully review the results to see if the tagging produced the desired review tag segmentation. If not, delete the DocReview and start over. If everything is OK, then announce that the DocReview is open to the team members.

4.3.3.2 Deleting a DocReview

Often a DocReview is prepared incorrectly and, on review, it is decided to correct the errors and reissue the DocReview. On other occasions, a DocReview that has served its purpose and does not need to be archived needs to be deleted. When a DocReview is created, there are several actions taken that need to be undone: directories and files need to be deleted, and other files need to have entries removed. There are so many small items to be done that there is a program in DocReview in order to automatically take care of deletions.

Deletion of a DocReview is managed by filling out a form that is presented when "Delete a DocReview" is selected from the "Managing the DocReviews" page. The deletion form asks the editor to select the name of the DocReview to be deleted from a list of all active DocReviews. When the editor clicks the "Delete the DocReview" button a verification page pops up with the directory name as well as the DocReview name and asks the editor to verify the deletion operation. If the "Yes" button is clicked, all traces of the DocReview are removed from the system.

4.3.3.3 Archiving a DocReview

The normal operation of the document refinement process leads the document through a sequence of edit/annotate/revise cycles. Before document revision. the DocReview of the current version must be archived in order to preserve the old version and all the annotations on it. In this way a complete revision record is maintained of every document. DocReview allows the archived versions and their annotations to be read. but not revised or added to.

A DocReview may be archived by filling out a form that is presented after "Archive a DocReview" is selected from the "Managing the DocReviews" page. The form asks the editor to select the name of the DocReview to be archived from a list of all active DocReviews. The archiving form contains many options that are explained through hypertext links from the form page. Fields that must be filled out are:

- *the nickname for the archive.*

All the files for the archives are all kept in a single subdirectory. This directory needs to have a legal directory name for the URL that accesses the archive. In the case of UNIX machines this means some combination of upper and lower case letters (a-z). digits. and the underscore character. The program checks for this. so if your operating system accepts other characters. don't use them. An archives "nickname" must be relative to the DocReview/archives directory.

- *the title of the archived DocReview*

When a DocReview Installation is archived. an index page is updated. The entry in the index page contains a title. which is set up as a link tag.

- *a description of the archived DocReview*

When a DocReview Installation is archived. an index page is updated. The entry in the index page contains a description that informs the user of the contents.

4.3.3.4 Deleting an Annotation

From time-to-time it becomes necessary to remove a single annotation from the record of an active DocReview. When an annotation is submitted, several actions are taken, all of which must be undone to properly expunge the annotation. An annotation may be expunged by filling out the form that is presented when the "Delete a Comment" button is clicked on the "Managing a DocReview" page. The form requests the following information:

- *the DocReview*

The form asks the editor to select the DocReview from a list of active DocReviews.

- *the number of the review segment*

The number of the review segment may be read from the filename of the annotation file for the review segment (the *nn* of point*nn*.html).

- *the number of the annotation within the review segment*

The number of the annotation may be read from the annotation file.

4.4 The Annotated HyperBibliography

The Annotated HyperBibliography (AHB) is the tool that manages the references for all the literature used in the Research Web (RW). The primary functions are: to display bibliographic information by clicking citations in RW Essays; to display abstracts of the works; to display full text of the work where available; and to provide a place for research team comments on the work. The AHB is an important component of the Research Web Essay (§3.4), providing a link to several increasingly detailed representations of the cited literature. If it were used in electronic journals, this facility would provide a way that "classical citation behavior may reach a much higher level of activity ..."[19].

The AHB is a suite of programs and web pages. A personal bibliographic manager (PBM), for example ProCite or EndNote, must be available on the facilitator's workstation. The PBM contains the basic bibliographic information for the AHB, all the bibliographic fields, abstract, URL for full text, and an identifying key. The PBM must have a "style template" installed that will translate the PBM data into an interface file that the AHB server software uses to display the information on web pages. There is a suite of management tools that accomplishes the conversion of the interface file into web pages. The only "manual" editing of files that may be required is the excision of inappropriate annotation.

4.4.1 Preparing the Bibliography

Bibliographic information is entered in the PBM largely just as one would for a conventional bibliography. The exceptions are to add a unique ten digit identifying key in one of the fields (usually the time of data entry in yymmddhhmm format is added to the ISBN or ISSN field); and to add the URL for full text if available (a seldom used field is usually appropriated). The fields used are at the facilitator's option. The "style template" will need to reflect the choices made. Any corrections to the AHB's bibliographic information are made in the PBM.

4.4.2 The Interface File

The interface file is produced using a PBM command to write a bibliography using the "style template". The style template is a modification of a copy of the file that produces the bibliographic format selected, for example Chicago B or APA. The style template causes a text file to be produced that contains not only the correct bibliographic format in HTML, but also keywords that the AHB's management software recognizes. Here is an example of one record of an interface file:

***key*9803031043**

***biblioentry*Agre, Phil. 1998. Designing genres for new media: Social, economic and political contexts. In <I>CyberSociety 2.0: Revisiting CMC and Community</I>. Editor Steve Jones. Sage.**

***abstract*This Chapter is a revised version of a manifesto for a course on conceptual design for a new media, taught to communication undergraduates at the University of California, San Diego from 1996 through 1998.**

***URL*http://dlis.gseis.ucla.edu/people/pagre/genre.html**

***author*Agre, Phil 1998**

***title*Designing genres for new media: Social, economic and political contexts**

EOR

Figure I An Interface File Record

4.4.3 Creating, Updating and Maintaining the AHB

Once the interface file has been created for the latest version of the AHB, the interface file must be transferred from the workstation to the web server. The management software of the AHB is then used to either create or update the AHB. The creation and updating programs are run from the WWW by clicking a button on the "Managing the Annotated HyperBibliography" web page. A form will be displayed for the facilitator to enter the necessary information, the name of the interface file and the directory of the AHB. After clicking "Submit" no further action is required. The management programs create or update the "catalog cards" and the author index and title index. The only maintenance tasks performed on the server are the occasional correction of an annotation, or the excision of inappropriate annotation. Correction of the bibliographic information is performed on the facilitator's PBM.

4.4.4 Uses for the AHB

The principal use for the AHB is to support bibliographic annotation of the Research Web Essays. The user of the essay can with a click pull up the bibliographic information for a citation. The popup window displaying that information has a button that will bring up a "catalog card." The catalog card provides the user with an abstract of the work (if present) and offers buttons to view full text (if on the WWW), and gives the user the opportunity to annotate the reference. The AHB also provides the EssayAssistant program with the information used to automatically build the references section for the RW Essay.

The annotation feature of the AHB is what sets it apart from static bibliographies. Criticism is a sharp intellectual tool that can perform several functions, many of them quality related. Errors or omissions may be noted. Interesting ideas can be highlighted. If a reference is superseded or challenged by new work, then that work may be linked directly from the annotation. Works that form the foundation of the team's research may be identified. Relationships between references may be established. Annotation allows the research team to add value to the references of the enterprise.

4.5 The Annotated HyperGlossary

The Annotated HyperGlossary (AHG) is a tool that allows the research team to document the language of the research enterprise. In an interdisciplinary research team, the vocabulary may contain terms that have substantially different meanings. The AHG allows not only the entry of definitions and alternate definitions, but technical glosses as well. The definitions are each contained in a web page that may be displayed at the click of a marked term within a document, usually a RW essay. The entire AHG may be displayed on the WWW. Each term and alternate definition may be annotated or glossed by any team member.

The AHG is a suite of programs and web pages located on the server. There is a program that allows insertion of a new term by filling out a form on the WWW. Every time a new definition is added the Annotated HyperGlossary web page is regenerated with the new material included in the proper place. Access to this program is usually restricted because the definitions and glosses usually contain cross-references to other terms, and cross-referencing requires some minor programming by the facilitator. When a definition is displayed, there is a button that may be clicked to bring up an annotation form. Annotations are displayed on the definition page. Should any annotation, gloss, or definition need to be revised, the facilitator must perform the editing as the text is contained on the server machine.

4.6 The EssayAssistant

The *EssayAssistant* is a tool that enables the author or facilitator to insert specialized popup windows into HyperDocuments, principally Research Web Essays. Displayed by a single click, these popup windows allow the reader to obtain additional information about the content of the document without leaving the HyperDocument. The windows may contain footnotes, sidebars, bibliographic information, glossary definitions, or simple notes. These features constitute the scholarly apparatus of the Research Web Essays, and they are complemented with the critical apparatus provided by DocReview. In order to create these popup windows, "poptags"— HTML-like tags, must be inserted into the base document.

The base document is then processed by a computer program, poptags.pl, that automatically converts the poptags into the much more complex JavaScript code. The program produces an output HTML file which contains all the HTML tags and scripts required to make the output file pop up the windows containing your information. The program also inserts, after the text, appendices for references, notes and definitions, all with return links. These insertions make the document read well in hardcopy where the user cannot pop up windows. As a matter of course, this HTML file is provided with a link to a DocReview of itself. This gives each HyperDocument a built-in critical apparatus.

4.7 What's New?

A distributed work group needs powerful tools to stay "glued together." One of the principal needs is to be informed about the group's activities, or "What's New?" What's New essentially allows anyone to receive a list of notification messages that were sent to members at the time of accession or document revision. As currently implemented *What'sNew?* only provides information on DocReviews. It needs to be expanded to include new documents, document revisions, comments on Annotated HyperBibliograpy (AHB) references, comments on Annotated HyperGlossary (AHG) definitions, and perhaps new entries in the AHB and AHG. When completely implemented, there will be a checkoff list for types of documents to be listed. Eventually, *What'sNew?* may be augmented with a program running in background on all team members' computers. This sort of background program could instantly inform the member of any activity as it happens: rather than seeing or hearing "You've got mail," you might see "New RW activity."

Notifications not only inform, but also remind members that there is work to do. These notifications, which are without cost to the contributor, are expected to increase access to the content of the RW[20] and thus participation. Xerox provides e-mail notification to changes in its Web-based repositories, including URLs rather than attachments[21].

What'sNew? presents the user with a form that asks for a beginning date for notifications. For instance the user may as for all comments on all DocReviews or a selected DocReview from some date forward. If no date is provided, the program will present a complete page showing the selected activity since project inception. This page will present transactions (creation/acquisition, commentary, archiving) chronologically and will have clickable links to the comments, archives, or current document.

4.8 Lexicon

The language of discourse for the Research Web must be well defined, especially in a multidisciplinary team. *Lexicon* is a tool designed to tease out the terms used by every discipline associated with the issue domain. The basic idea is very simple; a set of carefully central terms is defined and entered into the tool. Each of these definitions is then opened to criticism, and a request is made to identify and define terms associated with the parent term. Each of these new terms becomes a parent term of a new subhierarchy. Since a parent may suggest many terms, only a few steps can produce a very large number of terms. The lexicon of the issue domain is then fairly well established and can be moved to the more formal alphabetically ordered Annotated HyperGlossary where it can be further refined.

> *"There is a strong sense that the encyclopedic method, grouping words by themes, meets far more efficiently the need to see links and method amid the chaos of existence."*
> --- Jonathon Green, 1996[2]

The purpose of *Lexicon* is to convert the mental lexicon of the participant into a glossary that can be shared with other participants. The process of reflection and explaining helps the participant sharpen the internal personal meaning of the term. The existence of multiple meanings and nuances helps to explain the existence and causes of misunderstanding among colleagues.

Lexicon is organized in a hierarchical manner. The start of the lexicon is a set of contributed terms that are hopefully the major root words of the vocabulary of the issue domain. Each of these terms is then presented on a page that allows for discussion of the proposed definition. Every entry page can also propose subtopics which are presented on their own page. This process can extend without limit to finer and finer distinctions.

This sort of organization follows the lead of P.M. Roget who, in 1852, with his sons created one of the indispensable references for the English language, Roget's Thesaurus[23]. Roget took as his issue domain all the words of the English language. His initial categories were only six: Abstract Relations, Space, Material World, Intellect, Volition, and Sentiment and Moral Powers. The Fourth Edition, published in 1977, includes eight initial categories: Abstract Relations, Space, Physics, Matter, Sensation, Intellect, Volition, and Affections. A brief look at the Thesaurus will show its hierarchical organization.

The multiple and nuanced meanings of the terms are explained and debated in the commentary on each entry page. Within the lexicon, this debate will produce variant definitions or glosses. When the lexicon is fully matured, there is little use for the hierarchical organization --- its purpose has been served. Thus, at some point the lexicon is closed and the dictionary or glossary becomes the repository of the vocabulary of the issue domain. In our environment the lexicon is converted into an Annotated HyperGlossary.

4.9 Other Tools

The tools mentioned in this section are not ready for inclusion in the environment, but are needed. PicReview is a tool that allows annotation of any image. The Landscape of Reason is a tool that creates a graphic layout of an argument. This tool will give a synoptic view of the argument surrounding a proposition, including warrants, backing, and rebuttals. Three tools, not further discussed, have potential for use. The IdeaMill is a proposed brainstorming tool that incorporates features that mitigate the production blocking of "standard" brainstorming sessions, and features that capitalize on the advantages of asynchronous dialog. TimeMaps graphically describe the distribution of team members with respect to the position of the sun in the sky, showing how our circadian habits make synchronous communication difficult. State-Graph is a graphic method used to describe process behavior.

Tools appropriated by its team members will augment and evolve each Research Web. All disciplines and most specialties have software and conceptual tools that may contribute to the processes of modeling, understanding, and coordination. Geographic information systems cross all boundaries and find applications wherever physical distributions or differentiations are important. While this dissertation describes Research Webs dedicated to pure research, many if not most team efforts will likely be applied research efforts. Such RWs may need decision-making tools including voting tools and negotiation tools.

> *Rather than impose structure on the [Research Web] from the outset we want to support the evolution of its own gradations of structure, cohesion, and hence community dynamism.* — **m.c. schraefel 2000**[24]

4.9.1 PicReview

PicReview is a WWW-based interactive reviewing tool that allows the posting of an image that users can annotate by referring to regions demarcated by the user. This tool is the graphic analog to DocReview. Any user may define and name features or regions on the image; others wishing to comment may then reference these features or regions. Each annotation becomes the focus statement or question for public discussion just as if the annotation is a DocReview review segment. A complex image may be subdivided into separate reviewable areas or themes. Types of images that might be reviewed are: maps, diagrams, photographs, etc.

4.9.2 The Landscape of Reason

This tool is to be designed to allow informal argumentation about propositions or hypotheses. It is based on a technique outlined by Toulmin, Rieke and Janik[25] and explored by Liebow, et.al. [26]. This technique is somewhat more formal than gIBIS [now QuestMap][27], a technique that is slanted toward policy and decision-making.

The program builds a graphic presentation that is a map of a dialog about a single topic. The dialog surrounding any proposition is a great branching tree of claims, rebuttals, backing, and modal qualifiers. The tool builds a case graphically, showing the relationships in the argument. Much of the complexity of the argument is simplified by using hyperlinks to move sub-arguments to new pages. The claims, rebuttals, and backing are the findings that will come from documents such as minutes, essays, journals and reports. The Landscape of Reason could provide a framework for the analysis of the dialog. There is an active community of scholars working on this problem, referred to as Computer-Supported Collaborative Argumentation (CSCA).

Conklin, in a position paper[28], reports on the difficulties that inexperienced, or only moderately experienced, people encounter when using QuestMap. The learning curve is steep and for that reason, I propose using The Landscape of Reason only as a representation of the argument as prepared by the facilitator, not as an interactive tool. Like all representations, it will, however, be annotatable. Through annotation the team members may point out errors in the presentation and suggest inclusion of parts of the argument that may have been overlooked.

Notes to Chapter 4

[1] Ruhleder and King 1991, 352

[2] Orlikowski and Yates 1994, 555

[3] Marshall, et.al. 1999

[4] Bosak and Bray, 1999

[5] Valdes 2000

[6] Wooley 1998

[7] Palme 1995, 2

[8] Anon 1999, 348

[9] Holzschlag 2000

[10] Orlikowski 1993

[11] Grudin 1994

[12] Star, 1989

[13] Henderson, 1991

[14] Kaye 1992, 17

[15] Gächer and Fehr 1999

[16] Ackerman and Starr 1996

[17] Kraut, Galegher and Egido 1988

[18] Anon 1999, 346

[19] van Raan 1997,447

[20] Markus 1987, 502

[21] Rein, McCue and Slein 1997, 84

[22] Jonathon Green 1996, 13

[23] Roget 1997

[24] m.c. schraefel 2000, §4

[25] Toulmin, Rieke and Janik 1979

[26] Liebow, *et.al.* 1998

[27] Conklin and Begeman 1989

[28] Conklin 1999

Chapter 5 --- Empirical Investigations

In the sections that follow two collaborative tools will be examined: DocReview (see §4.3) and Research Webs (see Chapter 3). DocReview is a web-based tool that allows readers of documents to become reviewers. This critical capability allows the collaborators to correct, expand, and refine the documents. DocReview is an integral part of Research Web Essays, the principal textual tool of the Research Web.

The Research Web is a customizable collaborative environment that permits the research team in a long-term, large-scale enterprise to examine an issue domain thoroughly. The Research Web (RW) has a WWW site that serves as the repository of the team's corporate memory and research results. Tools available include a basic set that includes scholarly services of an annotatable bibliography and glossary, and an augmented web page format used for research essays. It incorporates any tool that the team finds necessary to its mission, provided that tool can be made web-compatible. Research Webs are unique, and for that reason may best be examined as case studies.

Table I Definition of Terms Used in Case Studies of DocReviews

Author, authoring team: the owner(s) of a document.
Base document: the document under review in DocReview.
Comment: the contents of an annotation returned by a reader.
Effectivity: the ratio of the size of comments received to the size of the review segment or the size of the base document.
Nature of participation: the number of people participating, the number of comments received, the volume of commentary (size), and the value [subjective] of the comments received.
Notification: e-mail sent to the reviewing team whenever a comment is received.
Quality of document, type of document: a score of value to the enterprise from 0 to 5 with zero being irrelevant and five being an essential product of the enterprise.
Review segment: a fragment, or chunk, of the base document that is the focus of annotation in DocReview. Usually a paragraph, element of a list, or a graphic insert.
Reviewing team, reviewers: people asked to participate in the DocReview.
Size (of document, comment, or review segment): the number of words longer than three letters.
Social character of comments: the content of the comments coded using the Bales IPA codes (see §5.1.4.2 below)
Substantive character of comments: the content of the comments coded using the Meyers structurational argumentation codes (see §5.1.4.2 below)

5.1 Case Studies of DocReview Installations

Since 1995, over 400 DocReviews have been installed. There are (or have been) at least nineteen DocReview sites, fifteen at the University of Washington, and one each at: University of California at San Diego, Haverford College, and the University of Wisconsin. Since the software has always been offered free of charge over the Internet, it may have been installed on several other servers, but these installations are likely to be inaccessible passworded intranets. The author has hosted several DocReview installations for other researchers to see if the system would help them in their work. Most of these installations were made at the request of people who wanted to use it as a tool to review independent documents, rather than as a part of an enterprise approximating the nature of a Research Web.

Five sets of DocReviews have been selected for detailed quantitative analysis in order to examine several propositions (see §5.1.6) that arise from the basic research questions. The basis of selection was their similarity to DocReviews that might be found in active Research Webs. These DocReviews were all under the control of a knowledgeable facilitator (the author). These 101 DocReviews contained 1929 review segments that attracted 294 comments. These comments were coded into 767 Bales codes (see Table V) and 425 Meyers argumentation codes (see Table VI). The data was mounted in a relational database to support data conditioning and analysis. Analysis was performed with a spreadsheet program.

Two of the selected sets of DocReviews were the minutes of 59 meetings. The meetings were task-oriented meetings with an attendance averaging six members, with occasional participation of others by telephone. The minutes were quite comprehensive and averaged two pages of text. DocReview was integrated into the meeting routines by directing the attendees to review the minutes on the WWW before the next meeting. At the next meeting the scribe would distribute copies of the minutes with commentary inserted inline. The scribe would then explain how the minutes were revised in light of received annotations, and the team would then approve the minutes or suggest other changes. Usually this discussion was over in two or three minutes, thus saving considerable meeting time.

One set of seven DocReviews was sections of a draft of a professional paper. The paper was divided into seven sections in order to reduce the time required for each reviewing session. In reducing the review time, the busy schedules of the reviewers could accommodate the small time slices. The reviewers were professional colleagues of the author, some of who were involved in the design of DocReview. The author found the annotations very useful and most were incorporated into the final draft of the paper.

Another set of DocReviews was 19 workshop position papers for the 1999 conference on Computer-Supported Cooperative Learning (CSCL). Reviewing position papers was seen as an excellent application of DocReview from the beginning of design. In practice it lived up to its presumed promise. Perhaps the greatest impact was not intellectual, but in opening networking channels.

The final set of DocReviews was a set of 17 documents, Research Web Essays, written for a Research Web for the issue domain of chromium (CrVI) contamination on the Hanford Nuclear Reservation. The set was quite successful in accomplishing the objective of refining the initial versions of the documents, each of which centered on one aspect of the contamination.

5.1.1 Research Questions

The major research questions and the propositions derived from those questions are:

A. How does the behavior of dialog using DocReview compare to dialog that is face-to-face?

Does the *social* character of comments in DocReview differ from comments in face-to-face dialog?

Does the *substantive* character of comments in DocReview differ from comments in face-to-face dialog?

B. How should DocReview be segmented in order to maximize the effectiveness of the participants?

For complete DocReviews

- Long base documents are ineffective relative to shorter documents.

For DocReview segments receiving comments:

- The amount of commentary received on a review segment will be directly proportional to the segment's length.

- The ratio of size of comments received to size of review segment will decline proportional to review segment size. (Long segments are less effective than short segments.)

C. How does the design of DocReview serve the research team?

Products similar to DocReview will emerge and will, by similarity, validate the design.

D. How does the quality of the document being reviewed affect the participation in the review?

Higher quality documents will attract more participation.

The nature of social commentary will vary with the type of document.

The nature of *substantive* commentary will vary with the type of document.

5.1.2 Design of Data Collection System

DocReviews have a very complete set of data. There are three types of data: text data, installation data, and transaction data. Text data includes the base document for the review and the annotations received from reviewers. The text data is contained in files on in single directory on the server (either active or archived). The text files include: the base document (basedoc.html), the HTML code for the document to be reviewed; comment files, either in a cumulative file (cummulate.html), or in files that contain the commentary on each commented review segment (point[nnn].html). Installation data is a set of parameters established by the editor at creation. Installation data includes the name and e-mail address of the sponsor, a list of e-mail addresses to be informed when annotations are received, and a descriptive title of the DocReview. The log file (log.txt) collects transactions (creation, annotation, reading and archiving) on the DocReview as they occur.

A program written by the author extracts and formats data from the files mentioned above. The program (makecsv.pl) creates several comma separated variable (.csv) files suitable for import into a database and thence to a spreadsheet program for the analysis. This program also does a word count on the base document and each of the document's review segments.

The analyst supplements two of the .csv files in order to add information that cannot be automatically extracted. A file (docrev.csv), that captures attributes of each DocReview, is augmented by including a description of the DocReview and a document type attribute designed to indicate the degree of quality, or the degree of completeness, of the document. This attribute is entered as a number from 1 to 5 and is defined as:

- 1 – a sketchy document designed to collect ideas or impressions before investing any more effort in the document. A brainstorming dialog.
- 2 – a first draft of a document, designed to catch major omissions, correct big mistakes and perhaps attract other authors.
- 3 – a working document not intended to be advanced to publication. Minutes and position papers would fit here.
- 4 – an advanced draft meant to polish the document before release as an essay for local use, or before submission to a journal for publication.
- 5 – a released essay, or a published article. Under review for picking up new material as time passes, or to attract rebuttals or support.

The coder modifies the comments.csv file to add both the Bales codes (Interpersonal Process Analysis) and Meyers codes (Structurational Argumentation).

5.1.3 Quantitative Descriptive Statistics

There are three levels of abstraction used in the evaluation of DocReview: the base document, the document being reviewed; the review segments, sections of the base documents that are the annotatable units; and the annotations or comments that are made by the reviewers. This section reviews the descriptive statistics for the quantitative data collected on these levels of abstractions. The unit of analysis is a count of words of four or more characters.

Base Document

The document that is prepared for DocReview is called the base document. It varies in size, and quality (the degree of development). Very large base documents are usually broken into sections, each a DocReview, in order to allow the usually busy reviewers to complete a section at one sitting.

Data collected on the base document for a DocReview includes a word count, the document type (quality), the sponsor (author), and date of creation of the DocReview. The text of the base document is also available.

Table II Words in Base Document

Base Document Size (word count)				
Characteristic	***All***	***Type 2***	***Type3***	***Type 4***
Mean	459.26	135.61	465.47	798.82
Median	422	130	469	598
Standard Deviation	325.27	91.259	196.71	695.66
Sample Variance	105801	8328	38693	483946
Kurtosis	20.77	-0.59	2.49	5.44
Skewness	3.44	0.48	0.88	2.22
Range	2647	309	1279	2657
Minimum	10	10	140	206
Maximum	2657	309	1279	2657
Count	100	13	76	11

The sample variances are too heteroscedastistic to employ an F test, so a logarithmic transformation was attempted in hopes of reducing the sample variances. The transform also failed to reduce the heteroscedasticity to an acceptable level. Differences between document types cannot be said to exist based on the base document word count.

Review Segments

Commentary other than general comments are directed toward a fragment of the base document called a review segment. Review segments are most frequently paragraphs or list elements (bullets), but occasionally include images or entire tables. The facilitator determines the review segments. The DocReviews in this case study were all prepared for review by the author and reflect a personal bias toward using relatively short review segments: paragraphs, at the largest; where lists are present, list elements; where large tables are presented, table cells; and individual graphic images. Section headings, bibliographic entries, and titles are usually excluded from review segments. Data collected on review segments consist of the text of the review segment and a word count.

Table III Words in Review Segments

Review Segment Size (word count)				
Characteristic	***All Types***	***Type 2***	***Type 3***	***Type 4***
Mean	24.89	35.60	21.09	73.86
Median	14	8	14	65
Standard Deviation	28.19	43.33	20.41	55.23
Sample Variance	794	1877	417	3051
Kurtosis	17	1.5	5.6	4.7
Skewness	3.2	1.4	2.1	1.7
Range	306	165	158	306
Minimum	2	3	2	2
Maximum	308	168	160	308
Count (Number of segments)	1822	48	1656	118

The sample variances of both the raw data and a logarithmic transformation are too heteroscedastistic to perform a reliable analysis of variance. A null hypothesis of no differences between the three document types cannot be rejected. Examination of the means and standard deviations points out and obvious difference between types 3 and 4. This conclusion is supported by the nature of the genres represented: type 4 documents are drafts of conventional papers dominated with paragraph-long segments; and type 3 documents are dominated by meeting minutes composed of short segments such as action items and list bullets.

Comments

Each review segment attracts a set of comments, usually an empty set. The set may include not only comments on the review segment, but also comments on the other comments on the review segment. The comments are entirely free form. either text or HTML. and may include emphasis, paragraphing and even images.

Data collected on comments includes: the text of the comment. a word count. the name of the commentator. the commentator's e-mail address, the time and date, and the qualitative coding of the comment, both Bales codes (see §5.1.4.1) and Meyers codes (see §5.1.4.2). Due to the unrestricted length of comments. the unit of analysis for coding purposes must usually be a fragment of the message. The Bales codes were assigned to comments by dividing multi-sentence comments into written equivalents of speech acts. These fragments. as noted by Henri cannot be rigidly determined. but must be parsed out based on the analytic objectives[1]. This same conclusion is seen in Meyers. *et.al.*. where the units were "complete thoughts." rather than words or turns[2]. Occasionally. there are additional. usually social. meanings that can be read into the commentary. For example. the wording of a comment may contain aggressive or supportive intent.

Table IV Words in Comments

Comment Size (word count)					
Characteristic	***All Types***	***Type 2***	***Type 3***	***Type 4***	***General***
Mean	31.83	34.80	21.49	54.46	30.73
Median	19	22.5	12.5	43	12.5
Standard Deviation	37.61	36.98	26.79	48.01	36.77
Sample Variance	1414	1367	717	2305	1352
Kurtosis	14.6	1.2	40.3	7.9	0.8
Skewness	3.1	1.5	5.1	2.2	1.5
Range	289	122	256	288	124
Minimum	1	3	1	2	1
Maximum	290	125	257	290	125
Number of Comments	233	20	148	65	40

The sample variances are too heteroscedastistic to employ an F test. so a logarithmic transformation was attempted. The sample variances found in the transform were 1.18. 1.09. and 1.02. Using the transformed data a value of 22.1 was found for F. The value of $F_{2,232(.001)}$ is 6.9. so a null hypothesis of no differences between the three document types can be rejected at the .001 level. Comments made on type 4 documents are much longer on average than comments made on type 3 documents such as meeting minutes.

In analysis of the DocReview commentary. it was discovered that the DocReviews of meeting minutes constituted a subset of commentary that demonstrated very random annotative behavior (see Figure VII). When the comments for meeting minutes are removed from the Type 3 comments, the sample variances are too heteroscedastistic to employ an F test, so a logarithmic transformation was attempted. The sample variances found in the transform were 1.18, 1.26, and 1.01. Using the transformed data a value of 2.65 was found for F. The value of $F_{2,104(.10)}$ is 2.36, so a null hypothesis of no differences between those three document types can be rejected at the .10 level.

5.1.4 Qualitative Coding Systems

Analysis of the content of the annotations must start with the selection or invention of a qualitative classification system. Many investigators have seen the wisdom of creating coding systems that are fitted closely to their problem. I chose to use existing systems, thus providing a possibility of drawing comparisons. I chose two systems, one for gauging the social functioning of research team, and the other to show how commentary became argumentation in the review of the document.

Any classification scheme must serve to differentiate between members of a group of cases. In our study the cases are DocReviews, an object that consists of a document that is partitioned into "review segments", and a set of comments made on each segment. The number of comments may be zero or more, and is usually zero. In uncommented segments, the question of implied agreement must be raised. One may be tempted to assume, since there is no limitation on reflection, that the reviewers agree with the review segment. Implied assent is very dangerous because it enables power mechanisms. No comment just means that the reviewers chose not to add to the dialog[3].

So how can we differentiate between the DocReviews? Certainly there are descriptive statistics such as size of the base document, the number of review segments, the number of comments, when the comments were made with respect to opening the review process, the size of the comments, and who made comments. These data were maintained in the log files, which are features of DocReview.

Beyond these physical statistics are the study of the character of the social interactions of the review team, the interpersonal process analysis (IPA); and the study of the efficacy of the review process, how the review contributed to the refinement of the knowledge represented by the document. Both the IPA and studies of efficacy can be conducted only by analysis of the content of the annotations. Measurement of the value of the comments to the collaboration is quite impossible in most cases, but a qualitative categorization of comments can be done by at least two classification schemes: an observational scheme and a scheme based on how the comments would fit into a formal argument. We must then code the DocReview multilogues twice, once for the social dimension of process-orientation and again for the knowledge content dimension of task-orientation.

To analyze the interpersonal process analysis of behavior in DocReviews, I classified the annotations using the Bales' codes[4], a well developed and respected tool. Analysis of how comments within a DocReview contributed to the knowledge-building content of the document will be conducted using a coding system based on the function of the comment from a task-oriented viewpoint, rather than from a social viewpoint as in IPA. The task-oriented functions are defined as the character of the comment (or comment fragment) in a formal argumentation framework. Meyers, Seibold and Brashers developed this coding system that was based on, and extended from, their previous work[5].

Classification schemes need to satisfy three conditions[6]:

- There are consistent, unique classificatory principles in operation.

- The categories are mutually exclusive.
- The system is complete [exhaustive[7]].

The coding schemes I use vary in compliance with these desiderata. Bales codes are not complete; there is no place for nonsense or muttering. The Bales codes are not mutually exclusive, they instead are derived from four fairly distinct major categories that are each divided into three quasi-ordinal codes that have very fuzzy boundaries, e.g. what is the difference between giving information and giving an opinion? Bales attempts to close the ambiguities in the codes by a very thorough explanation of each[8], but overlaps and gaps exist.

Meyers' scheme provides a less complete guide to coding[9] (appropriate for a research article as opposed to Bales' book). Both coding schemes are well described and coders can become facile with them in a reasonable time period. In reference to mutual exclusivity, a continuous system like Bales' IPA, must have fuzzy boundaries. Meyers' system is not a continuous system so is immune from this argument.

Meyers' scheme neatly solves the completeness problem with the introduction of the category "non-arguable." Fortunately, this category can contain no contextual knowledge, so it can safely be excluded from our analyses. Bales asserts that his categories are made complete and continuous by being concerned with the interaction content rather than the topical content and by eliminating any requirement for the observer "to make judgments of logical relevance, validity, rigor, etc."[10].

Correct assignment of codes could perhaps be tested by comparing actual results from dialog in the source research and the coding of the same material by the author. In short, such testing would require studying intercoder reliability between the teams of Bales and Meyers and the team (myself) that would code the annotations. Bales offers six pages of coded dialog[11]. Meyers et. al. offers some short examples. Both papers do offer good definitions of the categories. The categories are based on dialog quite familiar to any literate individual. A larger issue is the absence of gestural side-channel communication (head nodding, eye-rolling) in DocReview. As face-to-face dialog would present frequent "speech acts" that are gestures, facial expressions, or voice tones, there will be a loss of that dialog in the coding of DocReview annotations. This loss may account for some of the significantly lower "social-emotive" codes in the DocReview annotations.

I can only compare DocReviews to DocReviews since there was no attempt to set up a control review method by other means. In the DocReview study, all DocReviews use the WWW and are thus device independent. Usually, the participants within a given set of DocReviews are homogeneous, though between sets, they may vary in number. The same task is always performed: review of a document, though the nature of the documents may change (meeting minutes, position papers). Almost all users are invited, since most DocReviews are on intranet sites. Other than the exceptions noted, most dependent variables are identical. Most studies that apply IPA compare computer-mediated communication with face-to-face communication. In a meta-analysis of studies of computer-mediated collaboration, McGrath and Berdahl[12] make several cautionary points based on differences between face-to-face interaction and computer-mediated interaction: studies often use different computer systems; different kinds of participants are used; different types of tasks are performed; and there are different patterns of dependent variables.

5.1.4.1 Interaction Process Codes

These codes are intended to assign speech acts, including backchannel communication, to categories that are based on social processes rather than substantive content. Since we are social animals, the nature of our dialog will to a great extent determine both how we respond emotionally to our collaborative environment and how effective that environment is in attracting productive participation.

The Bales Code

Commentary of hyperdocuments through DocReview can be evaluated by use of categorization, volume and quality. DocReview comments can be categorized by using Bales codes[13]. Depending on the issue domain, these codes can be used to order value between categories. For instance, detection of errors in spelling or grammar is a low value contribution in studies of social behavior, but a high value contribution in the development of a manifesto or epic.

Table V Bales Code for Acts in Social Interaction

Main Categories	Frequency	Types of Acts	Frequency
Positive reactions	25.9%	Shows solidarity	3.4%
		Shows tension release	6.0%
		Shows Agreement	16.5%
Problem-solving attempts	56.0%	Gives suggestion	8.0%
		Gives opinion	30.1%
		Gives information	17.9%
Questions	7.0%	Asks for information	3.5%
		Asks for opinion	2.4%
		Asks for suggestion	1.1%
Negative reactions	11.2%	Shows disagreement	7.8%
		Shows tension	2.7%
		Shows antagonism	0.7%

--- after Bales, 1955

Commentary that expresses support or disagreement is not valueless, for such commentary does influence the behavior of the author and other contributors. So most commentary is of some value, even if it is merely reinforcing the recognition of a team effort. Sadly there are comments of negative worth that occasionally emerge, such as personal attacks or senseless graffiti.

Gay et.al. and classroom discussion forums

Geri Gay and others studied the character of student contributions by computer-mediated communication in university classes[14]. The discussion forums were conducted in CoNote, a WWW-based annotation program functionally similar to DocReview. Gay's study included questionnaires and observer data as well as a repository of documents and comments thereon. Gay's codes, like Bales' codes, are not based on the relationship of the annotation to the collaboration task, but on the character of interpersonal activity. Content of the annotations was organized into three categories: technical comments, affiliative comments and advice. Presumably, a single comment could contain all categories, but not multiple occurrences of a category. 197 comments produced percentages of 50.3 technical, 45.2 affiliative, and 68.5 advice. These percentages were obtained in an environment dominated by students who came into frequent contact, thus by age and group structure more inclined to engage in affiliative commentary than professional groups might be.

These codes are equivalent to portions of the twelve category Bales Codes for Interpersonal Activity. The *affiliative* comments, which presumably could be positive or negative, would fall into one of six categories: Shows Solidarity, Shows Tension Release, Agrees, Disagrees, Shows Tension or Shows Antagonism. The *technical* comments would fall into the neutral task-oriented area: Gives Opinion, Gives Orientation, Asks for Orientation, Asks for Opinion. The *advice* category corresponds to the extreme range of the task-oriented area: Gives Suggestion and Asks for Suggestion.

5.1.4.2 Argumentation Based Codes

If research is analogous to argumentation, as Eisenhart and Borko suggest[15], then a coding system that is based on the argumentation process would seem to be a more effective alternative for characterizing task-oriented activity than the more process-oriented Bales IPA coding. The value of a comment fragment (coding unit) to the collaboration is more closely related to task than process. Perhaps we can assign a value to a specific type, or if the coder is familiar with the document, we can actually assign an interval measure for value. Three coding systems have been considered: informal argumentation codes, structurational argument codes, and an observational categorization.

Informal Argumentation

In *An Introduction to Reasoning*, Toulmin, Rieke and Janik develop a dialog classification based on argumentation[16]. Their system is proposed to be the basis for development of a tool (The Landscape of Reason) to organize dialog for the Research Web. Argumentation is broadly defined in this work, having a place in any "rational enterprise." As the authors put it, "... scientific arguments are sound only to the extent that they can serve the deeper goal of improving our scientific understanding." Every coding unit of a comment can be assigned a type based on this classification. The value of the comment in terms of value to the collaboration can be established through a surrogate, the value of the comment in the argument. There are six elements in argumentation: claims, grounds, warrants, backing, modal qualifiers, and rebuttals.

- Claims are assertions put forward publicly for general acceptance. In DocReview terms, every review segment is a claim. The claim is that the review segment, whatever its nature within the document, presents and argues its proposition well, and conforms to accepted standards. For example, the role of a review segment within the document may be that of, say, a rebuttal. Comments directed toward the review segment can, in a recursive way, present grounds, warrants, backing, modal qualifiers and rebuttals to the review segment's basic claim *as a rebuttal*.

- Grounds are facts that support a claim. Comments may be directed toward the grounds given, in our example the grounds supporting a rebuttal.

- Warrants are ways of describing how one can validly draw a conclusion from the grounds offered. This is the argument in argumentation.

- Backing makes explicit the experience relied on to establish the trustworthiness of the warrants. In scholarly documents, citations of literature are the principal means of supplying backing.

- Modal qualifiers are statements that show what kind and degree of reliance is to be placed on the conclusions.

- Rebuttals are statements showing exceptional circumstances where the conclusions might be undermined.

Structurational Argument Codes

In research on decision-making discussions in a face-to-face environment, a set of seventeen categories describing statements in terms of their place in argumentation was developed and used by a team that studied 45 discussions. This research had its roots in research by Toulmin (in 1958) and two other research teams in 1969 and 1980[17]. I can find no subsequent application of this coding scheme in the literature. Coding is extremely difficult, as meanings can shift with context. The coder must be thoroughly immersed in the argument, not just the words, but also the intent of the words.

In Meyers *et.al.* discussions were analyzed with 8,408 codes produced, having the distribution given in the following table[18]. This dissertation found 425 codes in the DocReview annotations.

Table VI Structurational Argumentation Codes

ARGUABLES (67.4%)	Potential Arguables	***Assertions***	Statements of fact or opinion.
		Propositions	Statements that call for support, action or conference on an argument-related statement.
	Reason-using Arguables	***Elaborations***	Statements that support other statements by providing evidence, reasons, or other support.
		Responses	Statements that defend arguables met with disagreement.
	Reason-giving Arguables	***Amplifications***	Statements that explain or expound upon other statements in order to establish the relevance of the argument through inference
		Justifications	Statements that offer validity of previous or upcoming statements by citing a rule of logic (Provide a standard whereby arguments are weighed).
REINFORCERS (13.6%)		***Agreement***	Statements that express agreement with another statement.
		Agreement +	Statements that express agreement with another statement and then go on to state an arguable, promptor, delimitor, or non-arguable.
PROMPTORS (2.3%)		***Objection***	Statements that deny the truth or accuracy of any arguable.
		Objection +	Statements that deny the truth or accuracy of any arguable and then go on to state another arguable, promptor, delimitor or nonarguable.
		Challenge	Statements that offer problems or questions that must be solved if agreement is to be secured on an arguable.

Table VI (continued)

DELIMITORS (2.1%)	***Frames***	Statements that provide a context for and/or qualify arguables.
	Forestall/ Secure	Statements that attempt to forestall refutation by securing common ground.
	Forestall/ Remove	Statements that attempt to forestall refutation by removing possible objections.
NONARGUABLES (14.5%)	***Process***	Non-argument related statements that orient the group to its task or specify the process the group should follow.
	Unrelated	Statements unrelated to the group's argument or process (tangents, side issues, self-talk, etc.)
	Incomplete	Statements that do not provide a cogent or interpretable idea (due to interruption, stopping to think in midstream, but are completed as a cogent idea elsewhere in the transcript.

after Table I Meyers, Seibold and Brashers[19]

While Meyers et.al. conclude that the structurational argumentation codes reflect *both* process-orientation and task-orientation (or system and structure, as they put it): the coding scheme clearly supports task-orientation much better than the Bales IPA. In terms of support to a collaborative task, some categories have more value than others.

These argument codes provide places for every element in the Toulmin informal argumentation scheme. The nonarguables Process and Unrelated are very convenient "bins" for trivial or procedural content. One of the seventeen codes is extremely unlikely to be used: the nonarguable *Incomplete*. The argument codes were developed to analyze transcripts of face-to-face interactions, an environment where interruptions are frequent.

It is difficult to imagine how an asynchronous contribution could be interrupted: if the writer is interrupted at the terminal, then the task can be resumed when the interruption terminates.

The Meyers, et.al. study used transcripts of actual face-to-face multilogue, with recourse to videotape only when the expression needed clarification[20]. Interruption and incomplete expressions were frequent, as in normal conversation. The computer-mediated environment of DocReview will make interruption unlikely and incomplete thought rare. I expect the distribution of message fragments in DocReviews to be quite different from conversational multilogues. As McGrath and Berdahl cautioned, these differences may be due to many different factors[21]; nevertheless, if the differences are great, the argument in favor of computer-mediated communication as a more reflective medium gains support.

An Observational Categorization

The author's five years of experience in the use of DocReview has led to a potential coding system based on observation and sorting. Interpretation and characterization of the codes are based not only the original context of the commentary, but on assumptions of what character the comments would take in a fully implemented Research Web.

This scheme categorizes several nominal classes of comments seen in DocReviews. It has the advantage of being completely specific to DocReviews; that is it is not time restricted, and is asynchronous, document-centric. Most DocReview review segments, especially paragraphs, will contain an assertion, a conclusion and give evidence showing how the conclusion follows from the assertion. In addition to this logical imperative (substantial) there is also the requirement to conform to appropriate standards of scholarship and presentation (formal). In the Research Web environment, the documents are also subject to both the criticism process and an editing process.

Table VII

Observational Categorization of DocReview Annotations

	Substantial	***Formal***
Editing Process	• Supplies references and citations. • Supplies new information or examples. • Suggests deleting information.	• Corrects spelling or grammar. • Questions document layout. • Questions sentence or paragraph structure.
Criticism Process	• Questions validity of statements. • Gives opinions or suggestions. • Supports or rejects substance with grounding.	• Supports a comment w/o supplying new information. • Disagrees with a comment w/o supplying new information. • Questions or discusses the philosophical bases of the document.

5.1.5 Qualitative Coding Reliability

In the analysis of the data, the distribution of codes in the DocReview commentary is compared to the distribution of codes in the studies that defined the codes. In comparing the distributions, there is the necessary assumption that all coding would be consistent and correct. Bales points out three sources of variation between coders: unitizing, the correct parsing of dialog into units of analysis; categorizing, correct assignment of codes; and attributing, the source and target of the dialog[22]. There is, in the DocReview analysis, no question of the source and target. Because this dissertation was not well funded, the author did all coding, so the skill and consistency of coding was not established by comparing the coding of dialog by independent coders.

Unitizing is a significant source of variability. The variability in unitization is induced by uncertainty in interpretation. Some methods of unitizing are less susceptible to variability than others. Time-based unitization, segments of elapsed real time, are not subject to interpretation[23]. Turn taking in speech dialog is more variable due to complications that arise in parsing of monologues; annotations in DocReview are essentially monologues. Parsing face-to-face dialog into speech acts (Bales) is yet more variable because there is a need for insertion of implied speech acts and gestural acts. Even more variable is the event-based coding that was used in the argumentation coding (Meyers). Nyerges *et.al.* chose time-based coding over event-based coding because event-based coding required at least two coding passes[24].

In the Bales coding, DocReview annotations were parsed during coding into approximations of "speech acts" by dividing the annotation into phrases, sentences or a set of contiguous sentences that dealt with a single topic. Not infrequently when the coder understands both the review segment and an annotation well, implied codes emerge. One comment usually contained a few codes (mean = 2.6) sometimes as many as a dozen. This parsing is assumed to be equivalent to the turn taking of face-to-face dialog.

In the argumentation coding, the unitizing protocol used in Meyers et.al. could not be employed since their unitizing was done by two judges concurrently. As Meyers used transcripts of dialog, so I used written dialog. The unitizing rule that Meyers et.al. used was: "any statement that functioned as a complete thought or change of thought." The Meyers team coded dialog that was parsed into turns, while DocReview comments are relatively long monologues. Rather than parsing the monologue into speech acts I parsed it into argument units that might include several sentences. Such units fit well into the

Meyers categories. One comment usually contained one to a few codes (mean = 1.4) sometimes as many as eight.

Coding and unitization of DocReview annotation requires the coder to place the annotation into the context of the review segment being annotated. This contextualization is done by mentally converting the annotation unit and review segment into a narrative equivalent. Unfortunately, returning to the exact same mind set is difficult for either independent judges or for the same coder repeating the coding at a later time.

5.1.5.1 Coding Reliability Tests

In order to test the reliability of the coding, it was decided to take a 12.5% random sample of all review segments that received comments. The author, who was the original coder of the entire set of comments, then recoded this sample. There was no recall of the original coding.

Four sets of codes were tested for reliability: the Bales codes (twelve categories), the Bales categories (four sets of three codes each), the structurational argumentation codes (seventeen categories), and the five structurational argumentation categories derived from the seventeen codes.

5.1.5.2 Data Conditioning

The parsing of DocReview annotations into coding units (unitizing) proved to be uncomfortably variable. It seemed that the degree of engagement by the coder was the principal source of variability. When coding the annotations, the context had to be set by reading and understanding the review segment and then interpreting the annotation in context. When the coder is well engaged, the dialog shows more nuances (codable) than a perfunctory reading would provide. Of course coder drift and fatigue contributed to the variability too. If the coder is heavily engaged in reading between the lines, and sees and records an implied code that another does not, then there will be a difference in the number of codes. The two code strings may not align: for instance coder 1 codes "acbbbca" and coder 2, missing the implied code, codes "cbbbca".

Aligning codes at the beginning gives:

```
acbbbca
cbbbca
```

This results in 2 agreements, 4 disagreements, and one not matched.

If on the other hand we align like this:

```
acbbbca
 cbbbca
```

Then we have a probably more accurate analysis of six agreements and one not matched.

If such realignment is allowed it is subject to much abuse, so I allow only a shift of the entire shorter code string within the limits of the longer code string. If the code strings are of equal length, then no shifting is allowed. Any unmatched codes resulting from unequal code string lengths are removed. Both Bales and the structurational argumentation codes were conditioned this way, and the resulting conditioned data was converted to the aggregated categorical data (the four Bales categories and the five structurational argumentation categories).

5.1.5.3 Analysis

Intercoder or recoder reliability can be measured by several methods. Cohen[25] and Landis & Koch[26], in their examples, use nominal categories that are clear, complete and mutually exclusive. On the other hand Perreault and Leigh use more qualitative (though unstated) codes[27]. On this basis, plus favorable arguments from the Meyers et.al. paper, I am inclined to use the Perreault and Leigh measure. Since Cohen's kappa is so widely used, I include it for comparison purposes.

The conditioned data were placed in contingency tables comparing the two coding sessions. From the contingency tables, Cohen's kappa and Perreault and Leigh's Index of Reliability were calculated for the four sets of data.

Bales codes

From the initial set of 99 Bales codes, there were 82 codes remaining in the conditioned data. Each code could assume one of twelve values. Comparing the two sets showed 54 pairs in agreement, 28 pairs in disagreement and 17 unmatched codes. Cohen's kappa[28] for the Bales codes is 0.538, showing only moderate agreement between the two coding sessions[29]. The Index of Reliability[30] is 0.792 with a 95% confidence level of +/- 0.088. This mediocre result, in conjunction with some very low counts of several codes, provided the argument to use only the four Bales categories in the analysis of DocReview annotations.

Bales categories

In analyzing the four Bales categories, each code could assume one of four values. Comparing the two sets showed 80 pairs in agreement, 2 pairs in disagreement and 17 unmatched codes. For the Bales categories, Cohen's kappa is 0.878, showing almost perfect agreement between the two coding sessions. The Index of Reliability is 0.984 with a 95% confidence level of +/- 0.027.

Structurational argumentation codes

From the initial set of 70 structurational argumentation codes, there were 48 codes remaining in the conditioned data. Each code could assume one of seventeen values. Comparing the two sets showed 21 pairs in agreement, 27 pairs in disagreement and 22 unmatched codes. Cohen's kappa for these codes is 0.402, showing only fair agreement between the two coding sessions. The Index of Reliability is 0.668 with a 95% confidence level of +/- 0.133. As with the Bales codes, there were a large number of codes with low to zero counts.

Structurational argumentation categories

In analyzing the five structurational argumentation categories, each code could assume one of five values. Comparing the two sets showed 28 pairs in agreement, 20 pairs in disagreement and 22 unmatched codes. Cohen's kappa is 0.383, showing only fair agreement between the two coding sessions. The Index of Reliability is 0.673 with a 95% confidence level of +/- 0.133.

5.1.5.4 Conclusions

It was presumed that the Bales codes would measure the social aspect of DocReview "dialog." The reliability of the coding was acceptable, especially for the four Bales categories. It must be noted however that the strong concentration of the codes into the positive task-oriented category results in reliability that is perhaps misleading.

The structurational argumentation codes were too numerous and difficult to code to produce acceptable reliability. Applying argumentation codes to analysis of DocReview annotations will require the use at least pairs of coders working together (as Meyers et.al. did). The unitization problem was extremely serious, producing almost a one third rate of no matching codes. The combination of arbitrarily long review segments and arbitrarily long annotations will demand a very clever unitization scheme to produce any hope of consistent coding.

5.1.6 Analytical Results

The proposition designations below (e.g. A2) refer to the research questions discussed in §5.1.1. Three techniques were used to test the propositions: Chi-squared, regression analysis, and case studies.

Four of the propositions use the Chi squared test comparing the counts of DocReview codes versus the coding distributions in the original Bales and Meyers studies. In order to normalize the sample sizes a pseudo-sample of the Bales or Meyers codes was drawn with the same distribution as in the original studies but with a size equal to the DocReview sample.

Four of the propositions were tested using single variable regression analysis. In all these cases the independent variable (X) was the word count of the base document or a review segment of the base document. In some cases the dependant variable (Y) was confounded with the independent variable. This confounding was due to the definition of effectivity as the ratio of commentary to the size of the document (effectivity = Y/X). The shape of the best fitting regression line was found to be logarithmic.

One of the propositions was a case study comparing DocReview to three other web-based annotation programs. The comparison was made on the basis of a universe of features found in all the programs.

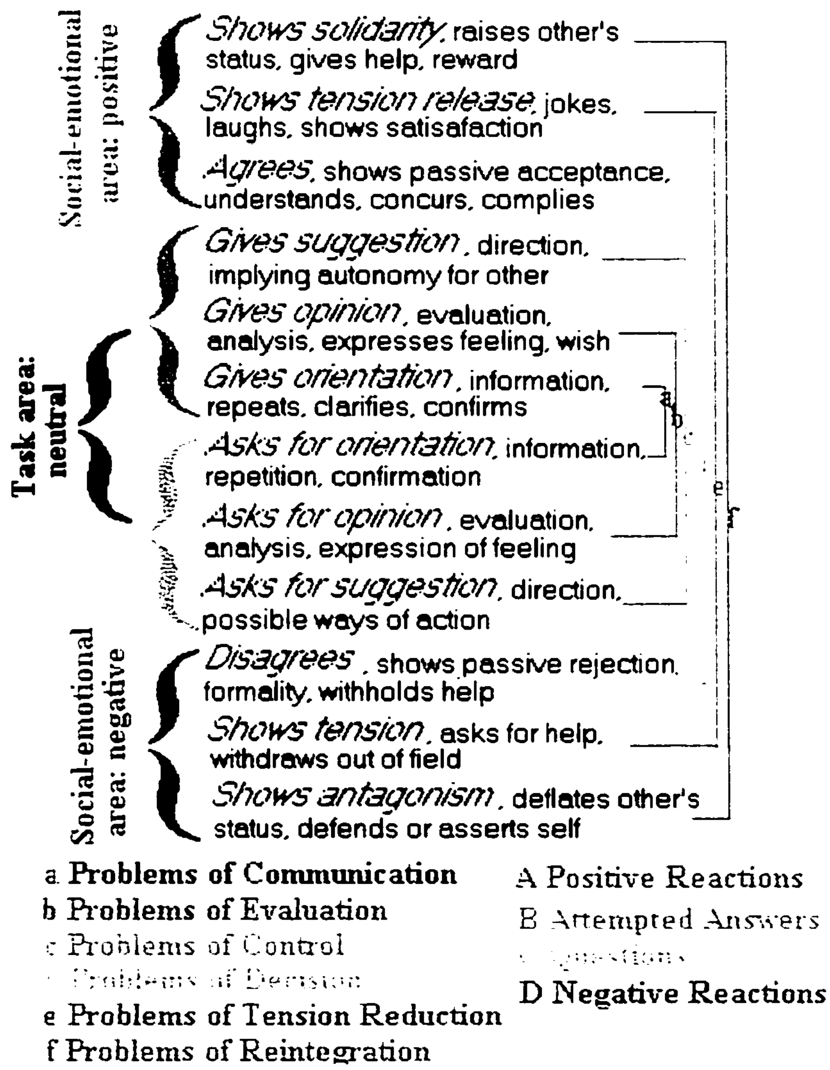
5.1.6.1 Proposition A1. The social character of comments in DocReview differs from comments in face-to-face dialog.

One of the most important questions arising from the use of DocReview is how the nature of dialog in DocReview is different from face-to-face dialog. Fortunately we have from Bales' work a distribution of codes assembled from thousands of face-to-face speech acts. If one makes the assumption that DocReview annotation is equivalent to one side of a face-to-face dialog, and further assume that in face-to-face dialog the two participants each produce an identical distribution of coded speech acts, then we can make a valid comparison. The assumption of equivalence is strained by the odd nature of this communication: essentially the document is the source of a series of propositions. The annotation is a set of responses to the proposition presented in the review segment by the readers. This set of responses is also complicated by the not infrequent presence of commentary on other annotations.

Operationalization:

Assigning Bales codes categories to all annotations operationalizes the social character of the comments. The Bales Interaction Process Analysis categorizes all speech acts, including gestures, into twelve codes. The differences between some of the Bales codes are very slight. These fine nuances result in a high variability between coders or between coding sessions by the same person. In order to reduce the intercoder variability it was decided to use Bales' broader classification: categories. Bales grouped the twelve codes into four categories that are generic and form a good basis of comparison. These categories are: positive reactions, problem-solving attempts, questions, and negative reactions. Problem-solving Attempts and Questions are further generalized into a supercategory of the task area, while Positive and Negative Reactions are generalized into the social-emotive area.

Table VIII Bales Interaction Process Analysis Codes



from (Bales 1950)

Data conditioning:

None.

Data Analysis:

The counts of codes of the entire set of DocReview annotations by Bales category demonstrates that DocReview annotations show a much higher degree of task-related dialog and a much lower degree of social-emotive dialog than is seen in face-to-face dialog. The comparisons (DocReview/face-to-face) are: for Negative Reactions -- 0.1%/11.2%; for Questions -- 7.3%/7.0%; for Problem-Solving Attempts -- 85.5%/56.0%; and for Positive Reactions -- 7.0%/25.9%.

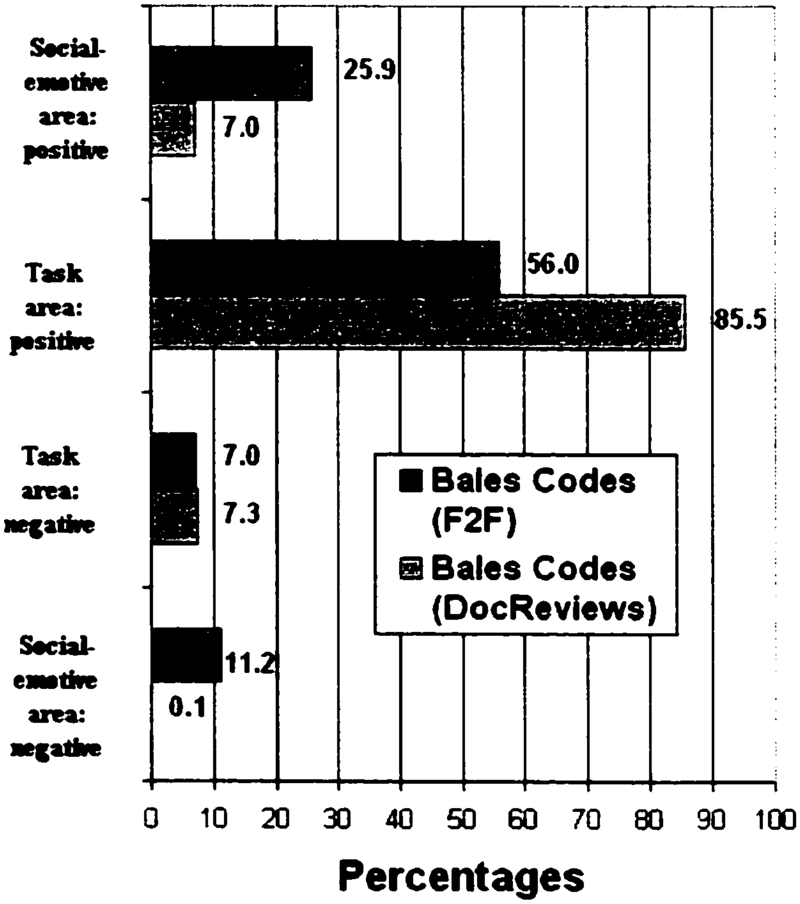


Figure I Distribution of Bales Codes

We find that the null hypothesis that there will be no difference between face-to-face and DocReview dialog when Bales coded can be rejected. With three degrees of freedom, Chi squared = 213.2. This result is significant at <0.000001.

Discussion of Findings:

The very low percentages of DocReview annotation in the social-emotive area (positive and negative reactions) may show the effect of moderation in dialog induced by the reflection afforded by DocReview as opposed to the more spontaneous nature of face-to-face dialog. The similarly low, though less extreme, percentages in the positive reactions category may show that there is less need felt for social reinforcement than in face-to-face dialog. Though DocReview annotations show less positive reinforcement, the reinforcement is there, it is simply less effusive. Questions (task area: negative) show an almost identical distribution. Problem-solving attempts (task area: positive) are much higher in DocReview annotation than in face-to-face dialog. This disparity may be the result of the ability of the reader to reflect much longer than is possible in face-to-face dialog. I suggest that this is the most important finding, demonstrating the value of DocReview in problem solving.

Interpretation of Findings:

The conclusions must be tempered with the realization that there are no gestural acts in the DocReviews and their annotations. While Bales does not record the percentages of gestural acts captured in his research, in his description of the codes gestures such as winks, nods, frowns, and even blushing appear. From Bales' description of the codes one can clearly see that most gestural acts are in the social-emotive categories. If an arbitrary portion of the Bales social-emotive codes (comprising 37.1 % of the total face-to-face acts) was assumed to be gestural, then in the annotation coding the missing percentage would need to be reassigned from the task oriented categories. This reassignment would cause the comparison between positive task-orientation to be somewhat less marked, and the comparison between negative task-orientation would shift from being almost equal to somewhat less negative than in face-to-face dialog.

5.1.6.2 Proposition A2: The substantive character of comments in DocReview differs from comments in face-to-face dialog.

The substantive nature of comments in DocReview is measured by determining the intent of the comment, or a portion of the comment. Intent is defined in this analysis as what place the comment would take in argumentation.

As in the analysis of social character of the comments above in Proposition A1, we have to assume that the dialog is quite one-sided, with the document providing propositions and the readers arguing with that proposition. Clearly there can be no negotiation of meaning and the document can make no rebuttals. In terms of argumentation, then we can have but one round of argumentation, but with several people participating.

Operationalization:

Assigning Meyers structurational argumentation code categories to each comment operationalizes the substantive character of the comments.

Data conditioning:

The raw data percentage comparisons (DocReview/face-to-face) are: for non-arguables -- 22.6%/14.5%; for delimitors -- 8%/2.1%; for promptors -- 23.1%/2.3%; for reinforcers -- 10.3%/13.6%; and for arguable -- 36%/67.4%.

Argumentation codes in the non-arguable category in the dialog were excised. In the raw data, DocReview annotations were 22.6% non-arguable, compared to 14.5% in the Meyers study. The difference in non-arguables is attributed to the assignment of annotations frequently complaining about grammar and spelling to that category. Arguably such commentary does not contribute to productive argumentation, and furthermore such corrections are seldom made in face-to-face dialog.

Codes in the arguable class were also excised. Difficulties in adjusting for the asymmetrical nature of DocReview argumentation are simply insurmountable. In the one turn dialog, responses to propositions (the base document's review segment) are much more prevalent than responses to annotations. Responses to annotation usually requires re-reading the comments; busy participants are not likely to return to review comments, even if they are reminded by e-mail notification. This would not be the case in face-to-face argumentation.

The data conditioning leaves us with three categories of codes: Reinforcers, Promptors and Delimitors. Unfortunately the excision of troublesome categories reduces our number of data points by 58% to 176. Since the central action of argumentation is carried out in these categories, I feel that they are an adequate basis for comparison.

Data Analysis:

The conditioned data comparisons (DocReview/face-to-face) are: for reinforcers -- 25%/75.6%; for promptors -- 55.7%/13.3%; and for delimitors -- 19.3%/11.1%.

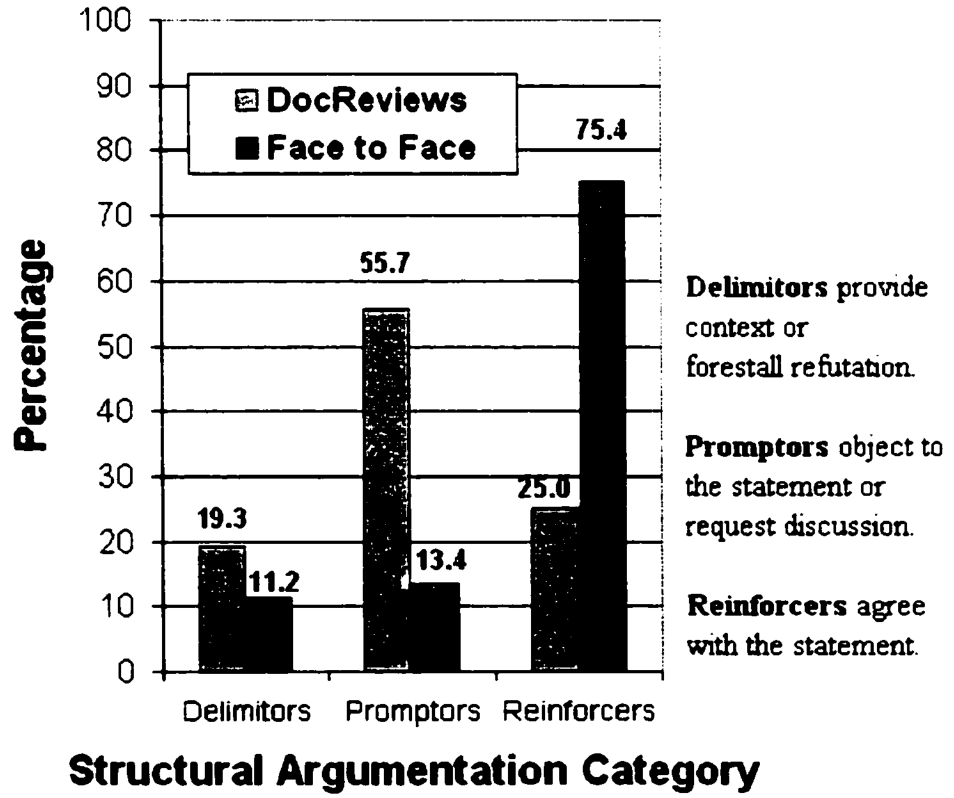


Figure II Substantive Commentary (DocReview vs. F2F)

Comparing face-to-face distributions to the distributions found in the DocReviews shows a very strong difference in both promptors and reinforcers. There are four promptors in DocReviews for each face-to-face promptor and three face-to-face reinforcers for every DocReview reinforcer.

We find that the null hypothesis that there will be no difference between face-to-face and DocReview dialog when Meyers coded can be rejected. We find that with two degrees of freedom, Chi squared = 93.3. This result is significant at <0.000001.

Discussion of Findings:

The differences of face-to-face argumentation and DocReview annotation are clear: people are much more inclined to suggest changes to the document in DocReview than in face-to-face dialog; people are much less inclined to agree with the document in DocReviews than they are in face-to-face dialog. I see this finding as suggesting that there may be some satisficing occurring as people are less inclined to annotate texts that they see as not far enough wrong to complain about. The vast difference in promptors may be explained by the nature of DocReview: documents are mounted with the intent of drawing out errors and omissions. A portion of the differences may also be explained by social mechanisms: it is much easier to praise than object; and power effects may also be seen as people are more inclined to agree with a proposition offered in a meeting (usually by a leader).

5.1.6.3 Proposition B1: Long base documents are ineffective relative to short documents.

The lives of researchers are fragmented into scores of tasks of varying importance. This produces the need to engage in multitasking, a mosaic of activity that fills the available time with periods of variable lengths. There will be short periods to review documents, provided they are of a size that will fit into the time slot. Very long documents may encourage a shallow reading, thus shallow and short commentary.

Operationalization:

Effectivity is operationalized as the ratio of the sum of comment size to the size of the base document. Size of comments and base documents are both established by software that counts the words of more than three characters. For each DocReview that attracted annotation (n = 78), the word counts for annotations to segments that attracted annotation for each DocReview were accumulated in one column and the word count for the DocReview was placed in another. The DocReview word count was plotted on the X-axis and the effectivity on the Y-Axis.

Data conditioning:

Records for DocReviews that attracted no commentary were excluded. A DocReview with segments containing graphics was excluded due to the low word count in the segments. and the heavy annotation of the segments. The same DocReview contained an anomalously long general comment.

Data Analysis:

A correlation of 0.665 on the logarithmic regression line confirms the hypothesis. With 77 degrees of freedom a value of $F = 60.1$ was found. As expected the slope was negative with $P = 3.27 \times 10^{-11}$. The P value of the intercept was 1.64×10^{-12}. A study of DocReviews by document type (§5.1.6.7) suggests that the logarithmic relationship is even stronger among base documents that are not meeting minutes.

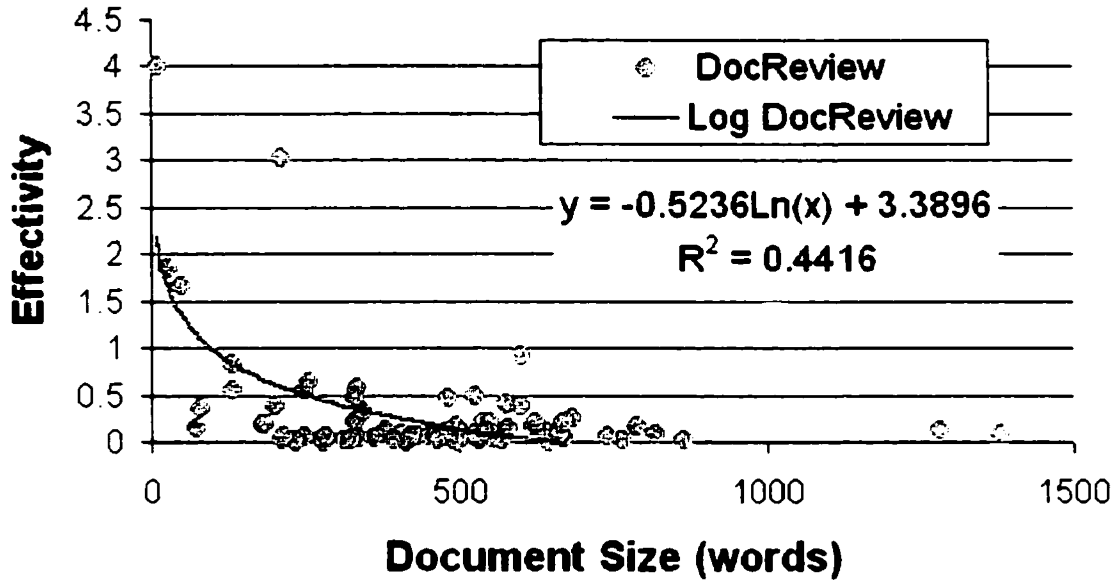


Figure III Effectivity by Document Size

Discussion of Findings:

The hypothesis is accepted. Smaller base documents produce more effective DocReviews. This leads to the conjecture that fragmenting a very long document will increase the effectivity of the review process. This conjecture could be tested, but not with the data from this study.

5.1.6.4 Proposition B2: The amount of commentary received on a review segment will be directly proportional to the segment's length.

An extremely long review segment may tax the reader's concentration, leading to a decline of effectivity. Short review segments such as list "bullets" are sharply focused and easy to grasp and critique. Due to a small denominator, the effectivity of such short segments may be inflated. The deleterious effect of long review segments is one of the basic assumptions of the design of DocReview.

Operationalization:

Size of comments and base documents are both established by software that counts the words of more than three characters.

Data conditioning:

Segments not attracting annotation are removed. Segments that were graphic images were discarded. General comment segments were discarded.

Data Analysis:

A correlation of 0.235 on the linear regression line weakly confirms the hypothesis showing a direct relationship between segment size and received annotation. With 49 degrees of freedom a value of $F = 2.80$ was found. As expected the slope was positive with $P = 0.101$. The P value of the intercept was 0.391.

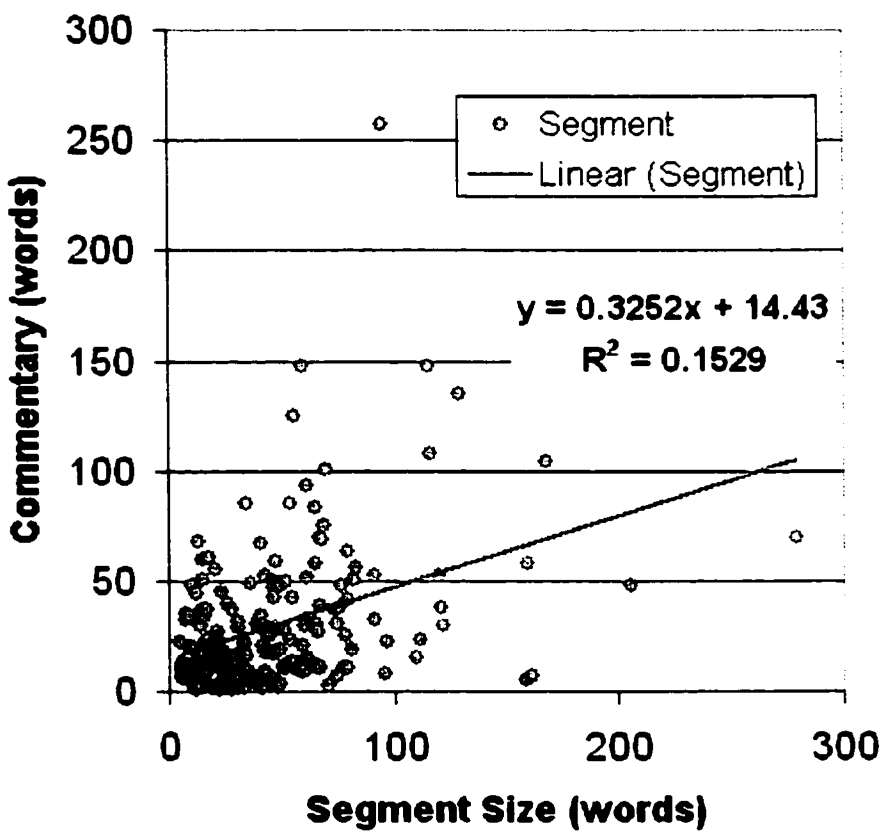


Figure IV Commentary Accumulated by Segment Size

Discussion of Findings:

The hypothesis is accepted. Commentary size is directly proportional to segment length; but while larger segments attract more commentary due to the positive slope, but they are not necessarily more effective (see §5.1.6.5) as seen by the low value (<1.0) of the slope of the regression line.

5.1.6.5 Proposition B3: The ratio of size of comments received to size of review segment (effectivity) will decline in proportion to review segment size.

Short entries in lists and cells in tables are very sharply focused and when they attract annotation, the annotations are likely to contain more information than the entry (effectivity > 1.0). The context of lists and tables are usually quite clear and contributes to their focus. When long segments such as paragraphs receive annotation, they are likely to contain less information than the segment.

Operationalization:

Size of comments and review segments are both established by software that counts the words of more than three characters.

Data conditioning:

For this analysis general comment segments were excluded, as they are not focused review segments. Segments that applied to graphic images were removed because the number of words in the graphic segment is simply the number of words in the title, and a picture is indeed often worth a thousand words. At this point outliers were examined and one more point was removed. This outlier was a document section heading that drew much commentary from the review segments within the section. Making a section heading a review segment is an error on the part of the facilitator: section headings are for ease of reading and are devoid of real content.

Data analysis:

The remaining segments that received comments were selected and two columns were produced by database query: size of the segment and the summation of the size of the commentary on the segment. This table was imported into the spreadsheet. For each segment, the size of the commentary was divided by the size of the segment to yield effectivity. A column was created for the effectivity. An XY scattergram was produced with segment size on the X-axis and effectivity on the Y-axis. A correlation of 0.451 on the logarithmic regression line confirms the hypothesis. With 184 degrees of freedom a value of F = 46.8 was found. As expected the slope was negative with $P = 1.1 \times 10^{-10}$. The P value of the intercept was 1.1×10^{-18}.

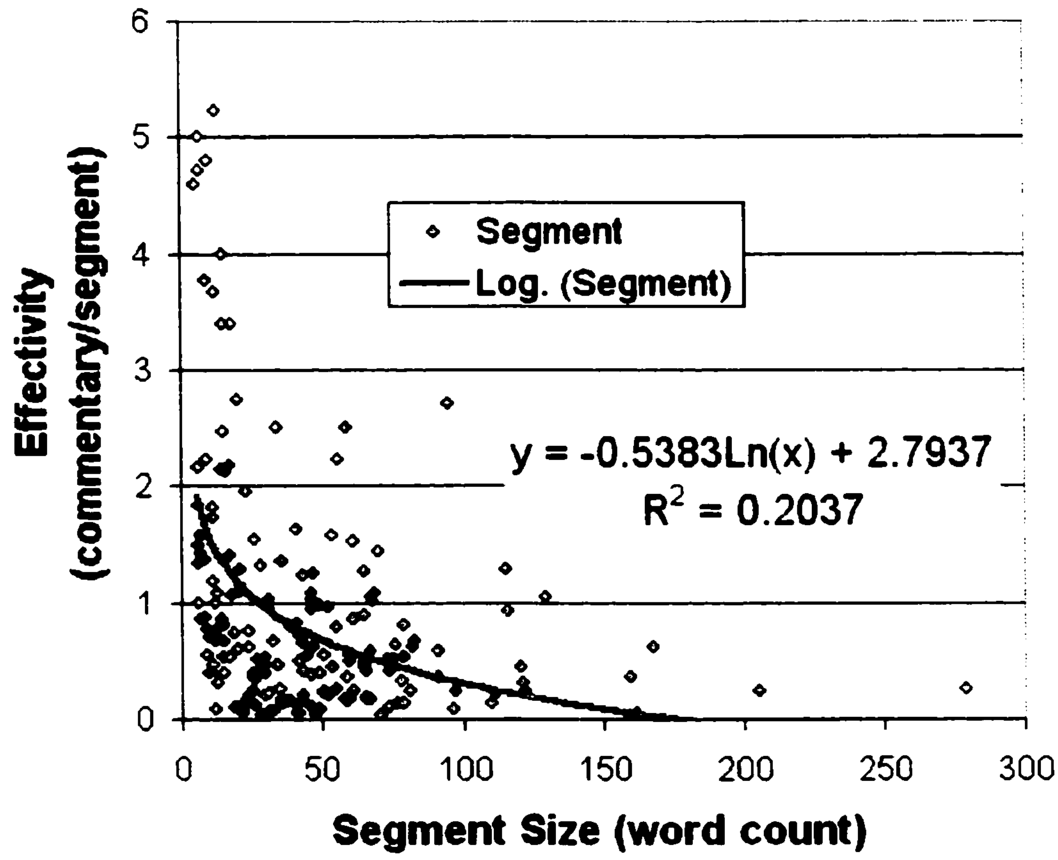


Figure V Effectivity by Segment Word Count

Discussion of Findings:

The hypothesis is accepted, with strong indications that effectivity decays logarithmically rather than linearly. This hypothesis is also supported by style guides for printed text[31, 32] and for the WWW[33]. Long paragraphs are problem-laden when reading from a screen: scrolling may be required, especially when small displays are used and when the user has the font size increased to compensate for poor eyesight. When the user has set the window to single column width, even moderate length paragraphs may need to be scrolled.

5.1.6.6 Proposition C1: Products similar to DocReview will emerge and will, by similarity, validate the design.

At least four other web-based annotation products have been put into service. One of these (Third Voice) was forced to withdraw after it was subjected to numerous lawsuits centered on copyright issues, specifically allowing anyone to copy any publicly available web page on someone else's web site for annotation.

Since DocReview's debut in 1995, three similar products have emerged: Living Documents in 1998, PageSeeder in 2000, and QuickTopic in 2001. The four products may be compared on a set of core features. The core features are: notification service, in-line commentary option, security, segmentation flexibility, comments on comments, general comments, and review all comments.

Operationalization:

The three products are compared on a set of core features.

A DocReview demo may be used at

http://students.washington.edu/~veritas/DocReview/review30.cgi?name=DrDemo.

Several Interactive Papers may be examined at http://lrsdb.ed.uiuc.edu:591/ipp/.

A Document Review may be examined at

http://www.quicktopic.com/6/D/QXx3sZA2kptQpnq9Rqwv.html.

A PageSeeder demo may be used at

http://ps.pageseeder.com/ps/ps/demos/tryit/choco/choco.pshtml.

Table IX Annotation Program Features

	DocReview	*Interactive Papers*	*QuickTopic Document Review*	*PageSeeder*
Notification Service	Yes	No	Yes	Yes
In-line Commentary	Yes, click for alternative format.	Yes, by request.	No	Yes, no other alternative format.
Security	Yes, your server.	Yes, your server.	By obscure URL.	Yes, commercial service.
Segmentation Flexibility	Yes	No	No, paragraphs and list elements only.	No, chunks only.
Comments on Comments	No, by design.	Yes, three deep.	No, by design.	Yes, unlimited.
General Comments	Yes	Yes	Yes	No
Review all comments	Yes	No	Yes	No

Discussion of Findings:

DocReview's design has been validated by the similarity of several commercial and academic products that were developed in the five years following DocReview's original release.

5.1.6.7 Proposition D1: Higher quality documents will attract more participation.

Document quality may be categorized on an ordinal scale. Degree of completion on a scale from conceptual sketches to completed canonical documents. We have categorized the documents on a five-valued quality scale (see §5.1.2).

Operationalization:

Participation is considered equivalent to effectivity and is operationalized as the ratio of the sum of comment size to the size of the base document. There were three document types represented: types 2, 3, and 4.

Data Conditioning:

DocReviews without comments were discarded. A DocReview with segments containing graphics was excluded due to the low word count in the segments. and the heavy annotation of those segments.

Data analysis:

Table X Effectivity of DocReviews by Document Type

Category	*n*	*total words in documents*	*total words in commentary*	*effectivity*
Type 2	10	1302	696	0.535
Type 3	58	27636	3181	0.115
Type 3 w/o minutes	8	4433	909	0.205
Type 4	10	8581	2914	0.340
All Types	78	37519	6791	0.181

The DocReviews that received comments were analyzed and two columns were produced by database query: size of the base document and the summation of the size of the commentary on the DocReview. This table was imported into the spreadsheet. For each DocReview, the size of the commentary was divided by the size of the base document to yield effectivity. A column was created for the effectivity. An XY scattergram was produced with segment size on the X-axis and effectivity on the Y-axis. Five effectivity distributions were studied: all DocReviews by document type, meeting minutes (most of the type 3 documents), and all DocReviews less the meeting minutes.

Studying the distributions of the three types shows three very distinct populations, type 2 with very strong logarithmic decay of effectivity with increasing base document size, type 3 documents with a very low effectivity and an almost random distribution (see Figure VI), and type 4 with logarithmic decay of effectivity. Considering the strong (R2 =

0.4416) logarithmic decay of effectivity with increasing base document size seen in Proposition B1 (§5.1.6.3), the nature of type 3 documents needs to be examined more closely.

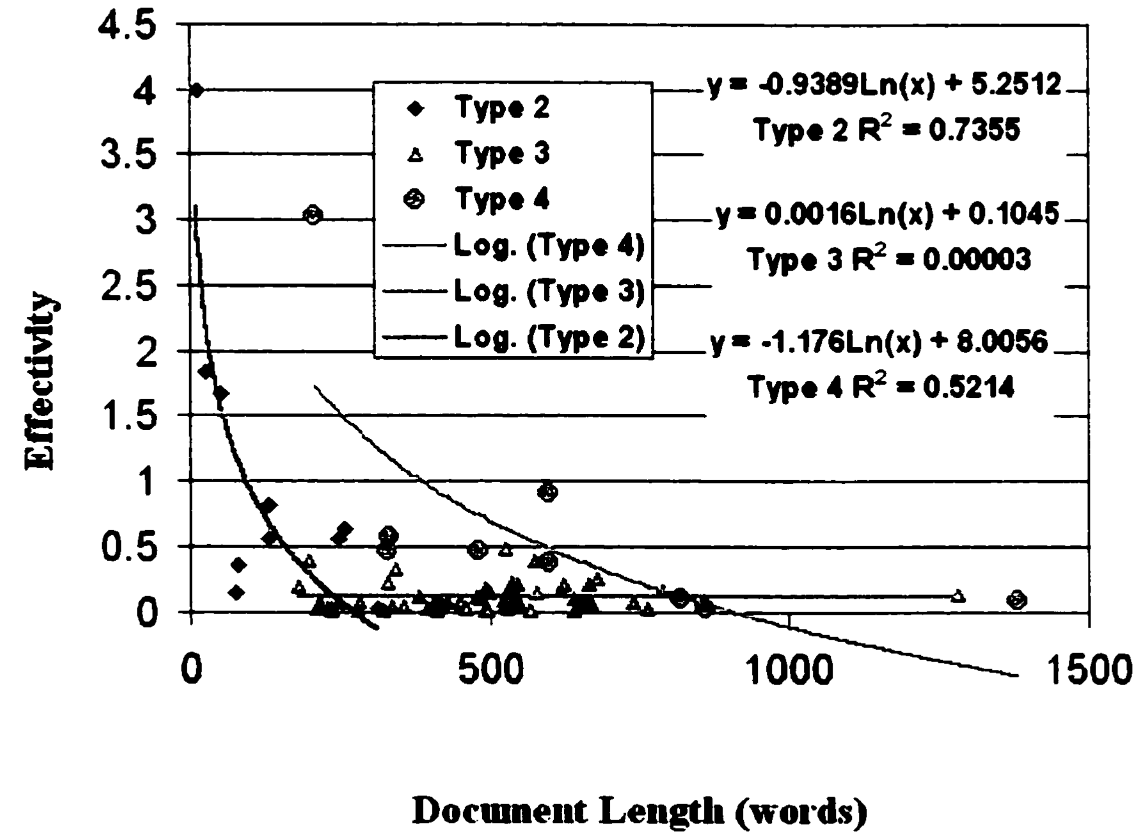


Figure VI Effectivity to Document Length by Type

Table XI Regression Analysis Summary

Type	df	F	P_{slope}	$P_{intercept}$	R	Std Err
2	9	22.2	0.0015	3.3×10^{-8}	0.858	0.593
3	57	0.001	0.966	0.644	0.0057	0.117
4	9	8.72	0.018	0.013	0.722	0.658

Type 3 documents are working drafts, in the data examined here either position papers submitted for a workshop or minutes of weekly group meetings. Meeting minutes are a highly stable and consistent genre that does not attract much discussion, unless discussion topics were not reported or were reported incorrectly. All the meeting minutes were consistently formatted and prepared by only three people. They were separated from the position papers and examined and the effectivity was found to be essentially randomly distributed ($R = 0.05$) with respect to document length (see Figure VII). With 49 degrees of freedom a value of $F = 1.21$ was found. The slope was positive with $P = 0.730$. The P value of the intercept was 0.033.

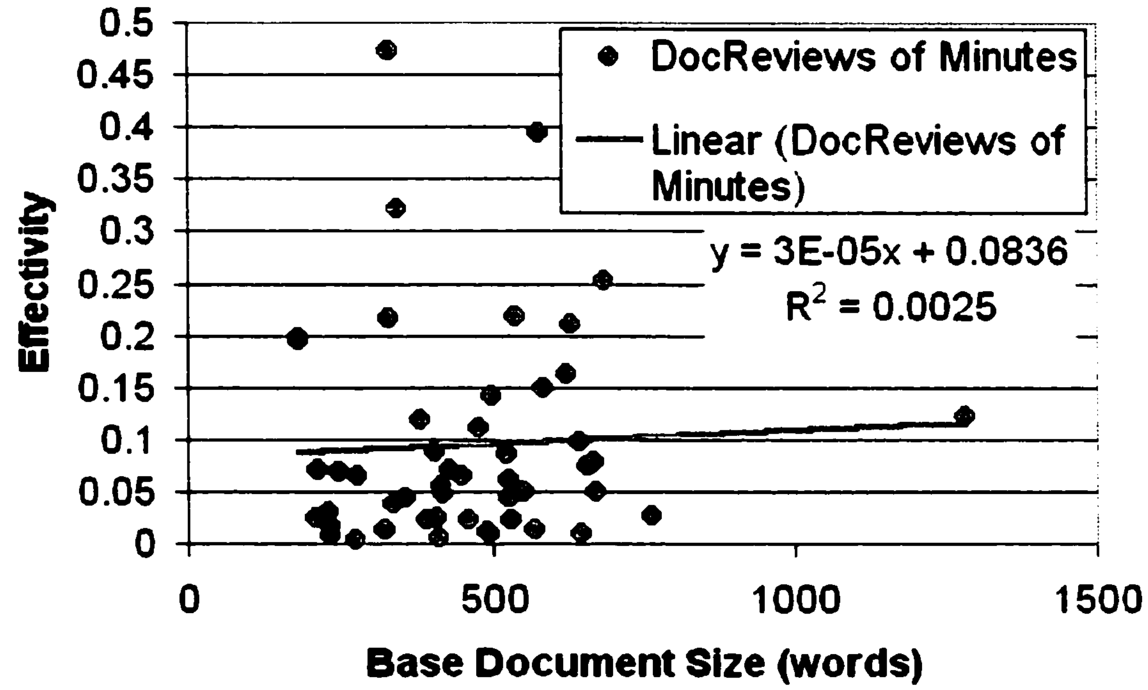


Figure VII Effectivity of DocReviews of Minutes

Based on the finding that meeting minutes formed an essentially random cluster of data points that was well distributed at the knee (document size 200-800) of the logarithmic regression line, it was decided to plot all DocReviews except the meeting minutes. This distribution contains documents (n = 28) that are more likely to stimulate substantive dialog.

A correlation of 0.714 on the logarithmic regression line confirms a strong negative logarithmic relationship. With 27 degrees of freedom a value of F = 27.1 was found. As expected the slope was negative with $P = 1.98 \times 10^{-5}$. The P value of the intercept was 1.7×10^{-6}.

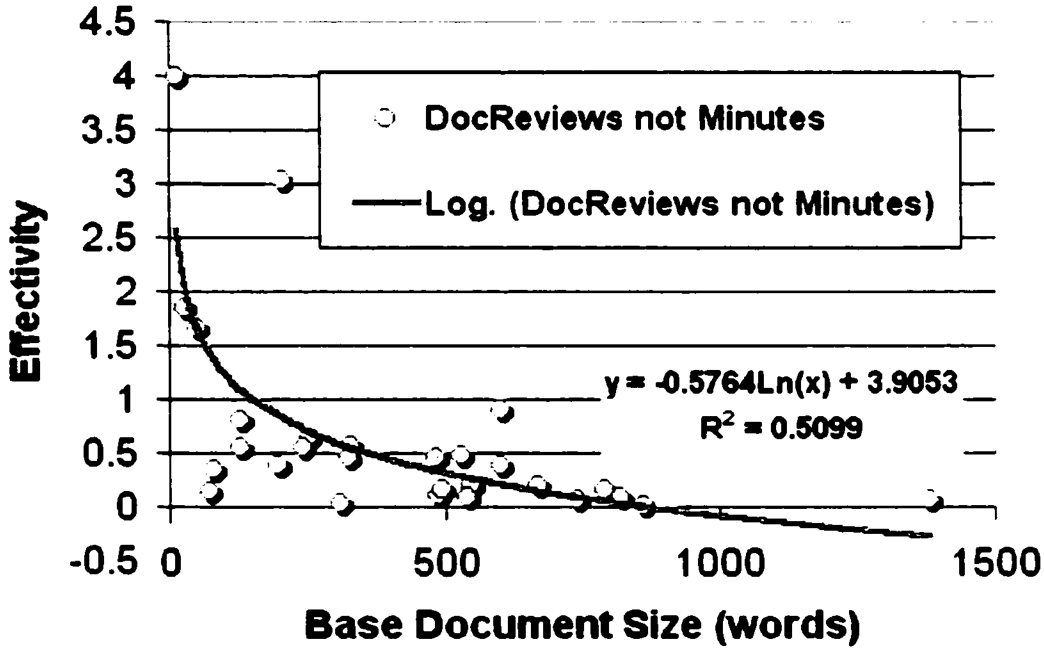


Figure VIII Effectivity of DocReviews not Minutes

Discussion of Findings:

The hypothesis is soundly rejected. It is clear that less finished documents attract more participation than do more polished documents. This is likely due to the presence of more opportunities for change through collaborative critique.

5.1.6.8 Proposition D2: The nature of social commentary will vary with the type of document.

It is expected that the more formal nature of higher quality documents will evoke a more formal commentary as opposed to the informal and preliminary nature of the less mature documents.

Operationalization:

The social character of the comments is operationalized as the distribution of the Bales codes categories for each of the document types. The Bales Interaction Process Analysis categorizes all speech acts, including gestures, into twelve codes. Many of the Bales codes are specific to face-to-face dialog, so we must eliminate those codes in order to make a comparison. Bales grouped the twelve codes into four categories that are generic and form a good basis of comparison. These categories are: Social-emotive area: positive (positive reactions), Task area: positive (problem-solving attempts), Task area: negative (questions), and Social-emotive area: negative (negative reactions). The central two categories are further generalized into a supercategory of the task area, while the extremes are generalized into the social-emotive area.

For each of the four Bales categories, the percentages of commentary codes by document type (n = 3) are graphed.

Data conditioning:

None.

Data Analysis:

The Bales category distributions of DocReview annotations by document type demonstrate that the annotations are almost never negative reactions. The annotations that show positive reactions are more often directed to the more finished documents (type 4) than to the working and rough drafts (types 3 and 2). Questions are asked over twice as often in type 2 (rough) documents as in type 4 (finished documents).

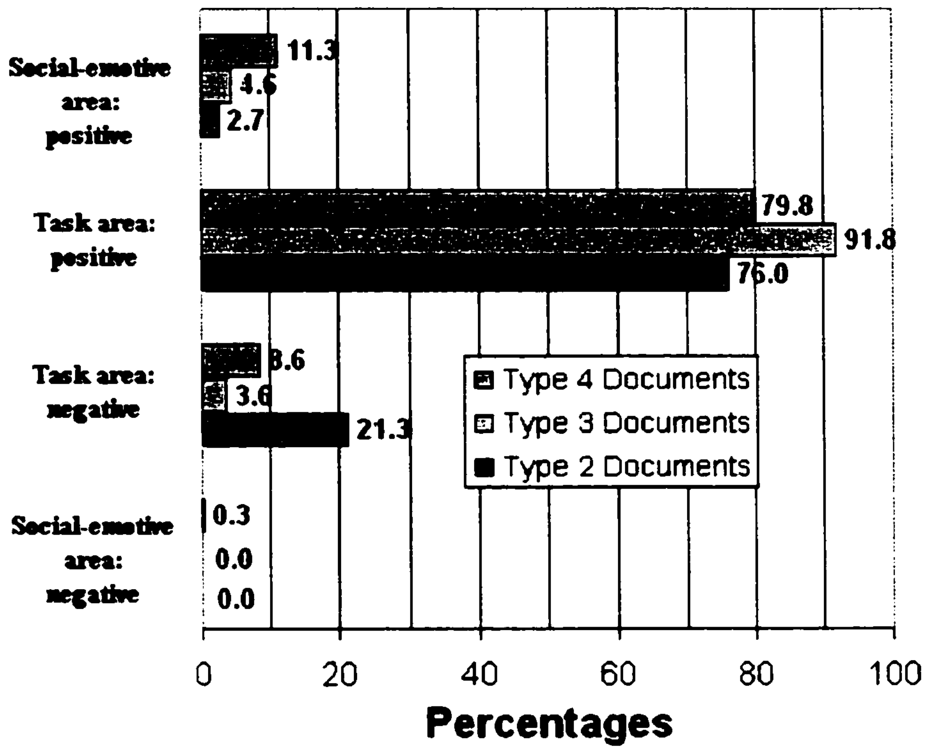


Figure IX Distribution of Bales Categories by Type

We find that the null hypothesis that there will be no difference in the Bales category distribution between document types can be rejected. With six degrees of freedom, Chi squared = 46.5. This result is significant at <0.000001.

Discussion of Findings:

Finished documents are viewed more positively than rough documents in DocReview. Most commentary is directed toward problem solving.

5.1.6.9 Proposition D3: The nature of substantive commentary will vary with the type of document.

High quality documents such as Research Web Essays (type 4) will attract relatively few negative comments, just because the documents are likely to contain few errors and omissions. On the other hand speculative documents (type 2) are likely to attract negative commentary due to their incomplete and unfinished nature. Working documents are likely to occupy an intermediate position.

Operationalization:

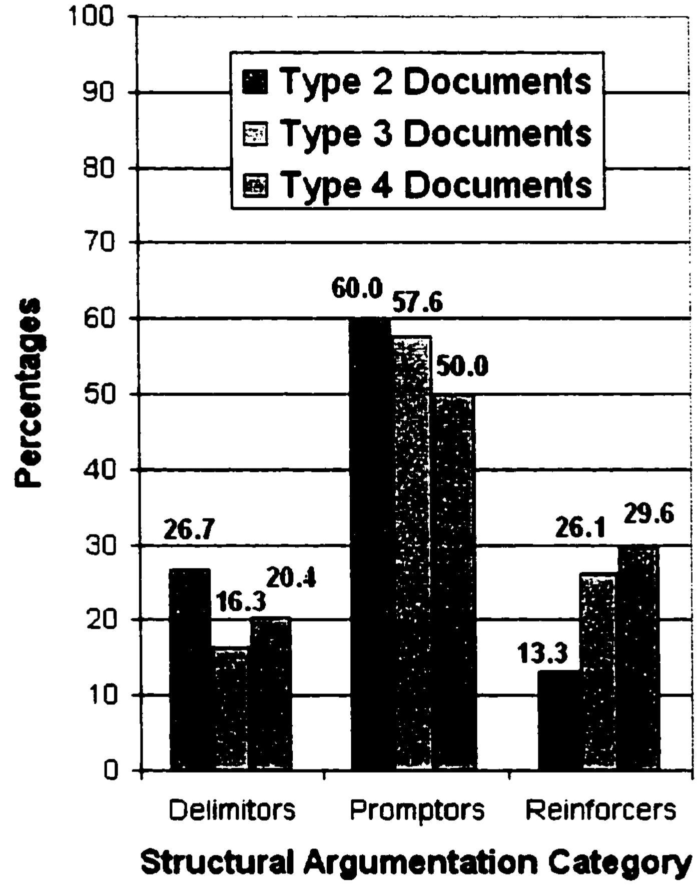
The substantive character of the comments is operationalized as the distribution of the Meyers structurational argumentation codes categories for each of the document types.

Data conditioning:

None.

Data Analysis:

Of interest is the distribution of reinforcer percentages among the types of DocReviews. The more polished (Types 3 and 4) documents draw over twice the percentage of reinforcers than do the rough (Type 2) documents. This is distribution is inversely mirrored, weakly, by a corresponding presence of a lower percentage of promptors in the polished documents as compared to the rough documents.



Delimitors provide context or forestall refutation.

Promptors object to the statement or request discussion.

Reinforcers agree with the statement.

Figure X Substantive Commentary by Document Type

We find that the null hypothesis that there will be no difference in the Meyers Argumentation Code category distribution among the document types can be rejected, but only very weakly. With four degrees of freedom, Chi squared = 3.92. This result is significant only at <0.5.

Discussion of Findings:

The distribution of argumentation categories is only weakly contingent on document type. There are indications that polished documents will attract more agreement and somewhat fewer objections than rough documents.

5.1.6.10 Other Findings

Exponential decay of multiple comments is seen. The regression line shows a correlation of 0.941 for classes of comment counts, 0 to 6.

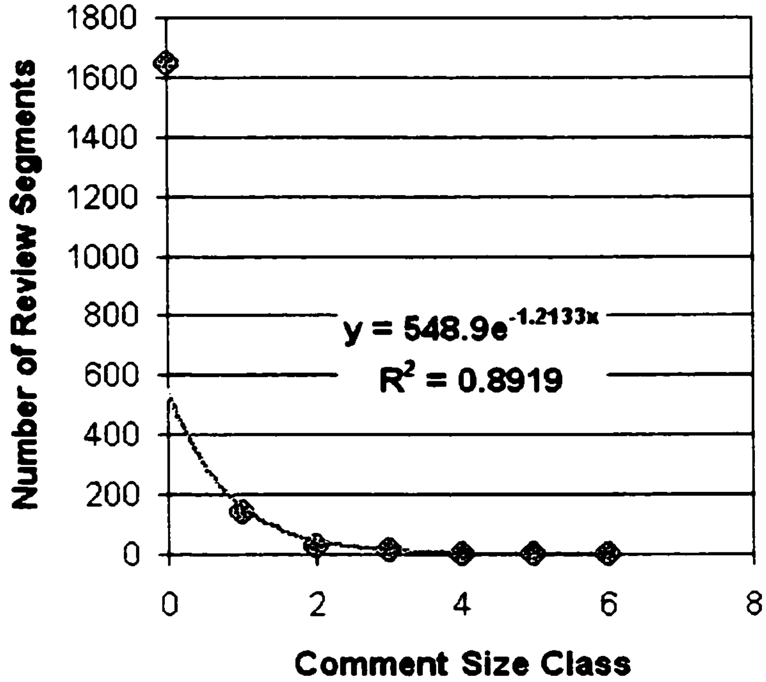


Figure XI Exponential Decay of Comment Counts

5.1.7 Conclusions

The social character of the dialog elicited by DocReview shows substantial departures from face-to-face dialog [prop A1]. The social character of the dialog is much less emotive than face-to-face dialog and the task oriented dialog is very clearly oriented toward problem solving, with questioning being only slightly less than in face-to-face.

The substantive nature of dialog in DocReviews [prop A2] is very concentrated in constructive disagreements with the statements in the DocReview. Conversely, agreements are much less frequent than in face-to-face dialog. Most of these agreements include amplifications. This finding reinforces the similar findings in the study of the social nature of the dialog [prop A1].

Findings related to the size of the base document and the segment size found that the effectivity of the DocReview decays logarithmically with increasing base document size [prop B1]. Commentary size is directly, but not strongly, proportional to segment size [prop B2]. The effectivity of a review segment shows logarithmic decline with increasing segment length [prop B3]. This finding indicates that the document segmentation strategy should avoid long segments.

Analysis of the descriptive statistics on the document size shows that the length of annotations is significantly longer in more finished documents (type 4), perhaps reflecting the willingness to spend more time on "serious" documents, and shortest in working documents (type 3). Annotations on rough documents (type 2) fall into an intermediate length class, perhaps because they need more work to bring them to acceptable quality.

Comparing DocReview to roughly comparable products shows that no important features were overlooked in DocReview, though no product has implemented the features just as DocReview has [prop C1]. This convergence of design demonstrates that DocReview's design is in the mainstream. The differences in design implementation are largely due to differences in audience and commercial aspirations.

An attempt to measure the effect of base document quality on the effectivity (the ratio of words of commentary to words in the base document) of the DocReview found [prop D1] that (with exceptions) effectivity of documents declined with increasing quality, corroborating the findings of prop B1. Measuring the effect of base document quality on the social nature of the dialog showed comparable distributions among the Bales categories [prop D2] in all document types. The minor differences speak perhaps more to the consistent categorization of documents than to the significance of the differences. In the case of substantive dialog (Meyers codes), similar comparable distributions were seen [prop D3]; however there was an apparent, but insignificant, increase in agreements (reinforcers) with increasing quality. A corresponding decrease in objections was also seen.

5.2 Case Studies of Research Webs

There have been four attempts to develop Research Webs, and while none were successful, much knowledge was gathered. The design of Research Webs was largely theory driven, but practical experience has been gained from the attempts to develop RWs. Much of the knowledge was applied to the tools, especially DocReview, but other knowledge gained has come from understanding human nature, especially the failure to participate.

While perhaps a few minor problems with RWs may be laid at the feet of technology, by far and away most barriers are related to human behavior: psychological, sociological, organizational, and cultural. The research questions we examine are designed to uncover behavior patterns and the reasons that may contribute to causing those patterns. Discussion of counterproductive behavior leads us to some suggestions to modify that behavior. To the extent that such causes may be remediated by technology, the tools applied to the RW will be augmented or changed.

5.2.1 History of Research Web Technology

Technological aspects of Research Webs have co-evolved with the World Wide Web. Beginning from the initial release of the Mosaic web browser in 1993, the potential of the WWW was clear. The technology was at that time blooming on a monthly basis and, as time allowed, the new capabilities were incorporated into the Research Webs.

The prototype RW was the Migration RW, originally a simple hypertext installation with but one image, a Dorothea Lange photograph of an Okie family on the road to California during the Great Depression. The first new feature incorporated was the inclusion of an organizing model, a diagram of the migration process from information gathering to settlement. The diagram, a petri net[34], was image mapped so the user could click on an object in the diagram, a node or link, and be transferred to a page that described the object. This RW was essentially a technical proof of concept site, and included crude bibliographic and glossary links, and a commenting capability limited to global comments on each web page. No research team was assembled.

The first RW, the Chromium VI RW, was the first opportunity to engage a team of scholars. By that time DocReview had been developed, allowing participants to make annotations on small chunks of text from the web page. DocReview was used to annotate documents and meeting minutes. In the later stages of that RW, JavaScript was employed to provide the ability to pop up small auxiliary windows on the screen. If the user wanted to view a DocReview, bibliographic information, a glossary definition, footnote, or a sidebar, those features would be displayed in small windows without overwriting the main document window.

In the final two RWs, the Soil Crust RW and the Earthquake Disruption RW, the ability to annotate bibliographic entries and glossary entries was added, bringing the RW technological environment to its current state.

5.2.2 Research Questions

There have been several research efforts that used the collaborative tools of the Research Web environment. Four of these efforts utilized the fully developed concept of the research web, while others used only parts of the concept or the incompletely developed concept. The case study of the Research Webs will address several research questions.

The research questions and associated propositions are:

1. What was the focus (issue domain) of the RW?

- A diffuse focus for the RW will destroy it.
- Confederations (groups with different focuses) under a single RW will fail.

2. What were the geographic distribution effects on the RW?

- RWs with strong concentrations of people who can easily communicate in person will fail.

- RWs with widely distributed members who live in different time zones are more likely to succeed than RWs with concentrated membership.

3. How many people were invited to participate in the Research Web?

- The critical mass theory holds for research webs.

4. What incentive(s) did each of the participants have to participate?

- In order to be successful the RW must provide rewards beyond authorship.

While several additional questions were considered. only these could be addressed properly. The questions were posed after the active lives of the Research Webs. Several could not be answered due to lack of data. Others would have needed questionnaires for proper evaluation. Several of these currently unaddressable questions are presented in the Future Research section.

5.2.3 Design of Data Collection System

The data collected on the research webs consists primarily of copies of the web sites. meeting minutes. and correspondence between the RW's scientific coordinator and the facilitator. Web sites include data not only in web pages. but also data in the form of annotations in DocReviews. Annotated HyperBibliographies. and Annotated HyperGlossaries. DocReview builds a log file. which contains all transaction activity: creation. annotation. reading and archiving. There were two hosting servers that went off-line during this research, but the four Research Webs described below were captured before destruction, or were recovered from the server host after the server software failed.

5.2.4 The Research Webs

In this section we will describe four cases, a prototype and three Research Webs, and using those cases and events and circumstances in associated enterprises will discuss the research questions (above §5.2.2). Each RW had as its issue domain a topic that was subjected to scholarly research. All the cases were hosted on web servers at the University of Washington and were facilitated by the author.

5.2.4.1 Migration Prototype Research Web

This Research Web was initiated as a prototype and test bed for the Research Web concept to demonstrate the power of the WWW to facilitate research. The topic was internal migration viewed from a behavioral standpoint. The site capitalized on the work done in my Master's Thesis, a section called "A Model of the Migration Process"[15]. The importance of this site is related to the testing of the technology later applied to Research Webs and to the realization that the Research webs were a social organization driven by social and personal goals, not technology.

5.2.4.2 CREAT and The Chromium VI Research Web

The Collaborative Risk Evaluation Approaches Team (CREAT) was an attempt to build an interdisciplinary team to investigate a small set of problems centered on the cleanup at the Hanford Nuclear Reservation. It was staffed with members who were supported by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) project at the University of Washington. CREAT was the first user of many of the tools now used in Research Webs. A Research Web was initiated to investigate one issue that concerned CREAT, hexavalent chromium contamination. It was hoped that the Chromium VI RW would serve as a template for describing several other contamination issues.

5.2.4.2.1 Mission and RW Topic

> *The mission of the Collaborative Risk Evaluation Approaches Team (CREAT) is to provide information about hazards and risks to human health, ecological health, economic health, and socio-cultural health within and around DOE sites. CREAT is developing an easily accessible, computer-based tool for collecting, cross-indexing, displaying, and comparing the components influencing risk. The tool will enable interested parties to understand what is at risk and how and why it is at risk. In addition, it will provide an analytical means for comparing risks within one site as well as across sites within the DOE complex. Finally, it will bring the results of research by members of CRESP to the attention of stakeholders, Tribes, DOE and other interested parties and will provide a forum for discussion of important issues in the area of risk evaluation and hazard reduction.*
>
> --- CREAT mission statement produced by the team, 1996

It was decided to open a Research Web on the topic of environmental impact and the remediation of hexavalent chromium contamination. The mission statement of CREAT's RW was, "Initially, the focus of this research web is to examine one specific hazard: hexavalent chromium found in the 100 Area [near the plutonium production reactors] along the Columbia River on the Hanford Site. The principal risk posed by this hazard is as a stressor to the salmon stocks that spawn in the Hanford Reach of the Columbia River. There are some risks to human health, and these aspects will be investigated as well. The research web will work with absolute risks not relative risks. By using this approach we hope to develop a conceptual and informational framework that can be applied to other hazards."

5.2.4.2.2 Organization

CREAT was always an ad hoc voluntary organization. It was never funded on any budget, but was a management-approved activity. Its existence was justified by two possibilities: that it might produce publishable research; and that it would produce explanations, "fact sheets," of detailed issues surrounding some of the health hazard problems from the contamination at the Hanford site.

The nominal leader of CREAT was a member of the CRESP administration and the administrative leader was a scholar funded as a member of a CRESP task group. There were six contributors of Research Web Essays, and twelve team members contributed annotations. An additional four team members participated in face-to-face meetings, but not in the RW. The team operated as a collaboration, with all documents open to annotation from all members.

5.2.4.2.3 Focus

CREAT emerged as a focus group within the Health Hazards Identification Group of CRESP. The group was founded in September of 1996 as the Health Hazard Identification Focus Group (HIF). Briefly this group was identified by its nature and methods as the "inter-disciplinary collaborative risk evaluation and analysis group" (ICREA). The group took the name CREAT on October 22, 1996.

The founding challenge for the CREAT group was to produce short essays on ten questions on hexavalent chromium contamination. Three members of the ICREA GROUP proposed the questions. At my urging, the CREAT group enthusiastically agreed to participate in a Research Web. The ten questions were placed on the RW's web site on December 6, 1996 and were refined by members of CREAT and other members of CRESP. The ten questions were then answered by short essays by team members, and were put into the RW web site for viewing and for critical annotation using DocReview.

The ten questions were:

What is Chromium?

How did Chromium become a contaminant?

Why is Chromium a "contaminant of concern"?

Where is the contamination and how much is there?

How do the levels of Chromium compare with regulatory standards?

How is the Chromium concentration measured?

What is the quality of the Chromium data?

How have Chromium concentrations changed over time?

What is presently being done to mitigate or control the Chromium hazard?

Have new methods of controlling the Chromium hazard been suggested?

In addition to essays on the ten questions, seven other essays were contributed to the site. One team member created four ecologically oriented essays dealing with bioremediation of hexavalent chromium and the effects of hexavalent chromium on salmon, invertebrates, and aquatic plants. I introduced three additional documents in order to introduce some measure of process modeling into the site. These documents were essays on the Environmental Remediation Disposal Facility (ERDF), the pump-and-treat decontamination processes practiced at Hanford, and a process model of the chromium contamination processes (See Figure XII below). The process model was designed as an organizing model to tie together several of the other essays.

CREAT's work was extended to a parallel study of tritium contamination. but this work never reached the Research Web stage. The efforts of the CREAT team members were directed by management toward a grander project called the Risk Information Tool (RIT) that slowly became moribund due to a number of issues: lack of resources. competition between CRESP management units for control of public information, lack of participation from most CRESP task groups, and a diversion of effort due to a management mandate for concentration on scholarly publications. Unfortunately for the Research Web, RIT was designed for a different audience than the chromium RW. so there was an incompatible conflict in goals. While RWs could provide information to the RIT. it was RIT that had a wider audience, and because of that. RIT received the attention of CREAT.

The Chromium VI RW was generally considered to be a good idea. but was destroyed by incorporation into RIT. an enterprise that languished. Its life. from inception to inactivity. was about ten months.

5.2.4.2.4 Case Study Data

Meeting minutes were recorded and archived. most in DocReview. In addition to CREAT minutes. minutes of the Data Characterization. Analysis and Statistics (DCAS) task group of CRESP recorded some CREAT activity. since several DCAS members were CREAT members. Personal e-mail archives also contain discussions of issues relating to CREAT.

5.2.4.2.5 The Web Site

There were seventeen essays on the site. the ten questions and seven others. Members contributed four essays on ecological topics, and the facilitator contributed three more to provide an organizing model (see Figure XII below) for the RW.

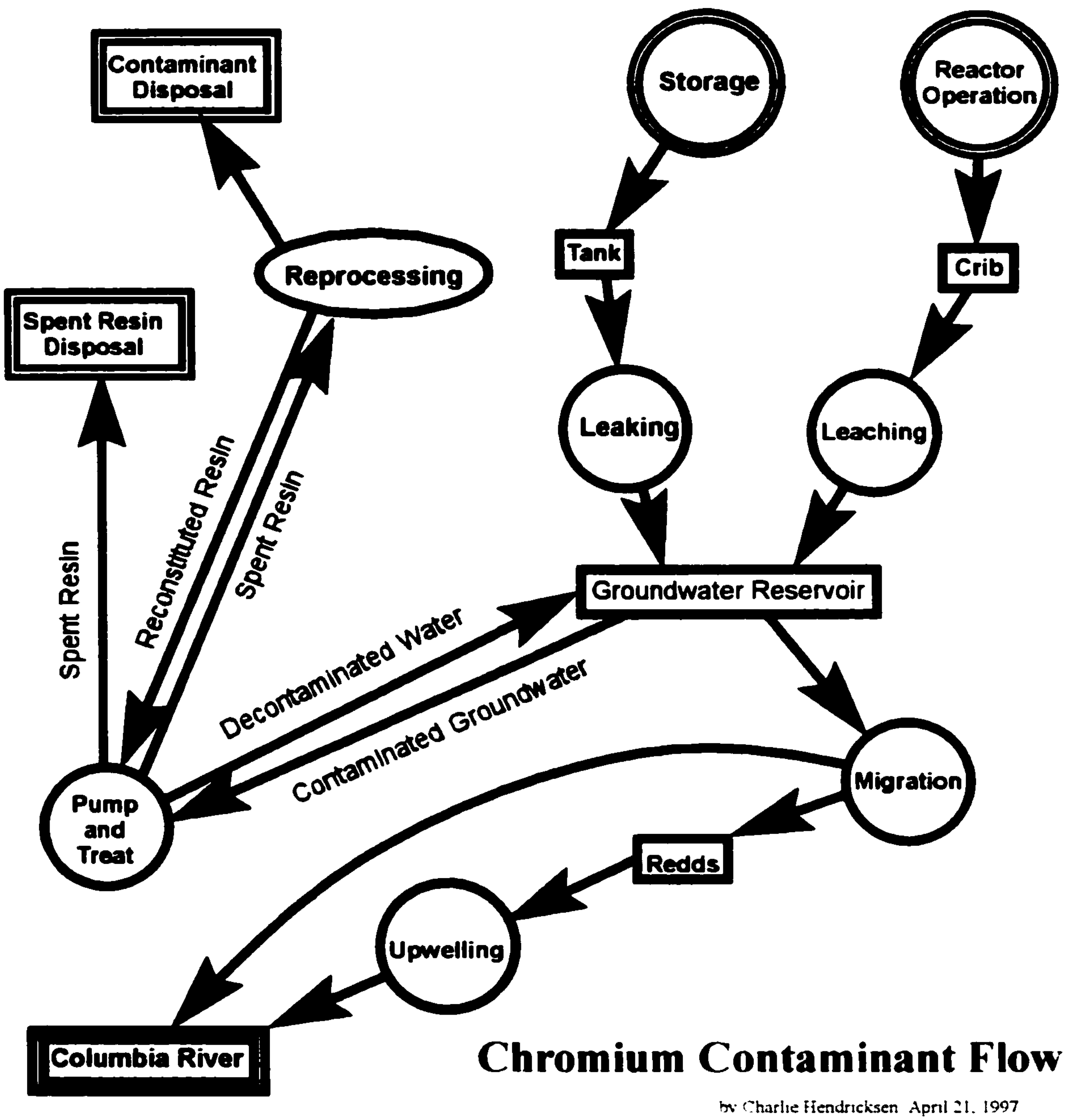


Figure XII Organizing Model for the Chromium RW

5.2.4.2.6 Conscription Devices

The seventeen essays were all DocReviewed and most received annotations. The process model was not image mapped, and because of that only general comments about the process could be made. There was no Annotated HyperBibliography or Annotated HyperGlossary, as that software was not yet in existence.

5.2.4.2.7 Participation Profile

Most members of CREAT, especially the content providers, were well engaged and participated in DocReviews. Several members of the team were frank advocates. Requests and reminders to review documents were issued freely, but consciously avoided importunity. Four members of the group never participated online, but did attend meetings. One of these was openly resistant to the Internet, and found hours of time to attend meetings but never the minutes to participate online. Participation by the team would likely have continued, but a motivating stream of new content (conscription devices) never developed.

5.2.4.3 Soil Crusts RW

The Microbiotic Soil Crusts RW was begun in late 1996 with the intention of creating a Research Web specializing in the study of crusts of lichen, mosses and cyanobacteria that form on some soil surfaces of semi-arid lands. The topic was a natural extension of the scientific coordinator's research interests, and would also provide a collaborative environment for the study and cataloging of soil crusts on the Hanford Nuclear Reservation in Washington State.

5.2.4.3.1 Mission and Topic

This Research Web was founded to coordinate the efforts of eight researchers that were studying microbiotic soil crusts in the northern steppe ecotone. The work that brought them together was a survey of soil crust lichens on the Hanford Nuclear Reservation. There was a need to obtain this data in order to determine the feasibility of using these micro-communities for indicators to measure disturbance of the ecological habitat on the Reservation.

5.2.4.3.2 Organization

This enterprise was funded indirectly by CRESP and Pacific Northwest National Laboratory (PNNL), and by a small grant from The Nature Conservancy. CRESP and PNNL have ongoing research interests at Hanford. The Nature Conservancy was a contributor and interested party by virtue of its long research association with the Fitzner-Eberhardt Arid Lands Ecology (ALE) Reserve. Team members were from the University of Washington (2), Washington State University, The Nature Conservancy, and Pacific Northwest National Laboratory (2).

5.2.4.3.3 Focus

The RW was begun in late 1996 on the heels of the successes of the CREAT Research Web. The scientific coordinator was one of the energetic collaborators in the CREAT Chromium RW. There were high hopes for this RW as it included a set of collaborators with an authoring project, funding, an enthusiastic scientific coordinator interested in long-term research, and an eager facilitator.

A paper was to be produced by the team as the result of field work performed by seven members of the team. The principal author was somewhat reluctant to share early drafts of the manuscript with the team at large, even by hardcopy; but eventually a draft of the paper was DocReviewed on the RW. Another paper was planned, on field sampling techniques, by the scientific coordinator, but never reached first draft stage.

The Research Web slowly became moribund in 1998 as its only effective conscription object, the scholarly paper[36], neared completion. The scientific coordinator and facilitator attempted to keep the RW alive in hopes of attracting interest among the very small and specialized soil crust community. Closing the server computer in 2001 terminated all activity.

5.2.4.3.4 Case Study Data

The complete web site and 344 e-mail messages related to the RW have been archived.

5.2.4.3.5 The Web Site

The web site contained a full complement of tools: a home page, essays, an interactive page to discuss research interests, an interactive page designed to discuss plans for Autumn 1997 field work, Annotated HyperBibliography with author and title indices, species list, a Lexicon installation, Annotated HyperGlossary, a photo album, indices to DocReviews (both active and archived), both public and team partitions, and an authoring team. Minutes of team meetings were mounted on the web site and were DocReviewed.

The facilitator, with the help of the scientific coordinator, planned and prototyped a new tool, the Species List. This software was designed not only for cataloging each of the lichen species found, but also to provide an online annotation capability so specialists could insert "micro-essays" on a species. These "micro-essays" called Specialist Views in the species list were designed to allow the appending of interdisciplinary knowledge to the species list. For instance, specialists in range management or fire ecology might have notes on species important to their work. This tool was an example of creation of a new tool suited to the distinctive needs of the team's research.

5.2.4.3.6 Conscription Devices

Conscription devices installed to draw out the knowledge of the team members included a Lexicon with many entries intended to assemble entries for the Annotated HyperGlossary, an Annotated HyperBibliography with 78 entries, two essays, a species list prototype, 7 DocReviews including a draft of a professional paper, and an interactive research interest page. There was no organizing model presented.

5.2.4.3.7 Participation Profile

The scientific coordinator promoted the RW actively. The facilitator worked closely with the facilitator, but engaged with the team only at the request of members, making no independent contacts. The collaborators were well distributed among four organizations in Washington State. The distance from Seattle-Tacoma to Richland was such that face-to-face meetings would require considerable travel time by road or air. At best, a meeting would take one very long day of travel. It was assumed that this distribution would encourage on-line participation.

Two invited members never participated in the RW, and one of those, a senior researcher who would have been of great value to the team, could not be convinced of the utility of the WWW, and absolutely refused to interact with materials not in hardcopy. The attitude of this person to the technology was so extreme that they were stereotypical. Attempts to recruit new members were made in 1997, but little interest beyond polite replies was encountered. Participation by members other than the scientific coordinator ceased after the first draft of the paper was DocReviewed.

The RW was presented at the 1998 convention of the Society for Ecological Restoration ("Can soil crusts act as indicators of the biological condition of the shrub-steppe? Using the world wide web to foster scientific collaboration."). It was received with interest and a few people expressed a desire to participate in such an enterprise, but nothing developed.

5.2.4.4 Earthquake Disaster Mitigation

In the Autumn of 1998 work was begun on a RW to support the US-Japan Cooperative Research on Urban Earthquake Disaster Mitigation. This project was based on the experiences of researchers with two major earthquakes in the early 1990's: the Northridge Earthquake in Southern California and the Great Hanshin Earthquake in Kobe Japan. Damage to regional transportation infrastuctures was profound in both these disasters.

5.2.4.4.1 Mission and Topic

> *This WWW site supports an interdisciplinary team of scholars studying the impact of catastrophic earthquakes on urban transportation systems. This team is distributed around the Pacific Rim in Japan and the United States. The team's goals are to develop both a broad synthesis of the impact of large earthquakes on transportation systems and several more specialized studies. The knowledge produced by the specialized studies is expected to support the broad synthesis; and the synthesis is expected to illuminate the specialized studies and to produce new insights and hypotheses.*
>
> --- from "Site Design and Research Support" web page

5.2.4.4.2 Organization

The team was composed of twelve scholars well dispersed on the Pacific Rim: one in Seattle, five in Los Angeles, and six in Japan. The Japanese scholars were all affiliated with the Disaster Prevention Research Institute (DPRI) of Kyoto University. The American scholars were not organized into a formal association. The scientific coordinator was a colleague of the author at the University of Washington.

5.2.4.4.3 Process

My colleagues were always on the lookout for research enterprises that might become Research Webs. Tim Nyerges, my committee chair, told Stephanie Chang about the concept and how it had worked in practice. She contacted me in September of 1998, and the decision to go ahead with a Research Web was made in the following month. At a team meeting in December, Dr. Chang presented the Research Web concept and it was accepted with enthusiasm.

Content in the form of meeting minutes. CVs. and professional papers were added over the year of 1999, but participation was minimal. In March of 2000. a public partition was added. but that did not spur any further participation. At the time of writing. the RW is moribund.

5.2.4.4.4 Case Study Data

The complete web site is available and 163 e-mail messages related to the RW have been archived.

5.2.4.4.5 The Web Site

There were 40 web pages in the RW web site. The site was partitioned into two partitions. a public partition with 14 pages and a passworded team partition with 26 pages plus DocReviews.

In the team partition. the web site contained several infrastructural pages: a team page. listing all members and their affiliations. with links to the five members who have home pages; a Mail Room page that allowed the user to send e-mail to any team member: a What's New page that allowed the user to obtain a list of activity in any or all DocReviews: a meeting schedule page: a page describing the web site and the support available for the researchers: a page with links to DocReviewed professional papers: an index to all DocReviews: a page providing links to transportation system data in Seattle. the region of interest to the scientific coordinator: and links to project archives.

5.2.4.4.6 Conscription Devices

Two published papers were mounted on the site in DocReview format so the team members could annotate the documents. No annotations were made. Eleven documents were DocReviewed and collectively gathered only seven annotations, all by the scientific coordinator and one colleague. There was no organizing model, Annotated HyperBibliography or Annotated HyperGlossary developed for this RW.

5.2.4.4.7 Participation Profile

Of the twelve researchers, only two participated in the Research Web. The scientific coordinator promoted the RW at appropriate times, avoiding overt advocacy. The facilitator engaged only at the request of members, making no independent contacts.

There was a lack of conscription devices to attract participation. Working papers were not shared except within the authoring teams. Two papers were presented for DocReview, not as working papers, but as finished or submitted documents. One computer model was produced, Walter Svekla's master's thesis, but was not incorporated into the Research Web.

5.2.5 Case Study Analysis

In this section, the data gathered from experiences with the four Research Webs are analyzed. Several research questions are introduced and interpreted, and the propositions arising from the research questions are discussed.

5.2.5.1 Research Question 1:

What was the focus (issue domain) of the RW?

Framework for Analysis:

The issue domain of the RW can be sharply focused or very diffuse. Even a sharply focused issue domain may be. however. far too large in scope for a RW team. An expansive issue domain may be so sparsely populated by content that the units are not interdependent. Independent units will not encourage mutual collaboration by their authoring teams. In other words. they will not be contributing to a unified whole. There is also the possibility that the scope of the RW is too narrow for a long-term collaborative enterprise. Such is the case where the collaboration is focused on a single scholarly paper with no interest in either enlarging the scope of the RW to include closely related topics. or elaborating the details of the objects or processes of the RW; in other words. by building neither a supermodel nor submodels.

Propositions:

I) A diffuse focus for the RW will likely result in little participation.

An organizing model that provides a central point of interest and a set of potential work objects. The function of work objects is not only to produce tangible results and publishable documents. but also to conscript the members of the team into active participation. The principal conscription devices are models of the issue domain. Other conscription devices. such as RW essays. bibliographic information. glossaries. discussion forums. and document reviews. encourage participation: but such participation is generally not central to the research but rather to discrete initiatives within the research effort.

Focus and scope are closely related. Focus is the issue domain at the core of the RW. Scope is the outer boundary of reasonable extensibility of the RW. A narrow focus is necessary to provide interdependency of the topics of the issue domain. If the authoring teams address unrelated topics, then it is likely that the research team will self-segregate into subteams. The volume of communications between the subteams will be minimal. Indeed, the division of effort may cause the subteams to drop below critical mass. An overly narrow scope will not provide sufficient research opportunities for a research team that is large enough to provide critical mass.

Chromium VI Findings

The issue domain of the RW was the universe of causes, processes, damage, hazards, and remediation efforts associated with Chromium VI chemical contamination from the plutonium production reactors along the Columbia River in the Hanford Nuclear Reservation. A process flow model provided the organizing model. This model related many of the physical objects and processes defining the behavior and character of the contamination. Each element of the organizing model provided ample scope for expansion of the topic by description and theory building. Many of these elements provided topics for potential research papers including the application of geology, natural history, engineering, ecology, and human health to the issue domain. Indeed, plans for research papers were begun on bioremediation and the effects of contamination on salmon spawning; and descriptive pages, such as one that described the Environmental Restoration Disposal Site, a repository for contaminated soil, were added to support the model. The life of this RW was not sufficiently long to determine if the organizing model would have been effective.

This was the first RW and as such all its aspects were not well understood by the participants. The organizing model was not criticized and little attention was given to contribution of essays to flesh it out. What *was* well understood was that ten questions needed to be answered in short essays. Those ten essays occupied the attention of many of the members. Two members did contribute essays beyond the ten questions. This RW had proper scope. focus and a coherent organizing model. Its ultimate failure was not due to shortcomings in scale or focus. but rather to changes in the mission of the research team.

Migration Findings

The issue domain of the prototype RW is migration by household units focused on the behavioral processes by which such migration comes about. This issue domain is far too broad for a RW as proposed in this dissertation. Its organizing model is quite adequate for the description of process and ultimately for theory building. Very likely. even the next lower level of abstraction is such that it will also be of interest only to scholars with broad synthetic theory building interests. Only at even lower levels still less abstract will issue domains be found that are properly focused for Research Webs. In support of the contention that such very high levels of abstraction preferentially attract theory building is the observation that three well-established scholars contributed (Tobler. Davis. Amrhein). Despite a personal appeal to a graduate seminar on migration. little interest was shown and no substantive contributions were made.

Soil Crusts Findings

The issue domain of the Soil Crust RW was the nature of the soil crusts in the northern shrub steppe biome. Soil crusts are mats of lichens. mosses. and cyanobacteria that form on undisturbed soil surfaces in semi-arid lands. The scientific coordinator and the facilitator agreed that the topic was sufficiently specialized to provide a proper scope for a RW. Given those assumptions, work was started immediately on a comprehensive bibliography and glossary of terms. There was no organizing model, though there were several bases for organizing models. The ecology of soil crusts is characterized by mutualism, symbiosis and perhaps parasitism. How an ecosystem dominated by only four classes of organisms: cyanobacteria, lichens (fungus and algae), and mosses interacts as a general system could serve as an organizing model. Microclimates and geographical models of the ranges of species are other potential organizing models.

The project's immediate goal was to provide a forum for the cataloguing of the soil crusts on the Hanford reservation, with the intent to expand the scope of studies in the future. Once the principal work object, a research paper cataloging the lichens, was finished participation dried up. Several conscription devices were available, but did not attract participation from anyone except the scientific coordinator. The fact that this properly scoped RW went moribund is a demonstration of the importance of rewards. When the reward of authorship had been spent, there was no further participation. If there had been an organizing model, a plan for a series of research articles, and scholars to perform the research, the RW might have survived.

Earthquake Disruption Findings

The issue domain of the Earthquake Disruption RW was the impact of large earthquakes on urban transportation systems. The grant proposal that described the work clearly indicated that the work to be done was a reconnaissance of the field designed to support scholars who would hopefully describe the field and generate hypotheses. The diffuse goals of the work precluded any organizing model, though the mandated synthesis of the field will perhaps provide one.

With no organizing model and a working mandate that encouraged independent, though related research, there were few common work objects. Furthermore, all rewards were clearly related to production of research papers. Potentially unifying conscription objects such as glossaries and bibliographies were not initiated. This RW had no research focus, thus little need for research collaboration outside the authoring teams.

Discussion of Findings:

A research web needs to be properly scoped to be successful. The scope of the RW is determined in part by topic and in part by size. The number of members required to perform the research determines the size or scale of the RW. The permanent members of the research team must be sufficiently interested in the entire issue domain to contribute criticism to all documents. Clearly there needs to be a critical mass of dedicated researchers; beyond that there is support staff needed, including at least a scientific coordinator and a facilitator. The topic, or issue domain, must cover a set of clearly interrelated elements that are sufficiently specialized. The specialization should be such that each element is either a good topic for a single research paper or a topic that can encompass a small family of very closely related research papers.

Scope was clearly an issue in the lack of success with the Migration RW. It was so vast that only philosophers could work at that level. While the organizing model was very interesting, the elements of that model were not sufficiently specialized to produce either research papers or small families of research papers.

A lack of interrelation is indicated by difficulty in developing an organizing model. The Earthquake Disruption RW showed this difficulty. Likely the work undertaken in the founding grant will act as a research reconnaissance and will synthesize organizing models for the issue domain. The Soil Crust RW also had no organizing model because the RW was organized around a single research paper. Had the team been interested in developing the RW around biological or ecological system models rather than a cataloging of species present in a given area, it may have survived.

Both proper scope and focus were demonstrated in the Chromium VI RW. Lack of success can be attributed to a failure of leadership. While management initially approved the RW, it failed to recruit specialists to contribute research essays (and eventually papers). The RW ended when management redirected the efforts of the research team into a project focused on providing information rather than supporting exploratory research.

II) Confederations (groups with different focuses) under a single RW will fail.

The CRESP project that supported two of these cases was formed as a large-scale collaborative project joining several disciplinary specialty groups with a single support group dedicated to gathering data, providing statistical services and supporting a Geographical Information System. While CRESP was far too large for a single RW, it could easily have provided an umbrella organization to support several loosely interrelated RWs. Instead it devolved into a successful confederation of independent authoring groups that generated many professional papers, but little collaborative work toward its original mandate. Failure to provide an organizing model resulted in pathologies that ended all collaboration. Not only did each disciplinary group stay within their specialty, but also the existence of two cooperating Universities locked into an inferior/superior structure took its toll. The research team was fragmented both by discipline and institution. These same pathologies can destroy RWs.

Chromium VI Findings

The Chromium VI RW had only a single group of collaborators (CREAT), but their efforts were fragmented in several directions. First, the members of CREAT were participating under a matrix management agreement, essentially on part-time loan from several task groups of the CRESP project. While this regime was interdisciplinary, and thus positive from a collaborative sense, there was competition in agenda setting. The research direction could remain interdisciplinary, or could veer off into a specialty area such as ecology, toxicology or human health hazards. Specialists could satisfy personal, disciplinary and task group goals by writing papers that dealt with more narrowly defined professional issues. And secondly there was a mandate in effect that had defined one of the CREAT goals as developing a set of "fact sheets" (the ten questions) for each of several contaminants. Several of the team members withdrew after these fact sheets were done. The efforts of CREAT were also split into the study of two contaminants, chromium VI and tritium.

Soil Crusts Findings

The Soil Crust RW team had only two authoring teams, one large effort to produce a paper on lichens on the Hanford Reservation, and the other a solo effort on sampling techniques in field work. The purpose of the sampling techniques paper was to discuss methodology for field studies of soil crusts. Unfortunately, the field sampling methods had already been selected, so there was little interdependency between these efforts. While there was no competition between the authoring teams, the only active participation from the Eastern Washington state members was directed to the lichen paper. Only members from Western Washington participated in the sampling techniques paper, but also contributed to the lichen paper.

Earthquake Disruption Findings

This RW had a confederation organization. By mandate, the research team was encouraged to investigate independently. A set of investigators in Southern California had collaborated on papers many times before and intended to continue that team effort with new papers. The Seattle investigator was isolated from the California team, though she had worked with them in the past. She produced a paper that was geographically focused on her locality. The Japanese team was unified by membership in (DRPI), but was split into small authoring teams of scholars in close proximity.

Discussion of Findings:

If the RW is organized as a confederation of authoring teams with little interdependency of topics, then the authoring teams will be naturally isolated. This isolation is a product of attentional economics: there is no reward in paying attention to work not related to your own efforts, and your attention will naturally be given to the paper your team is producing. This isolation can be exacerbated by geographic concentration, as the relative lack of communication barriers favors working closely with neighbors, especially people one has worked with before.

The Earthquake Disruption RW exhibited several isolating tendencies: geographic clustering, existence of previously existing authoring teams, little interdependency between topics, and perhaps language preferences. The mandate from the granting agency specified that independent research be pursued by geographically dispersed authoring teams. None of these factors contributes positively to a RW collaboration. Faced with these difficulties, this RW degenerated from an attempt at collaboration to a file-sharing web site and finally simply vanished.

This finding demonstrates the importance of an organizing model that shows how objects and processes relate to the topic of each research paper. A well-defined issue domain will support an organizing model that will show how (or if) the constituent topics are related. If there is no mandate for synthesis and collaboration backed by effective leadership. then authoring teams will tend to isolate themselves. The academic reward system is such that research papers are essentially the only professional reward. so the leadership of the RW must provide incentives for participation beyond the writing of research papers.

5.2.5.2 Research Question 2:

What were the geographic distribution effects on the RW?

Framework for Analysis:

Geographic distribution effects include not only the physical dispersion of the team. but the existence of socially bound clusters of members and isolated members of otherwise concentrated teams. Another isolating geographic influence is native language: people do prefer to work in their native tongue rather than in other languages. especially since a research paper can always be translated as a single stand-alone document. Other geographic effects include the temporal dispersion of the team: for instance. though vast distances may separate team members. they may still be in the same or nearby time zones. Separation by several time zones makes synchronous communication problematical.

Propositions:

1) RWs with strong concentrations of people who can easily communicate in person will fail.

This proposition was suggested by the media competition theory. This theory suggests that the most accessible communication modes will be preferred to those requiring more effort. Thus synchronous communication, especially face-to-face communication, will be preferred to asynchronous communication. This preference will naturally lead to a tendency for interacting with colleagues close at hand, socially and intellectually isolating remotely located colleagues[37]. Furthermore, most face-to-face and telephone communication goes unrecorded and hence unavailable to members both remote and local.

Chromium VI Findings

The Chromium VI RW team was all located in the same city. Most of the team members were not, however located in the same office suites. The team members met frequently, and communicated by phone and informally. No indication of ill effects due to proximity was noted. There were no isolated members, since all members were drawn from a pool of people who were working on a single large grant project (CRESP). Participation in DocReviews of essays and minutes was active and successful. E-mail apparently was preferred to telephoning due to competing schedule demands. Messages were frequently shared by forwarding and multiple addressing.

Soil Crusts Findings

This RW had two members who worked at the same laboratory, and were near the lead author of an authoring team. These people were also close to the location of the field study that was the basis for the research paper. The scientific coordinator was isolated from these people, and could meet with them infrequently or individually by long-distance telephone. The scientific coordinator did actively participate in biannual fieldwork with that local group. There was a noticeable social strain in this RW, perhaps due in part to the communication problems.

Earthquake Disruption Findings

The Earthquake Disruption RW had three centers of activity with teams in Japan and Southern California and an isolated member, the scientific coordinator, in Seattle. Within the Japanese team there were four members from Kyoto, and two from other Universities. Four of the five members from Southern California were from the University of Southern California (USC). The USC members formed a particularly tight group, having authored over thirty research papers jointly in some combination or other. The RW team then consisted of two four-strong centers and four isolated members. The extent to which this configuration contributed to the failure of the RW is unknown.

Discussion of Findings:

In the Earthquake Disruption RW most collaboration was done within the authoring groups, each isolated in its own geographic region. It is expected that authoring teams will concentrate their attentions on documents of their own. Leadership and training materials will have to remind them that all members have a responsibility to contribute to the refinement of content contributed by others.

The Soil Crust RW had a similar lack of conscription devices, though the scientific coordinator did attempt to draw members into collaboration by several weak conscription devices: an Annotated HyperBibliography, a Lexicon designed to build the Annotated HyperGlossary, and an attempt to build a Species List. The only effective conscription device was a research paper that was DocReviewed in an advanced draft. Team members expressed an interest in collaboration on the WWW, but few work objects were offered.

In order to detect problems of this nature in any RW, both isolated members and collocated groups will have to exist in the RW. This condition was not present in the Chromium VI RW. Any conclusions drawn on the limited experiences herein are conjectural and will need to be investigated as a natural experiment in the future when a RW with a widely distributed team with clusters emerges.

II) RWs with widely distributed members who live in different time zones are more likely to succeed than RWs with concentrated membership.

People who live in time zones far removed from their collaborators cannot engage in synchronous activities such as teleconferences without disrupting their daily activity cycle. This fact is likely to make a very dispersed team more inclined to accept asynchronous communication, and with that the environment of the RW.

RW Findings

The Soil Crust and Chromium VI RWs were all based within a single time zone. The Earthquake Disruption RW was a transpacific enterprise that had teams separated by 8 time zones. Recognition of this fact was perhaps a factor that caused the team to accept the concept of the RW. Unfortunately, the lack of conscription devices made participation in the RW rather pointless.

Discussion of Findings:

There is little empirical evidence to support or reject this proposition. If there is an effect, it is likely to be weak when compared to strong influences like the presence of strong leadership, member commitment, and an abundance of conscription devices.

5.2.5.3 Research Question 3:

How many people were invited to participate in the Research Web?

Framework for Analysis:

There are very fuzzy upper and lower limits to the size of effective research teams. Team size is effectively left to chance when the RW concept is adapted to existing teams rather than building the team to suit the concept for application to a specific issue domain. Here we are left with the problem of comparing the teams that were assigned by circumstance to the teams that might have been designed for the RW.

Propositions:

1) The critical mass theory holds for research webs.

Critical mass is a function of the size and organization of the research team. There are upper and lower limits to the size of an effective RW team. The upper limit is reached when there are so many scholars studying of the issue domain that scholarship is exhausted, the field becomes known territory. The lower limit, critical mass, is reached by having enough active and interdependent conscription devices to hold the interests of the entire team. In a RW, critical mass is necessary to insure a reliable flow of new content, essays, e-mail, annotation, and research paper drafts. The presence of a large body of content open to annotation (conscription devices such as models, essays, bibliographies, and glossaries, etc.) is a good base, but new content is necessary to prevent the collaboration from going stale.

Chromium VI Findings

The Chromium VI RW directly invited 18 people to participate and made the URL for the RW available to the entire CRESP team, perhaps forty people. This RW failed to recruit a full range of scholars in fields that could contribute to the understanding of the issue domain. Remediation is an important part of the study of environmental contamination. Even though there was a well-funded contingent of environmental engineering scholars available in a CRESP task group, they did not respond to requests to join the effort; leadership was not able to persuade them to do so.

This team was very close to having critical mass. The research team was well represented in several appropriate disciplines: ecology, human health hazards, geography, statistics, and risk management. This team was comfortable with the RW technology, contributed content when requested to do so, and was not reluctant to criticize content through annotation. While the lack of participation from engineering was damaging, it may have been overcome in time, since several team members were capable of contributing essays on the topic of remediation techniques.

Soil Crusts Findings

The Soil Crust RW invited four members of the research paper authoring team, two people from a granting agency, two co-workers of the scientific coordinator, and two outside scholars. Despite a thorough briefing about the concept of Research Webs from the scientific coordinator, this small team seldom showed any inclination to participate in activities other than the authoring of a single paper. The lack of interest in any systemic studies of soil crusts ensured that there would be little likelihood of attracting new members. There was no interdisciplinary work and thus the group was not likely to attract new members. Critical mass was not approached.

This RW was started with the understanding that a recruiting effort would be required to attract critical mass. These new recruits would hopefully be drawn from scholars interested in systematic studies that would complement the existing team's interest in taxonomy and local inventories. The scientific coordinator attempted to attract these scholars but had no success, though a few scholars expressed interest. Perhaps organizing models need to be present in order for new members to understand how their work can benefit from the RW. With no funding or colleagues with plans to produce papers, recruiting was a rather hopeless task.

Earthquake Disruption Findings

The Earthquake Disruption RW invited all twelve scholars funded by the founding research grant. Critical mass was not reached in this RW for several reasons, principally a failure of adoption of the RW as a medium of communication. The failure of adoption was in turn triggered by a lack of conscription devices. In other words, contributions were not solicited effectively.

The character of this RW was such that interactivity was subordinated to independent research. Lack of interdependence leads to a paucity of reciprocal communication. It is difficult to see how this RW could have succeeded, indeed it epitomized the "confederation" organization: a loose collection of groups working on similar, if not competing research.

Discussion of Findings:

Critical mass implies the presence of not only a sufficient number of participating scholars, but also an organization that will support collaboration. The organizational character of the RW must create a generous number of interdependent interests[38], and the conveners must have set out the terms of team membership in order to reduce the possibility of free riding and non-participation[39].

The scope of the issue domain is the key to developing interdependent units that can engage the interests of the team members. The Soil Crust RW had a scope that was perhaps proper, but did not attract enough members. There was no organizational model set up to outline potential interdependent research units within the issue domain. Without a model there was no basis to attract specialists. The Earthquake Disruption RW had no stated organizing model, and the research units were not interdependent, but rather similar. The Chromium VI Research Web had an organizing model, several interdependent research units and, very likely, enough scholars to engage those research topics. On this basis, it seems that the only RW that approached critical mass, and thus a chance to succeed, was the Chromium VI RW. It was the largest RW, and still too small.

5.2.5.4 Research Question 4:

What incentive(s) did each of the participants have to participate?

Framework for Analysis:

This research question goes straight to the heart of the reward system. For lead authors and the members of their authoring teams, clearly the incentive is to have research published. This is the well-understood academic reward system in operation. For the critics, there is the reward of showing one's peers that you do understand the issue and can contribute. Criticism is the personal expression of the mandated skepticism of science. It is also obvious that critics can be invited to participate in authoring teams if their observations are acute and well expressed.

Conveners and scientific coordinators are likely to equate success of the RW to administrative as well as scientific accomplishments. The rewards at this level are likely to be career related milestones that transcend authorship, though their close involvement assure that authorship is almost automatic. Career milestones include being selected as Principal Investigator, awarded an endowed chair, and perhaps leadership positions such as Laboratory Director.

Collaborators, those that make modest contributions to infrastructure such as model building, glossaries and bibliographies, as well as criticism, can aspire to eventual inclusion in authoring teams. Graduate students and staff assistants can earn their bread in collaboration, and can also be rewarded for their efforts by acknowledged contribution in research, a mechanism called legitimate peripheral participation[40]. Facilitators may be staff or collaborators. Their incentives may be process related, contributing to the collaboration process; and/or topic related, contributing to building knowledge in the issue domain.

Propositions:

I) In order to be successful the RW must provide rewards beyond authorship.

There is considerable overhead in a RW. The costs of the knowledge-building efforts directed to the understanding of the entire issue domain must be borne by the team. Researchers focused on the writing of a single research report cannot justify these costs. There must be some additional rewards to encourage the team to invest in model-building and collaborative criticism.

Chromium VI Findings

The Chromium VI RW though short-lived, exhibited the presence of authoring incentives. The seventeen essays provided the authors the opportunity to exercise scholarship with essays that could have provided a start of research papers in several instances. Essays on the effects of hexavalent chromium on salmon, on bioremediation of hexavalent chromium, and on the measurement of chromium contamination could have been extended into research papers.

The need to develop some rather simple research essays provided opportunities for participation without great effort. The facilitator, a graduate student, was highly motivated by the expression of interest among team members. Several graduate students and professional staff members contributed opinions and knowledge in several of the DocReviews, fulfilling not only an obligation to contribute, but also showing interest.

Soil Crusts Findings

The existence of a research paper as a conscription device certainly rewarded all the scholars on the authoring team. The scientific coordinator saw the possibility of creating not only a successful RW with multiple products, but also a career-enhancing position as host of a site that might attract new members throughout the discipline. Her research interests, soil ecology, included soil crusts. That the soil crusts were being studied as funded research associated with her position made the fit perfect. One of the stakeholders, a grant provider, was an active participant in some DocReviews. This participation was clearly offered in a collaborative spirit since he was essentially office-bound by his position.

The RW provided the opportunity for two graduates student to join the research process. One of the members was a doctoral candidate studying lichens, her dissertation topic. The facilitator not only practiced the running of the RW's site and assisting the scientific coordinator in her efforts to make the effort a success, but was also carried as a co-presenter of a paper at a conference. The Soil Crust RW provided an opportunity for the facilitator to polish some of the tools and to produce a new tool specially suited to the issue domain.

Experience with the Chromium VI RW caused one of the contributors to start the Soil Crust RW, perhaps as a career-enhancing strategy. Recently, in a career move, this person accepted an environmental consulting position. She attributes her experience with the RWs as a major factor in obtaining the position.

Earthquake Disruption Findings

The Earthquake Disruption RW offered few rewards other than those offered by the founding grant. The mounting of research papers in the public partition of the web site gave the papers wider circulation.

Discussion of Findings:

Rewards emanating from the RWs were few. Other than authorship on one research paper there were no obvious rewards save the pleasure of active participation in a collaborative enterprise. Exposure to computer-aided collaboration has been reported to be positively viewed by potential employers. There was not a great deal of effort put into development of rewards, most effort was directed toward development of the web site and intellectual content. The short lives of the RWs did not allow development of any management philosophy.

5.2.6 Conclusions

These case studies provide explanations for failures, examples of successes, and suggestions for correcting pathologies and capitalizing on successes. In most cases the RW concept was applied to preexisting teams with either inappropriate or ill-defined issue domains. The establishment of goals should precede the determination of the research team's composition. In a RW, the principal goal of a research team is always the understanding of an issue domain. Secondary goals, such as publications, will be produced as a byproduct of the search for understanding.

There are two major problems in defining the issue domain: defining a scope that is large enough to develop critical mass, and defining a scope that is small enough to ensure that the majority of authoring topics will be interdependent. The prototype, a study of migration behavior, had a scope that was far too large. The Earthquake Disruption RW had a scope that was probably appropriate, but the team members were set on parallel tracks rather than interdependent tracks. The Soil Crust RW had an issue domain but never developed an organizing model. If one had to express an issue domain, the only statement would be: anything about soil crusts, but especially those factors that contribute to our work object, a single research paper. Once the research paper reached an advanced draft, the team had no remaining goals. The Chromium VI RW had a well-defined issue domain and proper scope. It failed due to withdrawal of management support.

Critical mass was approached only in the Chromium VI RW. The issue domain was defined with sufficient accuracy to determine where the team needed to be supplemented. Had the RW lasted a few more weeks, the needed researchers would likely have been recruited. The other RWs had small teams, but suffered from pathologies in addition to simple lack of critical mass. Based on these studies and suggestions from the literature, it seems likely that the critical mass for a RW may be as much as a couple dozen researchers.

> Proposition 1: *There are only two stable states of interactive medium usage in a community: all or nothing. Either usage will spread to all members of a community (universal access will be achieved) or no one will use the medium (for communications internal to the community), either because no one started using it or because usage fell off in the absence of reciprocity.* — Markus 1987[41]

In her discussion of this proposition, Markus depended on a small set of natural experiments, since it was difficult to find documented evidence of participation in interactive communities at that pre-WWW time. Since then the Internet has provided ample evidence in the form of listservers and discussion forums. In our case studies, none of the communities reached a positive participative equilibrium, providing evidence that if there is a threshold (critical mass), then groups of less than two dozen or so are below it. I find no difficulty in visualizing such a threshold since people very quickly abandon an enterprise when it is failing to thrive.

Participation is a necessary attribute for success. Only one RW had adequate participation: the Chromium VI RW. Why? This team was socially integrated: most people knew each other from team meetings on several levels. The team was technologically well served and were adept users. There was an abundant supply of work object, opportunities to participate. There were 43 web pages on the web site, and most of those were available for annotation. Several members were authors of RW essays. It appears that both critical mass and frequent introduction of new content are necessary to generate adequate participation.

Geographical and time zone distribution effects were not seen in these cases. Some obvious problems centering on team dynamics dealing with cliques and isolated members remain to be investigated. Distribution did not appear to alter the technology requirements of the teams investigated.

Financial support appears to contribute to success. In a world full of interests competing for attention, money provides a simple metric for selection. Members of the successful Chromium VI RW were all supported to some degree by grant money from the CRESP project. CRESP personnel in the Soil Crust RW were weakly supported as a "management approved activity," but some members had to scramble for support or approval. All members of the Earthquake Disruption RW were supported by grants. The unsuccessful prototype RW was a purely volunteer effort.

Leadership is another quality that must be present. Though all scientific coordinators and the facilitator were enthusiastic, clear and unambiguous continuing support from the team's senior scientists was evident only in the case of the Chromium RW.

Management's role in project failure is sufficient but not necessary.

— Charlie Hendricksen, 1983

5.3 Discussion

A synthetic work like this dissertation must eventually turn to evaluation of its products. Is the concept of Research Webs likely to survive a test in the real world? Under what circumstances is the RW effective and when not? Is the RW compatible with the research culture and academic institutions? Is the high overhead of the RW justified by more productivity and/or higher quality?

5.3.1 The Optimal Environment for a Research Web

The fundamental assumption underlying this work is that there is a great need for methods to support large-scale long-term research. If that is true, then we can discuss what kinds of research might benefit from the concept of Research Webs; and what kinds of research will not benefit (see §5.3.2). Where does the RW fit into the existing types of research? The question of "critical mass" has arisen so often in this work that we need to discuss that issue. What disciplines are suitable for employment of Research Webs?

The Nature of the RW's Research

Theory-building research is the logical home for the RW. Its models are the expression of theory, according to the tripartite models of realism[42] and conform well to the tripartite research methodology proposed in the VNS[43]. Problem solving does not involve theory building, but evaluates proposed solutions based on existing theories, assumptions, myths, or rules. Action research can employ the RW as a theory-building activity that operates in parallel to the design of action to solve a problem and the evaluation of the implemented action[44] (see §2.2.4.6.5). More appropriately, it might be better to look at action research as a technique to be employed to investigate portions of the issue domain. Actions applied to problems are field experiments analogous to experimental scenarios submitted to simulation models.

Size

Small-scale research simply cannot afford the high overhead of the RW. The RW needs economies of scale to justify modeling, bibliographic research, glossary building and the construction of an elaborate web site. This fact effectively eliminates the RW as an organizing method for solo and small group research.

Extraordinarily expansive issue domains, such as migration and poverty cannot employ the RW as an organization for the entire issue domain. The focus of such issues is simply too broad to be parsed into research tasks that are interdependent. Lack of interdependency reduces the potential for collaboration. Note, however, that such very large issues might contain smaller constituent issue domains that are quite suitable for treatment by the use of RWs. There are signs of this sort of organization in the MacArthur Foundation's work, where their Research Networks are all tied into on overarching objective to improve the human condition and community development[45].

The proper size for a RW's research team is an open question. In the limited body of experience, it does seem that there are definite lower limits, and that those limits are significantly higher then is usually seen in social science research. The upper limits are likely to be established more by the extent of the issue domain. The scope of the issue domain is established on the high side by the need for maintenance of interdependency.

and on the low side by the presence of an adequate body of related and attractive research topics (see §3.1.1).

Geographical dispersal

The initial reasons for investigating the RW came from the circumstances that academic social science is beset with. As discussed above, isolation of specialists caused by economic necessity ensures that a critical mass of scholars can only be found by reaching beyond local sources for collaborators (see §1.1). After the investigation was entered there were mechanisms found beyond geographical dispersal that make the RW and attractive organization for research. One of the most interesting findings was that, with modern technology, because of scheduling incompatibilities, even colleagues within shouting distance were likely to be contacted via e-mail. Once the medium of communication is asynchronous, dispersal becomes a less serious problem.

A corollary of physical dispersal is cultural difference. If the research team becomes intercultural, a number of negative factors come into play: language skills, power structures, and workday asynchrony. The pathologies introduced by all these factors are remedied to some extent in the RW. Written language skills are higher than spoken skills, power structures are blunted, and workday asynchrony becomes a minor inconvenience. The positive virtues of a culturally diverse team include a multiplicity of viewpoints.

One problem that remains uncertain is the effect of media competition. Whenever local groups, even pairs, collaborate, there is a strong tendency to revert to habits of speech and the building local tacit knowledge, thus neglecting the documentation and distribution of new knowledge. This unfortunate property may make such groups less effective collaborators in the RW. This mechanism may also increase the isolation of remotely located individuals.

Discipline

Physical sciences such as molecular biology have embraced general systems theory and from that have built some quite elaborate models of metabolism pathways[46]. The Institute for Systems Biology (ISB) in has integrated collaboration, modeling and thorough exploration of each element in the models. While the ISB has the transfer of knowledge to mankind as its goal, the presence of extremely large potential profits in industrial research may stifle free exchange of information.

Researchers in the humanities have done some collaborative work that makes good use of the current technological environment[47]. The issue domains investigated are often very elaborate catalogs of works of art or literature[48, 49]. The need for theory building in these issue domains seems slight.

The social sciences seem to be a natural home for the RW. Theory building is necessary to account for the behavior of human behavior. The need to accommodate several disciplines simultaneously is a characteristic of large-scale social science research. The social sciences routinely have to view their interests from several points of view and inferential methods. The inexact nature of the objects, processes and measuring techniques makes critical thinking not only likely, but also essential. Criticism is a major process in content development in the RW.

5.3.2 The Research Web Compared to Conventional Research Teams

The question of the value of Research Webs must be answered here. To provide a framework for evaluation of the Research Web concept, this section assumes the existence of two equally staffed research efforts, both long-term and large-scale. One of the efforts is assumed to be a conventional research team, perhaps a university institute, the other a team using the Research Web concept and tools.

Evaluation factors that remain similar for both teams:

Salaries and support requirements for scholars, administrators, research assistants, and a copy editor should be identical. The technical support environment (hardware) should be identical. In the academic environment WWW servers are part of the university infrastructure. Software costs are only very slightly higher for the RW, and any higher cost is miniscule compared to salaries. Travel costs may be higher in an RW because it is more likely to be dispersed; but, if the conventional team is dispersed as well, then its travel expenses will likely be greater than the RW team's expenses, because the RW has much better communication channels and therefore less need to travel.

Factors involving personnel cost:

Facilitator

The active presence of a facilitator is absolutely essential. Every member of the team must know that there is someone there to take on all the mundane tasks that the content providers are best relieved of. As Marwell and Oliver say about collective action[50], "The most important determinants of collective action in our models are the interest and resource (or contribution size) levels relative to the cost of contributing." The duties of the facilitator are simply to assume the technical workload introduced by the necessity to support the web site, models, and document formatting. The facilitator reduces the cost of contribution to the team every time one of the many gritty technical chores is taken off a contributor's plate.

From a management point of view the facilitator is not only a cost, but also a bottleneck in some aspects of the information flow[51]. In the RW, most communication is not mediated or facilitated, but some tools are designed under the assumption of intermediation. Access to those tools is by password, and should any team member care to operate the software, then the password can be shared. Experience shows, however, that most members are uncomfortable with the need to learn software and also are reluctant to spend time on such tasks.

Modeler

The services of a modeler may be required, probably on a part-time basis, especially if a simulation model is being produced. While the researchers will certainly become comfortable with the models from examples, there are nuances of data modeling that require more specialized knowledge. For the descriptive, auxiliary, and explanatory models, any moderately skilled programmer/technician should possess the necessary skills. The facilitator or a research assistant may assume these duties. In a mature RW, the services of a more highly trained modeler will be of great value. A skilled modeler can bring a rigor and intellectual clarity to the process that will increase the value of the models.

Training for Collaboration

It should not be assumed that members and staff have any experience with collaboration in large groups. As discussed in the preceding chapters, the experiences of most researchers are likely to have been more competitive than cooperative and limited to occasional small-scale shared writing (see 2.2.5.4). Training that introduces the team to the RW concept and the value and costs of collaboration must be undertaken early in the life of the RW and should be repeated as new members come on board. The cost of this training must be balanced against the value of acquired skills. I think it is likely that a couple of hours of training will be an unquestioned bargain.

Web Site content creation and maintenance

This expense is unique to the RW, although the conventional research team might have a "brochure" web site to publicize its work. A brochure site is equivalent to a token public partition (see §3.5.1) of the RW. The RW's team working area (see §3.5.2) and guest partition (see §3.5.1) have no equivalent in the conventional research effort. Many of the RW's software tools have been built with the intent of reducing the work required to create and maintain content. Much of the content of the RW's web site is actually collected and installed automatically by software. The costs and benefits of this content are discussed below under the "Artifacts Produced" headings.

Collaborative review of documents

In the Research Web team members are expected to review documents as the team produces them (see §2.2.4.6.7). This review process informs the reader and allows the reader to contribute insights that the authoring team may have overlooked, especially links to other research, not to mention the occasional correction of error or the offer of a reference to support a point. A trained collaborator will come to understand the value of critical reviews when his or her work comes under review. In conventional research, the obligation to review the work of those outside a single authoring team is likely to be minimal.

Artifacts Produced

Models

Models in conventional research are, if present, usually sentential or tacit and deal with only the topic of a single research paper. A good model provides a description that is far more complete than the usual abridged and partially tacit narrative description found in conventional reports.

> *"A fairly common strategy in group research is to conduct studies to explore some interesting phenomenon or technique. ... Each of these has produced a 'minitheory' of the phenomenon under study, and some of these are ingenuous and useful. However for the most part, these efforts do not attempt to tie into a larger theory and therefore remain isolated findings."*
>
> — Poole 1990[52]

In the RW, the "minitheories" are expressed, connected, annotated and thoroughly documented. More importantly, they are strongly connected to other minitheories in the RW's issue domain. The question that needs to be answered is, "Is the modeling effort worth the expense?" We discuss below each of the several models that exist in a mature RW.

<u>The Descriptive Model</u>

In conventional research, the objects and processes that apply to the topic of a research paper, usually an isolated phenomenon, are described by reference and narrative description in the research report. No attempt is made to describe attributes of the objects that are not essential to the report. These ignored objects include superclass objects (embedding objects) and objects that might have an unknown or presumed infinitesimal effect on the phenomenon. Process models concern themselves only with elements essential to the argument of the paper.

In the RW, every object within the issue domain that is mentioned in any document is described in the Descriptive Model (see §2.1.2). Every attribute of objects that suggest themselves to the members is listed: and attributes found of interest are elaborated in appropriate detail including operationalization methods. Every object's attributes are open to annotation by the research team. Since several authoring teams share the same models, attributes that are of no interest to one team may be essential to another. Furthermore, some attributes may constrain others.

Processes models are descriptions of observed behavior of the objects. Like obscure attributes of objects, processes may have "side effects" that are of little interest to the observers of the phenomenon being investigated for a single paper. In a RW, one team's side effects may be another team's phenomenon of interest.

The Auxiliary Model

In conventional research, the auxiliary model is generally restricted to narrative description of the operationalization of variables used in experiments and analysis of data. In the RW, all attributes of objects used in experiments, data analysis, or the simulation model are formally operationalized. The investigation is recorded by adding an extension to the Descriptive Model. The extension will include measurement criteria for the attribute: data type of value, precision, range, and a description (see Table II §3.2.4.2.1). In the auxiliary model several options for operationalization may be offered. Choosing the appropriate operationalization is the duty of theoreticians and experimenters. The auxiliary model will be open to critical annotation by the team, just as any document in the RW. The operationalization of the attribute is a directive to the programmer managing the simulation model.

The Explanatory Model

Conventional research expresses its explanatory model as a narrative discussion leading to the development of hypotheses. The hypotheses are the basis for experimentation or argumentation. In the RW, the explanatory model is likely to be somewhat more formal, but incorporates all elements of the explanatory model presented in conventional research. The hypotheses investigated in conventional research are related primarily to the topic of the single research report. The great difference is in the scope of the model. The explanatory model may be abridged for inclusion in research reports. In the RW, the team contains many authoring teams, each intimately familiar with the phenomenon under investigation in their own paper. The RW's explanatory model (see §2.1.3) will show how each phenomenon is related to another. Examination of the relationships is likely to modify the conceptualizations of the phenomena. Certainly additional hypotheses will be suggested.

The Simulation Model

Simulation models are infrequently produced in conventional research in social sciences. Their value is unquestioned in the physical and natural sciences. The reasons for the rarity of simulation in the social sciences are many and varied, but they center on modeling's frequent failure to produce reliable results. The RW can mitigate many of the likely elements of failure. First, the objects and their operationalization are better described and thoroughly discussed; second, the process models of the explanatory model that form the basis for the dynamics of the simulation are more accurate than the isolated "minitheories" of conventional research; and finally, the entire team will be able to "exercise" the model and thus expose potential problems. An argument could be made that high quality simulations might open the phenomena of any issue domain to experimental social science, just as has happened in some domains in economics.

The Context Model

The context model is the most abstract of all the proposed models. It describes the scope of the issue domain (see §3.1.1). In conventional research the contextual model is likely to be expressed only in the charter of the sponsoring organization. This expression is likely to be carefully crafted for political and organizational purposes. The political aspects mentioned are designed to demonstrate the moral grounding of the sponsoring organization. The description is likely to be purposely vague in order not to alienate too many sources of grants.

The context model in the RW has definite purposes. Precision in establishment of boundaries is important for two reasons: if the issue domain is too small, then the issue domain may become unproductive -- all potential research topics may be used up; if the domain is too large, then the authoring teams may not be interdependent --- the research team will be fragmented to the extent that critical mass is not maintained. The representation of the context model is still unexplored territory, but is likely to benefit from cognitive mapping[53,54] and concept mapping. The model must be able to establish not only the necessarily fuzzy boundaries of the issue domain, but also the adjacencies to other issues. The RW's research team will be in a position to contribute knowledge or conjectures about those boundaries and adjacencies.

Intellectual content

In conventional research, intellectual content takes the form of partial drafts, notes, outlines and other ephemera that eventually lead to a research paper. This mass of expressed knowledge is usually stored in the author's files, and is thus inaccessible. After publication of the research paper, much of this information is purged from the files. Even if the files were opened to the authoring team, they would not be searchable, and would thus present the reader with the necessity of wading through every scrap of information in order to find what is of interest.

In the RW, intellectual content is contained in the documents in the RW repository (see §3.2.2). Documents include essays, models, e-mail, drafts of papers, outlines, images, annotations, and others. Essays are a formal genre, the Research Web Essay (see §3.4), and are accessible to and annotatable by the entire team. They are organized in a hierarchy of web pages, linked hypertextually from graphic models, and subject to full text search; and the essays are annotatable. Notes may be expressed in e-mail messages that are in the team's searchable e-mail archives. Annotations are documents as well and can be found through full text searching as well as through DocReview. Outlines are a fundamental scholarly tool, a model of a document. In the RW outlines cannot only be annotated, but can form the backbone for preliminary drafts built by annotation with DocReview. Models are expressed in graphic and textual documents and are both searchable and annotatable.

Publications

Conventional research is focused on the production of research reports, often just the smallest publishable unit. Of course the strategy of least publishable unit could be followed in the RW as well. The RW views research reports as derivative, not as the sole objective. The RW can serve not only to produce research reports, but monographs and books as well. Even criticisms of reports or books in the literature can be generated by the team, leading to publication as brevia, reviews or letters to the editor. Such criticism of external materials can be archived and linked to documents in the RW repository.

It is extremely difficult to argue that the RW's research team would generate fewer publications than a conventional research team. While it is true that the effort expended in model building does not lead directly to publication, it is also true that the shared models may reduce the total expenditure of effort. The marginal cost of refining a model to include information generated in the research of a phenomenon is very small compared to the cost of reproducing the models in each research report investigation. I believe that contribution to models and the study of models will familiarize all the researchers with the issue domain to such an extent that many more hypotheses will be generated. These hypotheses are each a potential research report topic.

The purpose of a model is to rub the researcher's nose in the problem.

—paraphrasing a comment by Professor Dick Hamlet[55]

Bibliographies

In conventional research, as well as in the RW, an enormous quantity of information is gathered from the literature. The lists of references from research reports are usually the only permanent bibliographies produced in conventional research, references for literature investigated but not cited is lost. In the RW, the research team has several advantages that scholars in the conventional environment do not have. Possession of a corporate body of literature indexed and searchable by several methods will save considerable duplication of literature search effort. In the well-disciplined RW, every piece of literature examined by the team members can be incorporated into the Annotated HyperBibliography (see §4.4). The RW's team has the ability to read abstracts and full text at a click along with the opinions of colleagues. If a document is seen to be less than useful then the member who reported can annotate the entry with a warning to avoid it. With the assistance of the facilitator, bibliographic entries can be tagged so special purpose bibliographies can be produced. Hypertext links can be made to the bibliography from any document in the RW, even e-mail. The Annotated HyperBibliography can be searched by author, title, keyword, or text in the abstract.

Glossaries

Glossaries are seldom included in research reports, even though readers from disciplines outside the discipline of the authors may not be familiar with the intended specialized meanings of terms. The appropriation of widely used words for more narrowly defined disciplinary meanings is both necessary and widespread. In the RW, the team members have an Annotated HyperGlossary (see §4.5) at hand to investigate the language of the dialog. Should a scholar use a word in a technical sense, that word can be linked to the proper definition, in interdisciplinary teams often one of several. Should a RW team member choose to add a gloss or alternative meaning to the HyperGlossary, the facilitator can do that. The Annotated HyperGlossary provides the RW team with a forum to discuss the terms through annotation

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Services Offered

Facilitated document review

Conventional scholarship does not usually have the benefit of shared criticism: and review is often limited to electronic file swapping of drafts between the lead author and the authoring team. In the RW, the use of DocReview (see §4.3) provides the entire team the opportunity not only to criticize most documents, but also to discuss the commentary of others in a focused team-wide forum. Through the guest partition (see §3.5.1) selected scholars outside the team may be invited to review documents that would benefit from a review by qualified specialists.

Proposal production

The problem of controlling the costs of proposal production is widely recognized. Indeed the cost of producing a proposal for an Institute-level grant is very expensive and is cited as a barrier to commissioning such organizations[56]. Software is becoming available to manage the paperwork of preparing a proposal, but I am aware of no services that attempt to provide intellectual guidance to the proposal team. The mature RW has a very valuable repository of information that is available to support the preparation of the intellectual content of the proposal. Since any proposals generated by the research team must be related to the issue domain, there exists a set of points of contact with existing research and the models of the issue domain. The proposal can actually point to the connection of the proposed work to existing work within the organization as well as to the outside literature.

Technology training

In conventional research teams, any training of team members is provided by the infrastructure of their work environment. In the RW, the facilitator is directly tasked to provide any technical training that a team member may request. The RW is a more technical environment, but most tools appropriated should be web-based, thus the training required is minimal --- every page is a web page. Becoming familiar with modeling is quite another issue. While most representations of models are straightforward and can easily be used as templates, a real understanding of models may require some additional training.

Wider distribution of research documents

Conventional research generally publishes only documents that meet the standard of minimum publishable unit. The RW can publish any document regardless of its scope. The advantages of wider distribution of scholarly documents are now universally recognized. The RW distributes not only the documents themselves, but also links to the participants' home pages, thus informing others of their research interests. Many of the RW's documents may be available for WWW distribution from the public partition (see §3.5.1). Always requesting all the commercial search engines to index them aggressively publicizes those documents. The important research reports may be presented in several formats: in PDF format, for direct imaging of the document; in HTML for presenting the document in hyperdocument format, thus offering the reader the advantages of sidebars, the hyperbibliography and hyperglossary; and finally, in DocReview format, allowing the wider world to annotate the document. Many documents will not be published in journals; and others will be published in journals that may not be available to many scholars.

Central e-mail repository

In conventional research, e-mail is not universally archived. In the RW, unless e-mail is private, all email is archived and is searchable. This brings a new source of intellectual content to the research team; all that is needed to recall information are keywords or an approximate date.

5.3.3 The Tools of the Research Web

Finally we dispense with the technology. The Internet and World Wide Web have provided a home for the application programming that will make the Research Web possible. There is no argument that can object to the efficacy of the large body of software that is available to facilitate any kind of research on any topic. If the software isn't there, it can be built. Do the tools proposed for the RW really serve the research team? The core tools proposed for the RW: DocReview. RW Essays. Annotated HyperBibliography and Annotated HyperGlossary, have been placed in service and were found to be both useful and accepted by researchers. While only DocReview received enough use to collect empirical data and support research questions (see §5.1.1). no negative opinions were received on the other tools (aside from an unusual total rejection of the technology by two senior researchers). Both the Annotated HyperBibliography and the RW essays have received praise from members of the academic community. The real question here is the efficacy of the Research Web concept.

Notes to Chapter 5

[1] Henri 1991, 126

[2] Meyers, *et.al.* 1991, 53

[3] Sheard 2000

[4] Bales 1950, 9

[5] Meyers, Seibold and Brashers 1991

[6] Bowker and Star 1999, 10

[7] Cohen 1960, 38

[8] Bales 1950, 177-195

[9] Meyers *et.al.* 1991, 54

[10] Bales 1950, Chapt. 2

[11] Bales 1950, 93-99

[12] McGrath and Berdahl 1998

[13] Bales 1955

[14] Geri Gay *et.al.*1999

[15] Eisenhart and Borko 1993

[16] Toulmin, Rieke and Janik 1979

[17] Meyers, Seibold and Brashers 1991, 50

[18] Meyers *et.al.*, 45

[19] Meyers, Seibold and Brashers 1991, 54-55

[20] Meyers *et.al.* 1991, 56

[21] McGrath and Berdahl 1998

[22] Bales 1950, 101

[23] Nyerges *et.al.* 1998, 141

[24] Nyerges *et.al.* 1998

[25] Cohen 1960

[26] Landis & Koch 1977

[27] Perreault and Leigh 1989

[28] Cohen 1960

[29] Landis and Koch 1977, 165

[30] Perreault and Leigh 1989

[31] Zinsser 1980, 111

[32] Strunk and White 1979, 15

[33] Nielsen 2000, 110 *et.seq.*

[34] Peterson, 1977

[35] Hendricksen, 1994

[36] Link *et.al* 1999

[37] schraefel *et.al.* 2000, §2.2

[38] Markus 1993, 503

[39] Marwell and Oliver 1993, 36

[40] Lave and Wenger, 1991

[41] Markus 1987, 500

[42] Aronson, Harré and Way 1995

[43] Brinberg and McGrath 1985

[44] McKay and Marshall 2001

[45] MacArthur Foundation 2000

[46] Ideker *et.al.* 2001

[47] Ruhleder 1995

[48] Eaves 1997

[49] Landow 2002

[50] Marwell and Oliver 1993

[51] Professor Kirsten Foot 2001, personal communication

[52] Poole 1990, 239

[53] Kosko 1986

[54] Wellman 1994

[55] from a lecture by Professor Hamlet of Oregon Graduate Center, 1982. The original line was "The function of a software engineering methodology is to rub the programmer's nose in the problem."

[56] Task Force on Enhancing the Research Environment 2001, 11

Chapter 6 --- Conclusions and Prospects for Research Using Research Webs

This dissertation has presented several major topics: a critique of the current research environment as it relates to the conduct of large-scale, long-term collaborative research; a design for a new approach to such research; a set of tools designed and implemented for this new research approach; and empirical studies of both the Research Web concept and on of its major tools, DocReview. These topics have built a progressive argument for their adoption by research teams that meet certain standards of team makeup and issue domain properties. This chapter makes the case for the adequacy of the argument, and continues on to demonstrate through rhetorical questions how successful social science research can be conducted using Research Webs. The Chapter concludes with a challenge to potential conveners of Research Webs.

6.1 Contribution to Knowledge

This research has described a new concept called the Research Web (RW) that is designed to improve the efficacy of long-term large-scale collaborative research in the social sciences. The RW builds on concepts and techniques familiar to all researchers, but augments those existing concepts and techniques by appropriating modern information technology, specifically the Internet and WWW. The RW assumes an environment that is collaborative and a team that is dispersed. The design basis of the concept is found in a very harmonious merging of modeling, as advocated by scientific realism[1], a research methodology -- VNS[2]; and a suite of information tools that support the functions of conventional scholarship. The RW is firmly grounded in arguments presented in Chapter 2. This grounding produces a synthetic creation that provides scholarly backing from numerous disciplines including, among others: philosophy, psychology, economics, sociology, geography, and information technology.

In order to fulfill the promise of the RW concept, information tools were invented or appropriated to serve dispersed collaborative teams. Existing Internet programs provide the means of communication, storage and distribution. Invented programs provide new channels for collaborative interaction, a scholarly apparatus, and a critical apparatus. Collaborative interaction in the development of a glossary for the issue domain is provided by Lexicon (see §4.8), which populates the Annotated HyperGlossary (see §4.5). Bibliographic information is assembled into an annotatable format in the Annotated HyperBibliography (see §4.4). The scholarly apparatus of the RW is a hyperdocument format called the Research Web Essay that integrates the textual content with an enhanced bibliographic service, language definitions, improved graphics, and hypertext links to supplemental information. The critical apparatus of the RW is a tool called DocReview (see §4.3) that allows any document to be presented in an annotatable format. Every Research Web Essay contains a link to a DocReview of its own content.

A Research Web will begin with a well thought out definition of the issue domain and a long list of interdependent research topics that will contribute to a comprehensive knowledge of the issue domain. In the preproposal phase, interested scholars will be recruited from the appropriate disciplines to collaborate in the examination of those research topics. The research topics will support a number of authoring teams all working on interdependent topics. After the proposal is approved, the work begins and the authoring teams begin to codify their knowledge into permanent models of parts of the issue domain. Since the research topics will be interdependent, researchers from every authoring team will have an interest in most other topics. With the understanding that collaboration is not merely lip service to some ideal set by funding agencies, all members should become active participants. Leadership and peer pressure, if not actual penalties, will ensure compliance with the injunction to collaborate.

Authoring teams will model the objects and processes observed in their research topic area. The models of the issue domain will accumulate knowledge from every authoring team and all the reviewers of documents. Since all the research topics are interdependent, there will be a large number of common objects and processes. Each team will contribute nuances to each of the modeled objects. With the help of the facilitator, the models are linked to Research Web Essays written by the authoring team and to other documents. The Essays will form the basis for research reports, thus linking the RW and the authoring teams to the existing reward system of science.

Criticism will become the engine for successive refinement of the knowledgebase of the team, especially models and Essays. The knowledgebase will be an ever-expanding source of hypotheses suitable for providing the intellectual capital for further research proposals. The RW's leadership and committed scholars will likely issue a continuing stream of proposals in order to maintain a set of authoring teams that is large enough to maintain critical mass. As the body of literature produced by the team grows, the knowledgebase accumulates, and the reputation of the team becomes established, the proposals may become more attractive to the granting agencies.

Since the RW has a large number of participants, the loss of some by retirement, loss of interest or death, can be balanced by recruitment of new scholars. Should the issue domain become known territory, the issue domain may migrate to an issue adjacent to the original issue domain. Since the team will have been contributing to a context model that maps the boundaries of the issue domain and connections to adjacent issues, such a migration will be easy to make.

The Research Web and its associated tools were placed into actual service in numerous places by individuals and teams. Often the tools were used to augment conventional scholarship or to perform management functions. There were a few attempts to build functioning Research Webs. We discuss those attempts next.

6.2 Conclusions from Empirical Findings About Research Webs and Tools

Based on the literature and empirical results found by studying three attempts to establish Research Webs, there were three major problems: critical mass, funding, and selection of a suitable issue domain. Scholarly evidence was found to support the importance of critical mass[3,4]. Based on the relative success of the three case studies of RWs, critical mass was approached at 18 researchers in the Chromium VI RW. There was a decline in viability with declining team size in the three cases. The literature gives several examples of the success of large projects[5,6,7,8] that clearly reached critical mass. The size of those projects all exceeded the size of the most successful RW.

Funding was sufficient in two of the three cases, but one RW, the Soil Crust RW was damaged by lack of funding. After the single funded project was completed, that RW failed. Adequate funding is funding sufficient to support each of the authoring teams and their share of the overhead required to support the RW. This fact points out the need to include a share of the RW overhead in every research proposal. Justifying that share in the budget should not be difficult, and the requested overhead funding may in fact give the granting agency some confidence that the work will be managed as part of a larger research effort. The RW's founding proposal faces the special burden of having to ask for overhead funding that presumes that the overhead will in short order be shared by other research grants. This founding proposal is similar to a proposal to found an Institute, and such a proposal is in itself an expensive and long-term task[9].

Selection of a suitable issue domain is an intellectual problem that must be faced by the management of the RW. There are limiting factors in defining the issue domain: defining a scope that is both large enough to develop critical mass, and small enough to ensure that the topics of the authoring teams will be interdependent. In two cases the RW concept was applied to preexisting teams with either inappropriate or ill-defined issue domains. Attempting to establish a RW based on an existing research team assumes that the scope of the issue domain just happens to be appropriate. Establishing a RW on a small grant with a limited scope assumes that grants can be obtained for closely related research problems -- growing by accretion or bootstrapping. Both of these strategies are very risky, betting on the hope that something will develop.

Case studies of DocReview (see §5.1) showed that the nature of dialog produced in the interaction of the team with documents was of a different character than the dialog seen in face-to-face meetings (see §5.1.7). This dialog was less inclined to be emotional, and was more inclined to be constructive; in other words it was a vehicle that fostered reflective knowledge building. DocReview was enthusiastically accepted and used by not only RW teams, but by many other users for widely varying documents. It was used to form the backbone of initial drafts of research papers, was widely used to review meeting minutes, was adapted to AutoCAD (a drawing and mapping program) to allow annotation of civil engineering plans, and provided a vehicle for evaluating user comments in a participatory design exercise. In short, DocReview was not only successful in its intended use, but was flexible enough to be adapted to tasks outside its intended purpose. Software products that followed its introduction were quite similar to DocReview, validating its design.

The Research Web Essay incorporates features that vastly improve the information delivery of scholarly documents. There is nothing that conventional research reports have that the Essays do not have, aside from being printed on paper. If an Essay is printed out then it has even more features than most printed reports (a glossary). The ability to call up bibliographic information, sidebars, and glossary definitions at a click represents a service that is just now becoming more widely seen with the rapid adoption of electronic journals. Research Web Essays are superior to every electronic journal I have seen, without exception. This superiority is due not only to the features mentioned, but to the integration of the critical apparatus of DocReview, thus allowing controlled peer annotation of the reports.

The Annotated HyperBibliography has drawn attention from the community of scholars assembled in discussion forums on the Internet. Though impressed and interested, none have found a place to apply it, or have been willing to invest the time to set it up.

Tools were developed for the facilitator to ease the creation of DocReview installations, the Annotated HyperBibliography, the Annotated HyperGlossary, and for the creation of Research Web Essays. Though the users of the Research Web never see these tools, they are critical to the enterprise. Without these tools the burden of creation of the web pages that embody these tools would be so great that their production would simply not be practical. The tools allow the facilitator to create the web pages with form-driven scripts that minimize the information that needs to be provided to the computer that does the actual page layout.

6.3 Prospects for Research Using the Research Web Contribution to Knowledge

Below I pose a series of questions that help the reader focus on the contribution to knowledge made by Research Webs and the tools that implement them. These questions frame arguments that confirm the utility of the dissertation's contribution to knowledge.

Can the Research Web effectively host large-scale social science research?

I described modern research problems in the social sciences as being more difficult than the problems of the past. These problems are of such complexity that large interdisciplinary teams are needed to attack them. Such a set of problems can be examined effectively only by a collaborative, long-term, large-scale team. If such a team were engaged in building the knowledge to illuminate the issue domain, what environment would serve the team best? Certainly not a decentralized environment that allowed research groups to develop hypotheses independently and then design experiments and write up reports, leaving the job of linking their work to the issue domain to senior scholars who would write summary review papers to publish in the flagship journals of their discipline. Yet this is exactly how conventional scholarship works today.

Can the Research Web serve the social science research community?

Social science progresses through the processes of description and argumentation in the literature. At this point in history, the literature is a body of publications recorded in books and an immense number of journals, some highly respected, others highly suspect. There are several units of scientific knowledge: the book, the research paper, reviews, brevia, letters to the editor, reports and other member of a broad class of poorly indexed literature called "gray literature." To that literature, add the WWW, popular press and other unreviewed documents.

The Research Web's team has access to all of this material, just as do conventional teams. In the RW, however, the literature is cataloged in a corporate bibliography, the Annotated HyperBibliography (AHB), in a format that can be annotated by any member of the research team. This cataloging adds an additional layer of peer review. In addition to the core literature, the RW team, because of its interdisciplinary nature, captures literature from disciplines related to, but outside the "home" disciplines of the research topics.

Part of the knowledgebase of the RW is new synthetic knowledge produced by its members. This knowledge is indexed in several ways and can be searched by chaining down the hierarchical models of the RW -- or can be "full text" searched. The models of the RW are treated just like many of the other documents: they are hyperlinked to related documents, and are annotatable by the team members. In the social sciences, there are few models that extend beyond the topic of a single research paper. There are, within each discipline, broad general models, text based "laws", and codified behaviors; but these are seldom strongly linked to the work within a research paper. The RW is charged with the responsibility of modeling the entire issue domain.

The language of dialog takes on very nuanced meaning within each discipline. Those outside the discipline will not have good knowledge of all the terms used. In the RW, the language of the issue domain may span several disciplines. To bring order into the language of dialog, the RW employs the Annotated HyperGlossary (AHG). In the AHG, scholars within each discipline may contribute definitions of each term. If the difference between meanings is great, then multiple meanings can be listed. For minor differences, the terms may be annotated or glossed to explain any disciplinary nuance. In this way the RW attempts to solve the language problem; in a conventional work, the language is the language of the "home discipline."

Distribution of the knowledge products of the RW can follow normal academic channels in order to establish rewards for the contributors. In addition to publication in conventional journals, the RW can distribute the same report, without charge, in the Research Web Essay format. That format augments the paper with much ancillary information, such as bibliographic information, definitions, and sidebars. This information can be displayed at a click of the mouse. And above all, the Research Web Essay can be annotated online by anyone, thus expanding the reach of the knowledge-building team to the world.

It must be noted that the creative side of science is frequently cited as "the reason" why conferences and conversations are essential to doing science; and that creative scientific activity can only suffer from departures from face-to-face dialog. The environment of the RW does not proscribe synchronous dialog! It does, however, ask that the participants of such meetings be responsible to their colleagues by providing a record of such proceedings. Meeting minutes should be published online, and Memoranda of Communications summarizing important points be reported to the team by e-mail.

So, can social science be properly served by the Research Web? Most definitely, but primarily within well-defined issue domains. Social science, painted broadly, cannot be served by the Research Web – that is still the province of the philosopher and senior scientist. The RW will, however, be a canonical reference for knowledge within its issue domain. If someone doesn't like what is there, they can annotate it!

Can the Research Web foster collaboration?

The RW is designed for collaboration. Indeed, people who are disinclined to collaborate are likely to be asked to leave. The objective of the RW is to develop comprehensive knowledge of the issue domain. That comprehensive knowledge is built by the team through collaborative participation in many activities, including model-building, criticism of documents, assembling knowledge from existing sources, and writing synthetic works. The number of channels or work objects available to join in the collaboration is much greater in the RW than in conventional teams.

Collaboration within the RW can actually be measured objectively. Annotation to documents and writing memoranda of communication may be measured by a simple word count. Under the assumption that all words written are actually contributions to the knowledgebase, those who write more annotations and report more ideas are better collaborators. The discovery of literature, model building, and other activities not directly associated with the development of a research report must be measured more subjectively. Clearly those who do not engage in such activities contribute nothing to them.

The recommended practice of acknowledgement of anyone who contributes to an Essay is an incentive to collaborate. Though acknowledgement is an undervalued practice in conventional research, it is today more widely practiced in some disciplines than in the past[10]. All annotations and e-mail contain the author's name, for attribution if not acknowledgement.

The emphasis that the RW places on collaboration will attract people who feel comfortable with cooperation: and conversely, may alienate people who are of a more competitive nature. The conveners will have to make it very clear to scholars being recruited that collaboration is expected and that building a knowledgebase for the issue domain is the proximate goal, though the ultimate goal must remain publication of research reports. It may be a difficult adjustment for some people to understand that building a knowledgebase is an accumulation of small pieces rather than building grand creations. Evidence of a person's collaborative nature might be seen as a record of contributing reports with multi-author teams.

Can the Research Web accommodate large groups?

The limits to the size of the team are set by the number of active authoring teams working on the topics suggested by the team. Each of the topics must lie within the issue domain, so the limit is the number of identifiable topics in the issue domain. Practically, research reports on each topic must meet the test of minimum publishable unit; so the number of topics is not infinite. The lower limit is set by the need to maintain a critical mass of active researchers. If there is an upper limit, it is set by need to maintain interdependence of topics. In an extremely fecund issue domain, some planning may be necessary in order to develop knowledge in a manner that maintains interdependence through time. Maintenance of interdependence through coordination of authoring teams insures that the research team does not fragment.

Fragmentation into disciplinary subgroups is an ever-present danger. Left to their own devices, researchers will naturally be attracted to the rewards of working exclusively in their "home discipline." Just such a fragmentation was seen shortly after the establishment of the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) project. While the proposal called for interdisciplinary study of the problem of the environmental cleanup of the America's WWII and Cold War nuclear production facilities, in fact interdisciplinary study was never entered successfully. Management divided the research team into task groups that were dominated by single disciplines, rather than dividing the team into task groups that investigated problems that could benefit from research viewed from several disciplinary viewpoints. The Chromium VI Research Web was a happy, but short-lived, exception to that management choice. If each of these problems had been components of a process that contributed to an understanding of the overall issue of cleanup, then the initial objectives of the project might have been met.

Fragmentation by self-segregation of geographic clusters of researchers is also a threat to the unity of the research team. The pressures to revert to face-to-face communication (media competition) lead to a tendency to avoid documentation and thus knowledge sharing. When the MacArthur Foundation reorganized their Research Networks from nodes of collocated teams to an organization that selected members based solely on their ability to perform and to work in a collaborative environment, the Networks began to work much better[11].

Can the Research Web survive the passage of time?

There are two problems maintaining a long-term research project: maintaining interest and withstanding personnel turnover. If the Research Web produces new hypotheses at the rate expected, then there should be little difficulty in maintaining interest. The RW can be no less productive than conventional teams because all the mechanisms for hypothesis generation in conventional teams are present in the RW as well. In addition to conventional hypothesis generation, the RW has the added benefit of having more channels to carry follow-on activity. The models, for instance, will contain information on objects and processes that may not have been totally elaborated. Those partially defined elements may form the basis for additional investigations. Models will also have benefited from the attention of scholars from more than one discipline, and thus be richer than models developed conventionally.

The RW has within its knowledgebase not only models and essays, but also a body of e-mail and annotation, both of which may contain conjectures and paths for future research.

The third phase of research in the VNS is a building of robustness that will mine all sources for means of corroboration of results. Corroborating studies will enrich models further as well as providing opportunities to publish more research reports.

The problem of turnover may be reduced to some extent by the practice of providing graduate students and junior scholars with the opportunity to join more senior researchers on authoring teams. This "legitimate peripheral participation[12]" is an important practice and should be encouraged within the RW. Giving beginning scholars the opportunity to join established scholars in actual research will not only socialize them into the community, but should also develop them into skillful collaborators who are intimately familiar with the issue domain. One hidden benefit of the RW is its production of trained collaborators.

Recruitment of new members or of entire teams is an ongoing management task. The RW's public partition can be used to help in recruitment by introducing anyone who comes to the site to the environment that the research team works in. If a scholar is closely associated with one of the authoring team's research topic, that scholar might be invited to participate in review documents placed in the guest partition (see §3.5.1).

Long life can be assured by a steady stream of research grants. The RW may be large enough to enjoy economies of scale in proposal production. Since there will be several experienced proposal writers in the research team (all the conveners and most of the lead authors), a proposal authoring team might be constituted in order to produce that steady stream of proposals. With a dedicated facilitator and probably an administrative assistant, such a team could apply the tools and techniques of the RW to the proposal production task.

6.4 Prospects for Research About Research Webs

While we wait for Research Webs to become established we can prepare for the opportunity to study them by designing more refined protocols. Due to the *post hoc* nature of the case studies of the three Research Webs studied in this work. some important data escaped recording. For instance, efforts made to recruit participation in DocReviews needs to be recorded in order to manage DocReviews more effectively. Recruitment of team members was not studied; as the three cases studied all came with established teams.

A more thorough study of collaborations in web-based scholarly communities may lead to insights into survival characteristics and effectiveness in accumulation of knowledge. As noted in §1.3. there may be many intranets that demonstrate some of the features of the Research Web.

Research into the nature of issue domains suitable for Research Webs needs to go forward. The relationship between issue domain scope and Research Web viability studied in §5.2.5.1 must be examined in more detail. The entire issue of how to define. delineate and contextually model the issue domain must be clarified for the use of potential conveners. Establishment of a Research Web by accretion needs to be studied. There are many examples of informative web sites[13] that attempt to serve their communities by recruiting members to contribute scholarly content. Perhaps some of these sites might be converted to Research Webs. or could establish RWs to guide research in some constituent issue domains.

The tools developed for the RW have applications in other areas. DocReview has been especially flexible. Improvements can certainly be made in the tools. It may be possible to capture the elapsed time of a DocReview session by recording the ending time (the start time is already recorded). PicReview (§4.9.1) is an essential tool. It must be implemented and examined in applications. wherever they may occur.

6.5 Concluding Remarks

This dissertation is an argument for the establishment of a Research Web. The concept of the RW has been tested as a prototype and appears to be sound. However, the risks are substantial. The forces of inertia are extremely powerful and will not be overcome by those who chose research problems that fit well into the current environment: problems geared to a short term research cycle, the disciplinary cores, and the accumulation of minor academic credits. We must wait for the proper conjunction of research problems of the proper scope and conveners willing to take a risk for large payoffs. The issue is likely to be one that has failed to yield to conventional approaches, one that is beyond small-scale research, but is important, difficult, interdisciplinary, and has been explored by a few intellectual pioneers and is now ready to be examined in depth. The risks are the potential waste of building a large knowledgebase that few use. The potential rewards are comprehensive knowledge of the issue domain with a body of new canonical literature that will establish the research team as the commanding authorities.

We infer from the literature, the attempts to establish large collaborations, and from the case studies herein, that the concept is sound and the supporting tools developed and methods suggested support the concept. Proof of concept will emerge only with the success of a well-staffed, well-funded, committed research team lead by strong management able to recruit and sustain a collaborative team for a long time. That effort will be a case study of a proper size, one that has the characteristics of size, scope, staff, and leadership that have been discussed above. An expensive experiment to be sure, and not for the faint-of-heart. Should a team of conveners rise to the challenge, I offer to advise, assist in proposal preparation, give technical assistance, and will donate the software that I've developed.

Notes to Chapter 6

[1] Aronson, Harré and Way 1995

[2] Brinberg and McGrath 1985

[3] Markus 1987

[4] Marwell and Oliver 1993

[5] Bero and Rennie 1995

[6] MacArthur Foundation 2000

[7] Schade and Putlitz 1996

[8] Ideker *et.al.* 2001

[9] Task Force on Enhancing the Research Environment 2001, 11

[10] Cronin 2001

[11] Kahn 1993, 11

[12] Lave and Wenger 1991

[13] See the NetWatch column by Mitch Leslie in Science archived at www.sciencemag.org/netwatch.

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