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.

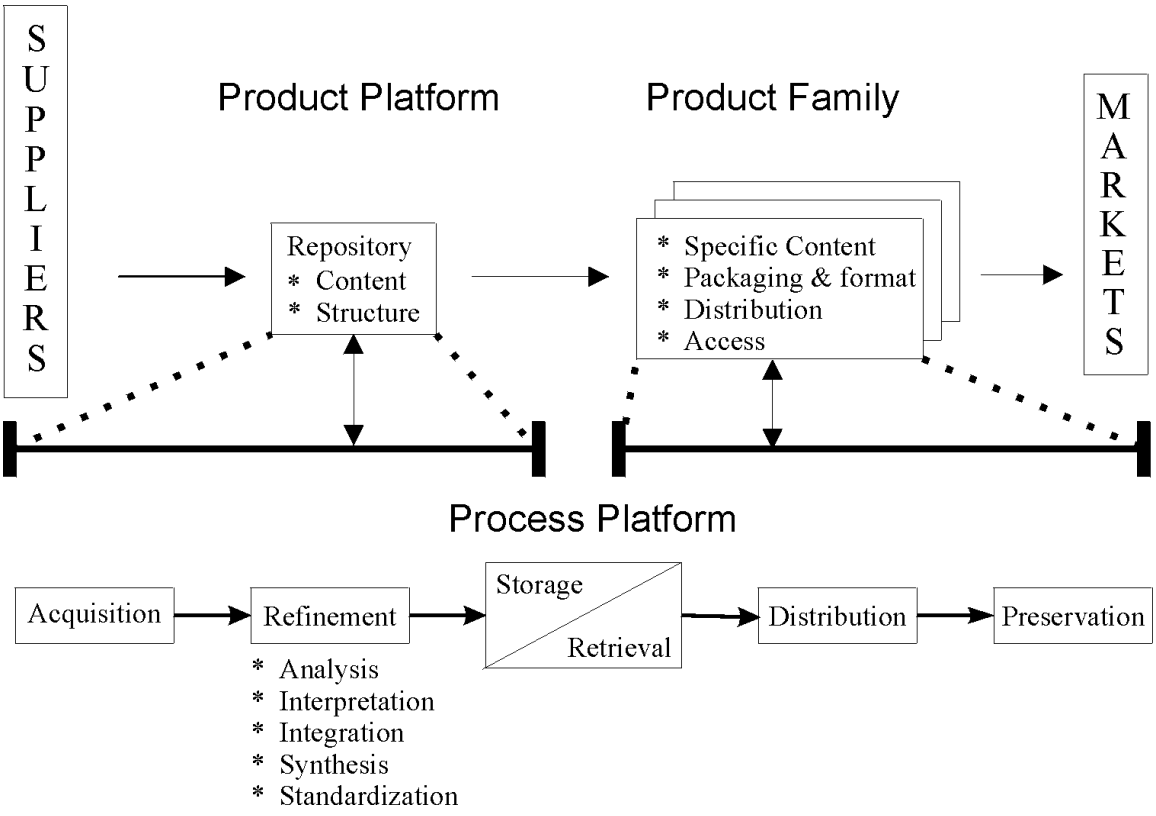


Figure I The Architecture of Information Products

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.

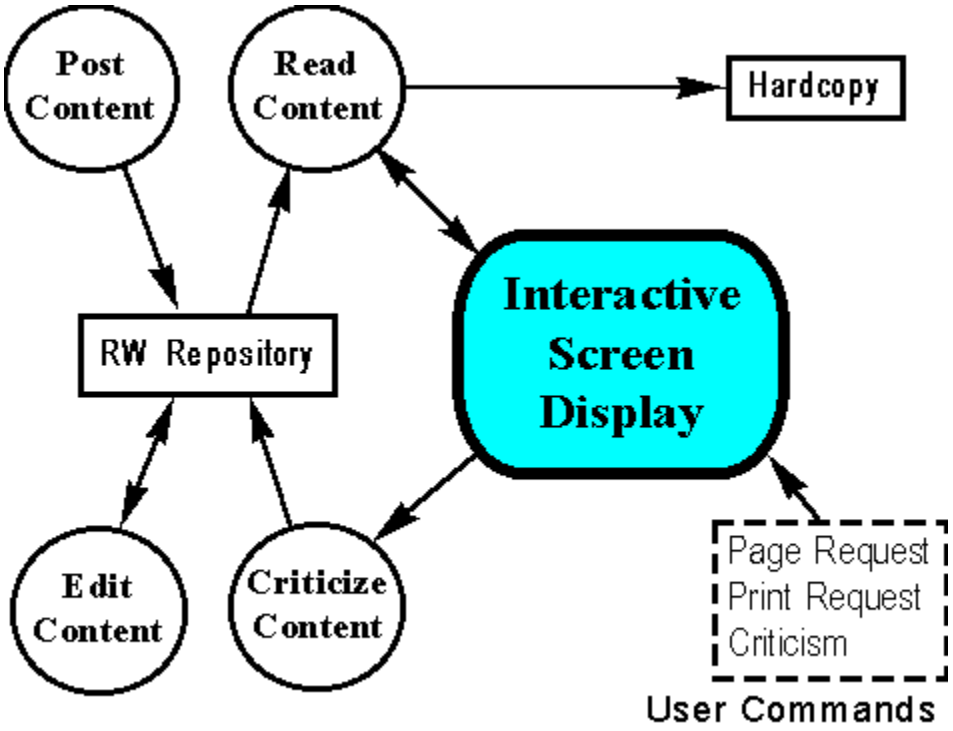
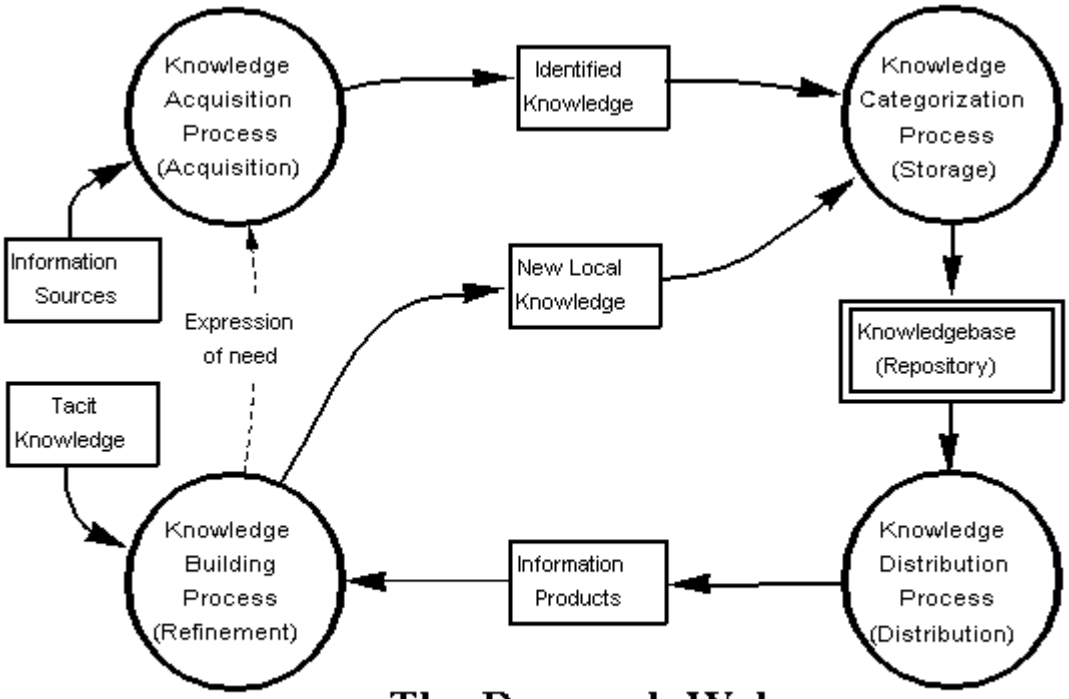


Figure II Information Flow in a Research Web

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