Humanity must derive and apply new knowledge to overcome the range of challenges of increasing complexity and potential harm to human civilization, such as replacing waning energy reserves, moderating climate change, overcoming poverty, preventing pandemics, revitalizing fisheries, the technical dimensions of proliferation of weapons of mass destruction, and the exploitation of near-Earth space. What unites all these and other major challenges is that solving them will depend to a significant degree on the capacity of the scholarly communication system (SCS) to adequately capture, evaluate, disseminate, archive, and apply the work product of scholars and researchers in academia. The Atkins Report[1] documents enormous opportunities to improve the efficacy of scientific inquiry through national-level investments in cyber-infrastructure, but securing such investment is a necessary but not sufficient condition for maximizing the contributions of cyber-infrastructure-enabled knowledge communities (CKCs).[2] Improving the functioning of the scholarly communications system is also required. Scholarly communications remain the lifeblood of basic research,[3] but rapid technological, economic, and social changes are converging to undermine many of their traditional foundations.[4] The Association of Research Libraries and others speak freely of a "crisis" in scholarly communications, referring to any one of several indicators, including spiraling subscription costs, high rights-management overhead, proliferation in both data volume and formats, a pronounced trend away from ownership and toward licensing,[5] and concerns about the preservation over long time horizons of digital knowledge owned by entities subject to market vicissitudes.[6] Any SCS capable of overcoming these challenges, by definition, must meet the needs of researchers and scholars in ways that generate trust if they are to induce continued participation.

Scholarly Communication

That scholarly communications are intimately connected to the efficacy of scientific and scholarly research is intuitive, logical, and empirical.[7] Since their founding in the 1660s in London and Paris respectively as the *Philosophical Transactions of the Royal Society* and the *Le Journal des Savans*, scholarly journals have risen to a position of dominance within the SCS that has now reigned for over a century.[8] Communication through personal letters and the occasional monograph was viewed by the middle of 17th century as impeding the expansion of new knowledge and gradually gave way to the journal and the refereed article. The journal emerged as the best achievable solution to prior inadequacies, but also arose in response to the ongoing scientific revolution itself and a growing emphasis on observation over deduction and the need for experimental reproducibility.[9] Changes in scientific practice emanating from cyber-infrastructure enabled collaboration may similarly drive the evolution of the SCS in the years ahead.

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[1] Atkins, D. et al., (2003). *Revolutionizing science and engineering through cyber-infrastructure*. Report of the National Science Foundation Blue-Ribbon Advisory Panel on Cyber-infrastructure. Washington, DC: National Science Foundation, 2003. Available: http://www.nsf.gov/cise/sci/reports/atkins.pdf [4 Mar 2005].

[2] Atkins, D.E., *Research Libraries and Digital Library Research for Cyber-infrastructure-enabled Knowledge Communities (CKCs)*. Available: http://www-personal.si.umich.edu/~atkins/papers/CHINA_DL_PAPER.pdf.

[3] Roosendaal, H., & Geurts, (1998). Forces and Functions in Scientific Communication: An Analysis of their Interplay. *Cooperative Research Information Systems in Physics*, August 31—September 4, 1997, Oldenburg, Germany. Available: http://www.physik.uni-oldenburg.de/conferences/crisp97/roosendaal.html [6 Mar 2005].

[4] Ward, R., Michealis, D., et al., (2003). Widespread academic efforts address the scholarly communication crisis: The results of a survey of academic institutions. *C&RL News, Vol. 64*(6), June, 382-383,389.

[5] University of Buffalo Libraries (2004). *Final Report*: *Scholarly communication, research, and libraries: An updated environmental scan.* 26 October 2004. Available: http://libweb.lib.buffalo.edu/sw/stplan/envscans/scholcom04_sum.pdf [17 Apr 2004].

[6] Ward, *supra note* 4, 382-383, 389.

[7] This connection is analyzed by Roosendaal and Geurts. Roosendaal H.E. & Geurts P.A.T.M. (1999). Scientific communication and its relevance to research policy. *Scientometrics*, *44*(3), 507-519.

[8] Fredriksen, E.H., (2001). (Ed.) *A century of science publishing*. Amsterdam: IOS Press.

[9] Schaffner, A.C. (1994). The future of scientific journals: Lessons from the past. *Information Technologies and Libraries, 13*(4), 239-248.

By the middle of the 19th century, the major elements of scholarly communication that are now familiar - the look and feel of a scholarly article, the journal, the role of peer review, citations, etc. - became part of the knowledge infrastructure within which scientists and researchers worked, particularly since World War II with the expansion of higher education and the emergence of government-financed basic research. The journal article as the archetypal expression of scholarly communication has successfully served several vital functions, including the provision of access (physical and intellectual) to the collective knowledge of fields, dissemination of new research, implementation of accepted credentialing mechanisms, and the production of measurable output for recognition and the distribution of rewards.[10] Despite these successes, there are a large number of indicators that a transition to a new SCS is underway.

Crises in Scholarly Communications

Formal communications within the current SCS rest on the several thousand scientific articles produced daily many of which are published across tens of thousands of refereed journals for which university libraries must devote increasing resources.[11] Serials expenditures by ARL institutions rose more than 200 per cent from 1996-2002.[12] This holds despite the fact that more than 90 per cent of all the costs of delivering a refereed journal article reporting new research are realized before submission for publication, costs frequently covered by public entities.[13] "Even if we look only at the costs of preparing of reviewing distributing, archiving, and retrieving scientific articles," notes one 2004 study, "excluding the actual production costs" of the reported research, "almost all the costs are in the end borne" by university and public libraries through subscriptions and the costs of archiving.[14] These perceived inequities join other factors[15] in driving a range of inventive responses by scholars and librarians, including the emergence of pre-print archives,[16] electronic journals with online submission and review,[17] open access journals,[18] institutional repositories,[19] and consortia of digital knowledge producers *cum* providers,[20] including guilds of knowledge producers.[21]

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[10] Schaffner, *supra note* 9.
[11] Resh, V.H. (1998). Science and communication: An Author/Editor/User's perspective on the transition from paper to electronic publishing. *Issues in Science and Technology Librarianship*, No. 19, Summer, np.
[12] Association of Research Libraries (2004). *ARL Statistics.* Available: http://www.arl.org/stats/arlstat/index.html [13 Mar 2005]. Kyrillidou, M. (2004, June). Serials Trends Reflected in the ARL Statistics 2002-03. *ARL Bimonthly Report 234.* This assessment does not include the opportunity costs related to negative impacts on the quality or pace of research.
[13] Björk, B.C. & Hedlund, T. (2004). A formalised model of the scientific publication process. *Online Information Review, 28*(1), 8-9.
[14] *Ibid*, 8.
[15] Delays in publication, preservation of digital knowledge, display quality, difficulties in managing access in light of intellectual property, are just a few additional concerns expressed by professional librarians and scholars.
[16] Manuel, K. (2001). The Place of E-prints in the publication patterns of physical scientists. *Science & Technology Libraries, 20*(1), 59-85.
[17] Committee on Institutional Cooperation (2005). Report from the CIC summit on scholarly communication: Access to journal literature. Chicago: CIC Reports. Available: http://www.cic.uiuc.edu/groups/CICMembers/archive/Report/SCSreportJan2005.pdf [16 Mar 2005].
[18] Willinsky, J. (2003). Scholarly Associations and the Economic Viability of Open Access Publishing. *Journal of Digital Information, Vol.4*(2), Article No. 177, 9 April 2003. Available: http://jodi.ecs.soton.ac.uk/Articles/v04/i02/Willinsky/ [20 Mar 2005]. Suber, (2004). Open Access Builds Momentum. *ARL Bimonthly Report 232*, February 2004. Delamothe, T. & Smith, R. (2004). Open access publishing takes off. *British Medical Journal, Vol. 328*. 3 January 2004, 1-3. *Also* Association of Research Libraries (2004). *Issues in Scholarly Communication: Open Access*. 20 December 2004. American Library Association. Available: http://www.arl.org/scomm/open_access/index.html [7 Mar 2005].
[19] Crow, R. (2002). *The case for institutional repositories: A SPARC position paper.* Washington, D.C.: Scholarly Publishing & Academic Resources Coalition, 1-37.
[20] Lougee, W.P. (2004). *Scholarly communication & libraries unbound: The opportunity of the commons*. Available: http://dlc.dlib.indiana.edu/archive/00001250/00/Commons_workshop_Lougee_rev_Mar29b.pdf [20 Mar 2005].
[21] Kling, R., Spector, K., & McKim, G. (2002). Locally controlled scholarly publishing via the Internet: The Guild Model. *JEP: Journal of Electronic Publishing, 8*(1), np.

These are exciting developments, but the pace and scale of change pose unique challenges to those charged with managing the current system and serving its users. There remain many "psychological, legal and institutional barriers to changing" the SCS, barriers that often receive insufficient attention from change advocates.[22] Failure to recognize the social and communicative dimensions of the SCS, for example, leaves unexamined the important processes by which legitimacy is conferred within individual disciplines.[23] The upshot is that despite the many laudable individual successes, concentrated in particular disciplines, tradition reigns across the overwhelming portion of the world of scholarly communications. Björk and Hedland found that "only a small part of the overall volume of the scientific communication process has so far been affected by isolated efforts involving [open access] e-journals and pre-print archives," concluding that "about 0.7 per cent of peer reviewed journals offer open access on the Web."[24] This is a startling fact considering it indicates essentially no change since Harter also found negligible impact seven years earlier.[25]

Purpose

The purpose of this report is to explore the essential characteristics of scholarly communications that must be preserved under any successful alternative model and to identify areas for potentially fruitful research into these minimum conditions. The basic question examined here is 'what essential assemblage of functions and user expectations generalize across academic communities such that any given alternative reflecting this assemblage will meet the minimum needs of all scientists and scholars'? What are the minimum conditions that must be satisfied by any alternative model of scholarly communication to attract and serve users and to justify the large investments required for their realization?

These are general questions that must be answered by advocates of any alternative model and must be satisfied before any new 'communication regime' can 'stabilize.'[26] The minimum functions examined here are *registration* of unique intellectual contributions, *certification* of research claims, promotion of *awareness* of relevant research to interested parties, and the *archiving* of key knowledge produced over time within various disciplines. In addition to these core functions, the SCS must be flexible and modular enough to accommodate a range of scholarly practices and norms, should become more transparent in its operations to promote awareness, and will meet the needs of researchers for recognition and rewards. The importance of 'trustworthiness' for generating participation is also stressed. The various issues implicated in these larger questions are put into sharper relief by briefly examining peer review processes[27] and even more briefly

[22] Björk & Hedlund, *supra note* 13, 9.
[23] Van House, N.A (2003). Digital libraries and collaborative knowledge construction. In A. Bishop, N.V. House, & B. Buttenfield, (Eds.) *Digital Library Use: Social Practice in Design and Evaluation*. Cambridge: MIT Press, 2003, 271-295. Available: http://www.sims.berkeley.edu/~vanhouse/van_house_book_chapter.htm [10 Mar 2005].
[24] Björk & Hedlund, *supra note* 13. They cite data from a Swedish School of Economics and Business study.
[25] Harter, S.P. (1998). Scholarly communication and electronic journals: An impact study. *Journal of the American Society for Information Science, 49*(6), 507-516.
[26] Sociologists generally stress the evolutionary processes of "regime change" within disciplines where practices generally change only slowly. *See* Bohlin, I. (2004). Communication regimes in competition: The current trend in scholarly communication seen through the lens of the sociology of technology. *Social Studies of Science, 34*(3), 365-391. Dr. Odylzko at Minnesota makes essentially the same point in commenting on how sociological concerns are the limiting factors in the transition to a new scholarly communications system. *See* Odylzko. A. M. (2000). The future of scientific communication. In P. Wouters and P. Schroeder, (Eds.), *Access to Publicly Financed Research: The Global Research Village III, Amsterdam 2000* (273-278). Amsterdam: Netherlands Institute for Scientific Information Services (NIWI).
[27] Campanario, J. M., (1998). Peer review for journals as it stands today – Part 1. *Science Communications, 19*, 181–211. Campanario, J. M. (1998). Peer review for journals as it stands today – Part 2. *Science Communications, 19*, 277–306. Pöschl, U. (2004). Interactive journal concept for improved scientific publishing and quality assurance. *Learned Publishing, 17*(4), 105-113. Schneider, D.S., & de Souza, J.M. (2003) Configurable Electronic Journal (CEJ): Towards flexible scientific knowledge infrastructures. *8th International Conference on Computer Supported Cooperative Work in Design Proceedings*, IEEE, 191-96.

proposals to capture and make faculty work product usefully available through institutional repositories.[28]

Though it is common to refer to the ferment underway in scholarly communications as a 'crisis,' perhaps a fairer characterization acknowledges both negative (push) and positive (pull of opportunity) dimensions. On the one hand, surging prices, Byzantine use restrictions, explosive growth in journal publishing, etc., pose daunting challenges to academic libraries and those they serve. Libraries in many cases also face stagnant budgets. On the other hand, the maturation of the digital academic environment is driving a period of practical and theoretical experimentation producing glimpses of the potential for quantum improvements in the quality and pace of scholarly research.

This report is informed by the belief that librarians sit in a strategic position within the evolving terrain of scholarly research and communication and must exploit this position by seeking new roles and functions to supplement, and perhaps supplant, some of their traditional practices. The joint CNI-ARL forum on E-Research and Cyber Infrastructure held in October 2004 emphasized the need for collaboration between libraries to exert a positive influence on the evolution of scholarly communications. There CNI Executive Director Clifford Lynch urged librarians and others to "put into place effective new support structures in response to these changes" or create a "tremendous risk to the enterprise of research and scholarship," stressing they assume a more pro-active role in managing scholarly communications in collaboration with their faculty.[29]

Method

Our primary focus here is scholarly communication of scientific information, often including the social sciences, but rarely including the arts and humanities.[30] This focus does not reflect a view that the study of changes to scholarly communications within the arts and humanities is unimportant. On the contrary, but much work remains to be done in this area and their discipline-specific needs often differ to a degree that new models serving this community are emerging only slowly.[31] At the level of the "meta-domains" of the sciences and the humanities, we find some fundamentally different needs.[32] Another reason for this limited focus is the greater experience with alternatives and a more advanced dialogue about various requirements outside

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[28] Crow, *supra note* 19. Lynch, C.A. (2003). Institutional repositories: Essential infrastructure for scholarship in the digital age. *ARL Bimonthly Report 226*, February. Available: http://www.arl.org/newsltr/226/ir.html [1 Apr 2005]. Ober, J. (2004). Reshaping scholarly communication. *Against the Grain*, 16(3), 1-7.

[29] Lynch, C. quoted in Goldenberg-Hart, D. (2004). Libraries and changing research practices: a report of the ARL/CNI forum on E-research and cyber-infrastructure. *ARL Bimonthly Report 237,* December, 1-2.

[30] Relevant scholarly literature was accessed via a range of academic databases, including ISI Web of Knowledge, Library Literature, CSA, IEEE Explorer, the ACM portal, Sociological Abstracts, Anthropological Abstracts, a variety of institutional web sites such as D-Lib, ARL, ACRL, ACLS, various institutional repositories, and some refereed E-journals.

[31] See the various public sessions held by the American Council of Learned Societies (ACLS) Commission on Cyber-Infrastructure for the Humanities and Social Sciences: http://www.acls.org/cyberinfrastructure/cyber_public_sessions.htm. *Also* Alonso, C., Davidson, C., Unsworth, J, & Withey, L. (2003). *Crises and opportunities: The futures of scholarly publishing*. ACLS Occasional Paper, No. 57. New York: American Council of Learned Societies.

[32] The ACLS observes that a "key differentiation is that the data and digital objects in the humanities tend to be more complex and decidedly more ambiguous" in smaller volumes. They add that the "creation and governance of data in sciences does not presently map" to the social sciences or humanities where there is a much higher need for contextual information and rich meta-data schemes. One example is that much more material is copyrighted or faces higher IP overhead in the humanities and social sciences than some basic science research. The ALCS task force talks about how this creates differing access norms. ACLS Commission on Cyber-infrastructure for the Humanities and Social Sciences (2004). *ACLS: Cyberinfrastructure Commission*. 27 April 2004. Washington, D.C.: American Council of Learned Societies. Available: http://www.acls.org/cyberinfrastructure/cyber_meeting_notes_april.htm [13 Mar 2005].

the humanities.[33] The very real technical, social, and policy challenges of implementation across all scholarly disciplines are set to the side in favor of a mode of analysis that operates on a level of abstraction above particularities.

The Canadian Association of Research Libraries observed this year there exists "no single agreed-upon definition" for **scholarly communications**, with some definitions drawn very narrowly to include only peer-reviewed articles while others include essentially any form of communication among scholars.[34] Among the purposes of scholarly publishing the most important are quality control, dissemination, and archiving.[35] Conceived thusly, scholarly communications aid the "generation of relevant research problems" and the production and evaluation of possible solutions by adding value to information in terms of its "use, availability, and retrievability."[36]

The meaning of **peer review** turns on the context of use. In the journal context of most interest here, it refers to those mechanisms by which the manuscripts authors submit to scholarly journals are critically evaluated by a small number of peer scholars selected by an editor. "True peer review," argue Bence and Oppenheim, "is using qualified experts to evaluate the work of fellow experts, with both answerable to a meta-expert, the editor, who is in turn answerable for his or her decisions via the quality and impact of their journal."[37] The axiomatic purposes of peer review are to "distinguish between good and bad research" and provide guidance to authors about possible improvements.[38] Current practices fall short in many respects and academic libraries may wish to use their strategic position to incorporate aspects of peer review now performed by their faculty clients as a future service. At the other end of spectrum are the highly dynamic and diverse faculty work products[39] that are growing rapidly in volume and number of formats and not generally available via traditional journals. Through **institutional repositories**[40] it may be possible to better archive and disseminate these various works.[41] The term '**knowledge work**' as used here emphasizes what scholars do (create knowledge), but also that these are not discrete objects of information, but the product of social effort, increasingly in collaboration with colleagues (individuals may produce information but knowledge requires the efforts of many parties).[42]

SCS model

Most models of the scholarly communication system explicitly or implicitly take the world of scientific publishing as their subject, in part because of the tight historical association between the journal report and scientific research. For more than 30 years, the Garvey-Griffith model has

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[33] Odylzko. A. M. (2000). The future of scientific communication. In P. Wouters and P. Schroeder, (Eds.), *Access to Publicly Financed Research: The Global Research Village III, Amsterdam 2000* (273-278). Amsterdam: Netherlands Institute for Scientific Information Services (NIWI).

[34] Canadian Association of Research Libraries (2005). *Integrated knowledge ecosystem: Canadian research strategy,* January. Available: http://www.kdstudy.ca/2005/finalreport.pdf [17 Apr 2005]. They cite Rowlands and Huntington (2004) at the former extreme and Harnad (1999) at the later. *See* bibliography.

[35] Bohlin, *supra note* 26, 367.

[36] Roosendaal & Geurts, *supra note* 3.

[37] Bence, V. & Oppenheim, C. (2004). The influence of peer review on the research assessment exercise. *Journal of Information Science, 30*(4), 349.

[38] van Rooyen, S. (2001). The Evaluation of peer review quality. *Learned Publishing, 14*(2), 85-91.

[39] Examples are the datasets updated continuously from remote sensing satellites, seismic detection, and sonar readings.

[40] Clifford Lynch provides a suitable definition: "[A] university-based institutional repository is a set of services that a university offers to the members of its community for the management and dissemination of digital materials created by the institution and its community members. It is most essentially an organizational commitment to the stewardship of these digital materials, including long-term preservation where appropriate, as well as organization and access or distribution." Lynch, *supra note* 28.

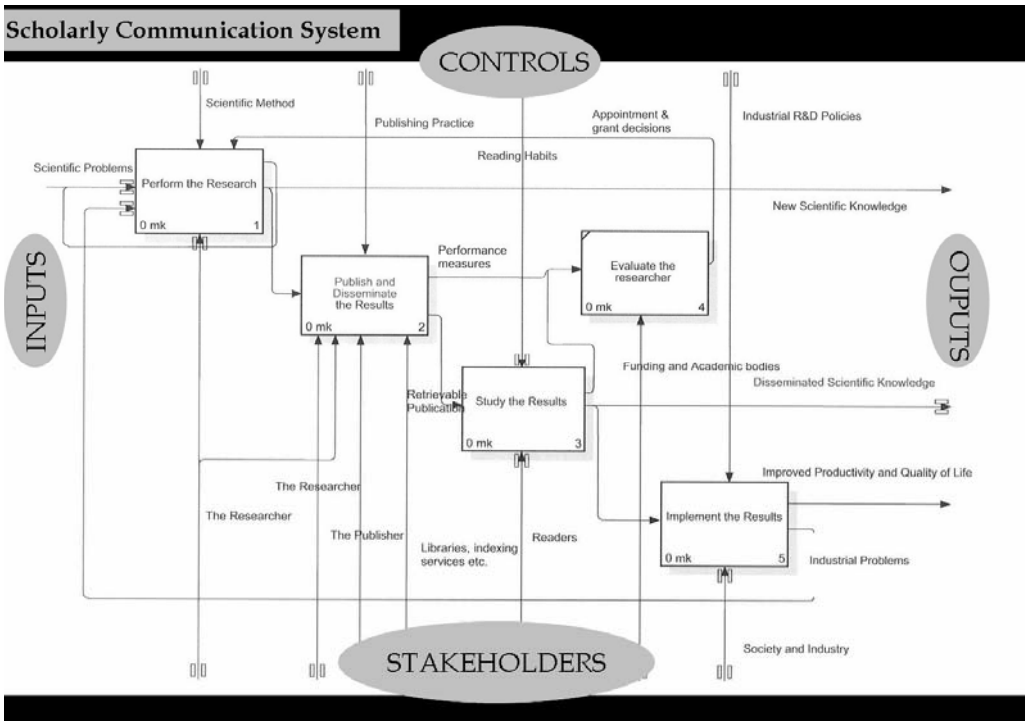
[41] *Ibid*.

[42] Van House, *supra note* 23. This approach is also consistent with the comments of Dr. Atkins to the ARL/CNI Forum on E-research and Cyber-infrastructure held in October 2004. *See* Goldenberg-Hart, *supra note* 29.

influenced thinking about the SCS.[43] In the models they inspired, the peer-reviewed journal article serves as the basic "unit of communication" between researchers and distinguishes formal from informal communication. Many SCS experiments are now undermining traditional boundaries between stakeholders and stages, but even more fundamentally they challenge many of the assumptions of the traditional approach. Most notable are assumptions about the static nature of units of scholarly communication and a view of the publishing process still largely informed by the experience of the print world. The factors analyzed here are more limited in as much as the intention is to identify the minimum conditions for any effective SCS, a task that requires abstraction from particularities. It also requires an approach that permits identification of required conditions removed from the interests of some stakeholders.[44]

A generalized SCS model, adapted from Björk and Hedlund, is provided below in **Figure 1: Scholarly Communication System,** identifying controlling or contextual factors that constrain and guide actions by stakeholders over time with respect to certain information objects as they circulate through the system.

Figure 1: Scholarly Communication System*



*Adapted from Björk, B.C. & Hedlund, T. (2004). A formalised model of the scientific publication process.

Studies of the SCS typically analyze the interests and actions of stakeholders beginning with article submission and ending with archiving in research libraries.[45] Such an approach is

[43] See Garvey, W.D. & Griffith, B.C. (1972). Communication and information processing within scientific disciplines: Empirical findings for psychology. *Information Storage and Retrieval, 8*, 123-126.

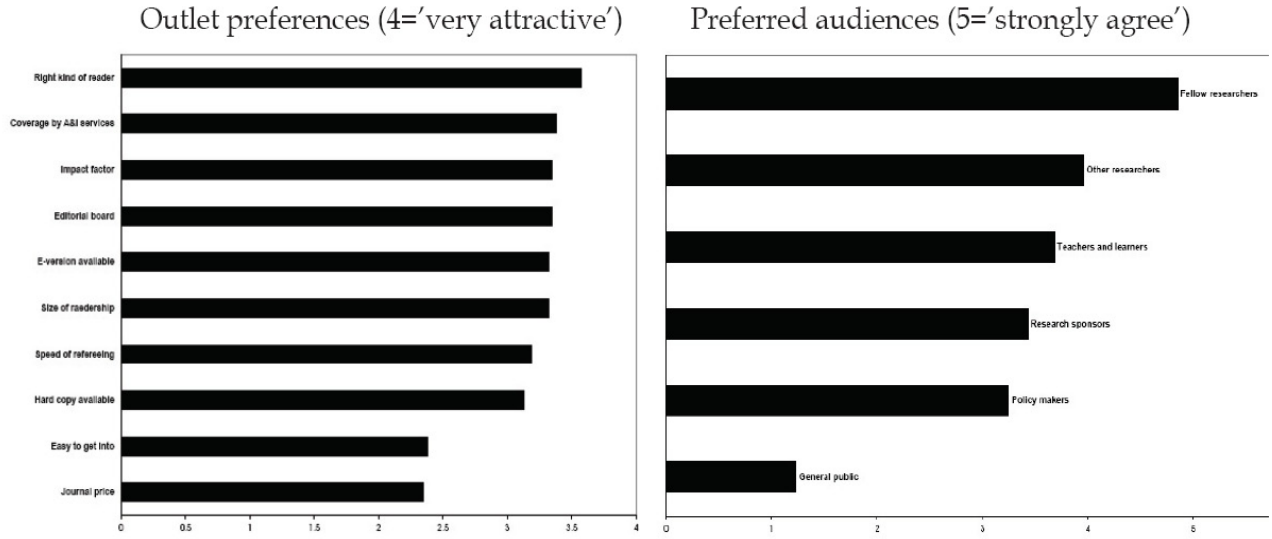
[44] I recognize the analogy is highly forced, but perhaps an analogy is found in the different tact taken by linguists who study the semantic properties of individual spoken languages from those studying universal properties of the language faculty. The latter attempt to identify properties of the language faculty that are invariant.

[45] ACRL Scholarly Communication Committee (2003). Principles and strategies for the reform of scholarly communication: Issues related to the formal system of scholarly communication. *C&RL News, Vol. 64*(8), 526-527, 547. University of Buffalo Libraries (2004). *Final Report*: *Scholarly communication, research, and libraries: An updated environmental scan.* 26 October 2004. Available: http://libweb.lib.buffalo.edu/sw/stplan/envscans/scholcom04_sum.pdf [17 Apr 2004]. Ward, *supra note* 4, 382-383, 389. Committee on Institutional Cooperation (2005), *supra note* 17.

valuable but limited. Alexander Hars[46] identifies three factors required for a complete description: A *process* factor that addresses the "sequence of activities" by stakeholders (author, editor/reviewer, publisher, distributor/library, and reader/library), an *organizational* factor that considers stakeholder objectives (sometimes in competition), and an *object* factor that describes the classes of objects (e.g. abstract, journal, issue, manuscript, table) that populate the SCS.[47] Because the focus here is to discern minimum conditions, some aspects of these important and interconnected factors are privileged over others. We are particularly interested in Hars' 'organizational' factors and in the process and object factors only at the highest level of abstraction. After all, an optimal outcome of the SCS transition now underway may reflect significant changes in the process and object factors in ways that better serve a relatively stable set of objectives. In this approach, the objectives of greatest interest are those of authors, user-researchers, and to a certain degree libraries, much more than publishers and distributors. The reason is simple: One can imagine an SCS without "publishers" as we now recognize them, however unlikely this prospect appears, but no system is possible without researchers and authors doing and reporting research. The objectives of authors and user-researchers must be satisfied.

Figure 2: Factors affecting choice of publishing outlet below reports the results of the most recent large study on the expressed preferences of thousands of scholar-authors from across the world.[48]

Figure 2: Factors affecting choice of publishing outlet (n=3787)



Adapted from Rowlands, I., Nicholas, D., & Huntington, P. (2004). *Scholarly communication in the digital environment: What do authors want? Findings of an international survey of author opinion: Project report.* London: Centre for Information Behaviour and the Evaluation of Research, City University.

The minimum conditions we identify should satisfy the objectives of authors and many user-researchers in so far as these users are typically authors as well. This valuable recent data tell us relatively little about user-researcher interests, but a great deal about the objectives of authors. As we consider the minimum functional conditions for an SCS, the objectives the authors will dominate our approach.

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[46] Formerly at USC and now with the Universität Bayreuth.

[47] Hars, A. (2003). *From publishing to knowledge networks: Reinventing online knowledge infrastructures*. Berlin: Springer-Verlag, 10-16.

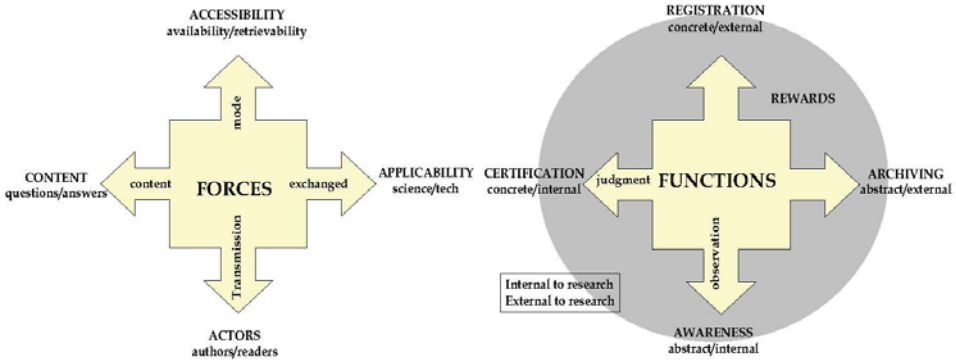
[48] Rowlands, I., Nicholas, D., & Huntington, (2004). *Scholarly communication in the digital environment: What do authors want? Findings of an international survey of author opinion: Project report.* London: Centre for Information Behaviour and the Evaluation of Research, Department of Information Science, City University, 1-37.

Processes, Forces, and Functions in Scholarly Communications

Roosendaal and Guerts published an influential analysis of the core forces and functions of scientific communication that are depicted visually in **Figure 3: Forces and functions of scholarly communication**.[49] One advantage of their approach is precisely that it moves beyond the *process* and *objects* factors and transcends the objectives of non-intrinsic stakeholders. The model also satisfies a basic premise of the social nature of knowledge work in assuming a unit of information of any type only becomes a functional unit of communication in the context of a relation between author and reader.[50] They take the author and reader as the indispensable actor pair, one of four 'forces' genetic to any SCS. Here we will mostly analyze the core functions of scholarly communication from the perspective of the author and the user-researcher to stress the special importance of researchers as a user type. Both actors require functional units of information that are available and retrievable, factors that as a pair constitute for Roosendaal and Guerts an 'accessibility' force. Actors negotiate access to valuable content to generate questions and answers (a third 'content' force) in order to apply this knowledge to either basic science or technological development (the 'applicability' force pair). These forces are an invariant part of any SCS.

Of particular interest though is their discussion of the basic functions of scientific communication. These functions are sufficiently abstract to apply to any scholarly context. It is impossible to imagine a functioning SCS in which these four functions are not served and an SCS that satisfies at least these functions, with one notable addition, is likely one that can sustain the research enterprise. Measurable success in each of these functions would appear to be minimum conditions at least from the standpoint of authors and user-researchers.

Figure 3: Forces and functions in scholarly communication*



* Adapted from Roosendaal, H., & Geurts, P. (1998). Forces and Functions in Scientific Communication: An Analysis of their Interplay.

All scholars and teams of scholars as authors wish to *register* their unique and valuable scholarly contributions. Their likely invariant incentives include peer recognition and prestige, institutional rewards, and facilitating validation and appropriate use.[51] The three critical outcomes of registration do not operate equally for all scholars but they do operate for all authors. Desire for recognition from peers is human nature and because scholarship is a social process with often high input requirements (money, labs, research support, etc.) that demand institutional support, effectively allocating such institutional support is foundational. Finally, authors need effective so

[49] Empirical evidence of this influence is revealed by citation statistics but anecdotal evidence also exists in the use of their work by researchers as varied as Van de Sompel, and colleagues, and in SPARC's major policy paper on institutional repositories. Roosendaal & Geurts, *supra note* 3.

[50] Roosendaal & Geurts, *supra note* 3.

[51] Obviously there are many other registration incentives, most notably securing patents or copyrights. I submit only factors intrinsic to scholarly communication, not to the larger politico-economic system are appropriate here.

there is an identifiable unit of scholarly communication against which to apply other functions (certification, archiving), to test for validity, etc.

Under ideal circumstances, user-researchers would like to identify, even to fine granularity (e.g. the particular scholar preparing a table that appears in a jointly-authored pre-print posted on the Web), the unique contributions of each scholar of interest. Scholars will always ask 'Who is responsible for *this* idea, *that* data set, *these* models, *this* photo or musical score?' and the SCS must provide answers. (It is always good to register new scholarly contributions but the SCS must also permit technical masking of registrants where necessary or desired for other functions, e.g. certification). Effective registration is a minimum condition of a healthy SCS.

Certification is an invariant function of scholarly communication. The dominant expression of the certification process within the traditional journal-bound SCS is peer review, the "lynchpin about which the whole business of Science is pivoted,"[52] though there are number of exciting experiments with alternative approaches underway. Certification mechanisms must be applicable to an increasingly diverse collection of information objects, including original data sets, experimental designs, models, etc., and flexible enough to co-evolve with changing formats while supporting the differing peer review processes used in both science and in the social sciences and the humanities. Within each discipline there have evolved practices and gradations of evaluation that are applied as appropriate in a given research context. An effective SCS must preserve the important historic values of peer review but in new and more transparent ways that better document previously hidden stages while providing greater recognition for those doing this valuable work.[53] Scholars will always need certification mechanisms, as we shall soon see, but they deserve the best possible models and should be able to determine the type of certification that best meets their specific need in a given context. The social value of having a work validated by peers, despite notable weaknesses, is crucial to structuring resource allocation decisions (for both projects and faculty), legitimizing and popularizing innovations, and to increasing the likelihood of detecting errors or weaknesses in scholarly communications. Certification invites a common platform of knowledge for those working in a given field. Weaknesses in peer review are largely remediable through greater transparency.

Authors and user-researchers share an interest in being *aware* of the relevant scholarly work of others. This is an invariant objective of all scholars: Producers of new research wish to make their findings widely available to all interested parties, but they do not wish to make everyone equally aware of all registered contributions at the same time. Indeed, of the many functions of scholarly communication, this is perhaps the most crucial. A primary rationale for this function is to avoid duplicative research while drawing attention to the most promising new research.

Authors wish to widely distribute their works, but with particular emphasis on reaching certain audiences (*see* Figure 2 above). Reaching the right type of reader was the single most important factor in choosing a publishing venue and that, among key audiences, other researchers ('peers') are the single most important target group. Under the existing journal-dominated structure of the SCS desired audiences are reached via a publication's reader profiles (e.g. *Science* vs. *Scientific American*). The ability to selective target audiences will remain valuable to authors while the ability to select the optimum vehicle for their own awareness is the objective of the user-researcher.

The user-researcher's interest in becoming aware of the work of others is even more obvious and similarly invariant (as an objective) across all disciplines. Awareness should be substantially automated where possible and desired to reduce long publication delays and high costs of the current system while supporting greater user-level control over dissemination. Automated notification, for example, seems clearly valuable for awareness from both perspectives.

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[52] Ziman, J. (1968). *Public knowledge: An essay concerning the social dimensions of science.* Cambridge: Cambridge University Press, 111.

[53] Pöschl, *supra note* 27. Schneider & de Souza, *supra note* 27.

Whether linked to motivations of prestige, reward, or validation, awareness is a precondition for the smooth operations of the other core functions of scholarly communications.

The aforementioned functions weigh heavily as factors over the short term, but over longer periods, *archiving* of knowledge work is of paramount importance. All scholars require access to prior work, but even more, they wish to have their work archived. Any stable and effective SCS must both ensure long-term preservation and do so in ways the create confidence in such preservation, particularly by authors. At a minimum, the SCS should facilitate the re-purposing of archival materials and data because these are important sources of new research (e.g. meta-analyses, recovered histories).

An ideal SCS would seamlessly support the emergence of new access practices over time, support the migration of existing digital resources to new formats, with potentially richer meta-data structures, and against which new retrieval algorithms and strategies are applied. Scholars deserve access under evolving best standards and improved interfaces. Optimally, specialized institutional repositories with the relevant expertise and collections will manage archiving. Access to objects throughout the SCS should be freely available whenever possible and at the minimal possible costs automatically when legally necessary.[54]

Development of interoperability protocols is a minimum condition for digital archiving because format standardization is not possible across all the various stakeholders and data products.[55] The needs of differing repositories - academic, corporate, and governmental - will inevitably vary. Some are likely to be richly layered and integrated with other collections while some will be highly specialized and more self-contained. Because software and hardware platforms will differ from one context to another and change over time within settings, interoperability is required to support the migration of data to new media decades hence and for exchange between repositories as required by user-researchers. These architectures must be scalable in terms storage costs but also for their required "logical representation" schemes and the interpretative software needed to render some data meaningful.[56]

Automation of the various stages of the acquisition and preservation process is a technological and economic necessity. Particularly challenging in this regard is the proliferation of multimedia data streams: video, audio, text, complex interactive data sets, maps, etc. Automated agents like robots and meta-crawlers will help to "ingest" new materials and faculty work product should be automatically configured as part of an institutional repository.[57] One unresolved research challenge is designing operability standards that are essentially backward-compatible in that new meta-standards entirely subsume earlier iterations.[58]

In a highly provocative article that builds explicitly on Roosendaal and Geurts, Dr. Van de Sompel, a librarian at Los Angels National Laboratory and Dr. Carl Lagoze and other Cornell computer scientists note that participants in the SCS must have incentives that *reward* their meaningful participation. Calculating and applying incentives requires a SCS that generates useful indicators or metrics of productivity over the course of normal operations without significant effort from stakeholders. It is important that participants during all stages of the SCS, from authors, to

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[54] Odylzko, A.M. (2004). Why electronic publishing means people will pay different prices. *Nature web forum: Access to the literature: The debate continues*, 25 March 2004. Available: http://www.nature.com/nature/focus/accessdebate/7.html [13 Mar 2005.

[55] Workshop on Research Challenges in Digital Archiving and Long-term Preservation (2003). *It's about time: Research challenges in digital archiving and long-term preservation: Final report: Workshop on Research Challenges in Digital Archiving and Long-term Preservation, April 12-13, 2002 Warrenton, Virginia*. Washington, D.C: Library of Congress

[56] *Ibid.*

[57] The emergence of meta-data standards for libraries (e.g. Dublin Core), for public repositories (e.g. Open Archives Initiative), standards for persistent naming of digital objects (Digital Object Identifier System -DOI), and other similar models are attempts to provide an assemblage of core standards around which convergence is possible. *See* Open Archives Initiative (2005) *Open Archives Initiative*. ONLINE. Available: http://www.openarchives.org/index.html [9 Mar 2004]. International DOI Foundation (2005). *The Digital Object Identifier System*. ONLINE. 25 February 2005. Available: http://www.doi.org/ [9 Mar 2004].

[58] *It's about time*, *supra note* 55, 38-39.

reviewers, to editors, to readers, receive at least the reward of either recognition or the retrieval and use of potentially valuable information generated by their participation. Because the SCS is tied to external reward structures (e.g. tenure) the SCS model must generate data useful to metrics for rewards.

Discussion: Minimum Conditions

Reframing the investigation of the SCS toward consideration of minimum conditions may reveal opportunities to apply to each stage of the scholarly communication cycle some of the value-added services characteristic of journal publishing, but under far more democratic, open, and timely conditions. Van de Sompel and colleagues describe the SCS as one "composed of an interoperability substrate" that enables boundary navigation. Their shift in focus away from journal publication and to a complex scholarly ecology model comprised of "units of scholarly communication" potentially unlocks "value-adding services" by disaggregating the various functions and services currently delivered within the SCS.[59]

The great potential of new models is that they may provide seemingly paradoxical functionality. They make possible disaggregating some of the core functions of communication (registration, certification, awareness, and archiving) from the traditional journal-oriented model in order to perform value adding services for each function in better ways and locations. The other half of the paradox is that achieving the transformative potential of disaggregating does not require a loss in the advantages of aggregation of content and interpretative schema (e.g., indexing, theme journals, quality control, etc.) that are products of scholarly journals. We will see this most clearly in our brief discussion of institutional repositories below).

A successful SCS must be "sensitive to the variety of communities' existing practices" and "indicators of credibility" while unobtrusively integrating into their "work, practices, artifacts, and communities."[60] A SCS embedded in the very processes of scholarly work, rather than mostly or merely as expressed in peer-reviewed journals, allows capture of more intermediate research products while making these more readily and rapidly available.[61] A crucial insight emerging from the sociology of science literature is that the SCS must be sufficiently flexible to support a diverse range of scholarly practices even while it facilitates increasingly inter-disciplinary research. Even as the SCS supports the universal requirements of scholarly communication, it must also support the unique requirements of diverse researchers in many fields, and it must enable research across these boundaries because interdisciplinary research is increasingly possible and necessary.[62] It must simultaneously permit boundaries while enabling their easy crossing by users with different needs and experiences.

Our investigations of the key functions of scientific communication and the sociological foundations of scholarly work point toward a useful set of minimum conditions satisfied by any successful and stable scholarly communications system. Such a system will possess at least these attributes:

SUFFICIENCY - Adequately serves 'Four Functions' of scientific communication.
FLEXIBILITY - Sensitive to diverse norms and practices while enabling boundary navigation.
TRANSPARENCY - Integrated seamlessly and openly.
REWARDING - Generates relevant productivity metrics during normal operation.

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[59] Van de Sompel, H., Payette, S., Erickson, J., Lagoze, C., & Warner, S. (2001). Rethinking scholarly communication: Building the system that scholars deserve. *D-Lib Magazine, 10*(9), September. Available: http://www.dlib.org/dlib/september04/vandesompel/09vandesompel.html [22 Mar 2005]. Van de Sompel and colleagues are working in the science context, but the observation generalizes.
[60] Van House, *supra note* 23.
[61] Van de Sompel, Payette, et al., *supra note* 59.
[62] Gallopín, G., Funtowicz, S., O'Connor, M., Ravetz, J. (2001). Science for the 21st Century: From social contract to the scientific core. [UNESCO] *International Journal of Social Science, 168,* 219-229.

TRUSTWORTHY - Generates trust to sustain long-term participation.

Specific areas ripe for additional research are discussed in the conclusion.

Having identified the minimum conditions of an effective SCS and highlighted areas for additional research, we turn now to a brief examination of these issues in two specific and important contexts.

CASE 1: Peer Review

As we have seen in our discussion of certification that all major scholarly disciplines share a need for processes that certify works are "trustworthy," however they may define the concept. Evaluating and legitimizing published research for identifying the most promising areas of research, for publicizing new knowledge in ways that make application more likely, and to fulfill important institutional metrics of productivity.[63] Assessing minimum conditions for a new SCS model would benefits from examining current deficiencies in two ways. First, it suggests that the current system, at least in the one respect, fails to satisfy all the minimum conditions for certification. We will see that the widely-embraced norm of peer review does not satisfy either of the axiomatic purposes of review. Second, exposing these weaknesses might help engender greater support for new models that better support certification functions.

Principle 4 of the ARL's *Tempe Statement* on core SCS principles urges that whatever their form, new models "continue to include processes for evaluating the quality of scholarly work."[64] They also note because practices vary substantially, new models must be sufficiently flexible to accommodate this diversity while providing a "more transparent mechanism" to inform readers of the "nature of the evaluation of the work has undergone in its various versions."[65] In addition to supporting the functions of traditional peer review, electronic peer review should be embedded in the very processes of review to better capture the ebb and flow of critique and feedback that is at the heart of the scholarly process.[66]

Kling and McKim at the Center for Informatics at Indiana examine the SCS as a series of *communicative acts* of a *social* nature reflecting practices of publicity, access, and trustworthiness (analogous to the dissemination, archiving, and quality control purposes discussed earlier). Trustworthiness entails "social processes" that "assure readers that they can place a high level of trust in the content of the document based on community-specific norms."[67] Peer review sits at one end of a continuum of practices to assess the value and relevance of an individual work and its producer(s). Dr. Weller, Director of the Health Sciences Library at the University of Illinois at Chicago, examined some 1500 published studies on peer review,[68] including her own of electronic models.[69] Other efforts include a comprehensive assault on the empirical and philosophical foundations of peer review[70] and a review of studies assessing the effectiveness of peer review on research quality.[71] The *JAMA* has published a number of studies assessing the effects of peer

[63] Brown, T. (2004). *Peer review and the acceptance of new scientific ideas: Discussion paper from a Working Party on equipping the public with an understanding of Peer Review*. London: Sense About Science.
[64] Association of Research Libraries (2000). *Principles for emerging systems of scholarly publishing* (Tempe Statement). Available: http://www.arl.org/scomm/tempe.html [13 Mar 2005].
[65] *Ibid.*
[66] Van de Sompel, Payette, et al., *supra note* 59.
[67] Kling & McKim, *supra note* 28, 897.
[68] Weller, A.C. (2001). *Editorial Peer Review: Its Strength and Weaknesses.* ASIST Monograph Series. Medford, NJ: American Society for Information Science and Technology.
[69] Weller, A.C. (2000). Editorial peer review for electronic journals: Current issues and emerging models. *Journal of the American Society for Information Science, 51*(14), 1328-1333.
[70] Lock, S.A. (1986). Difficult Balance: Editorial Peer Review in Medicine. Philadelphia: ISI Press.
[71] Meadows, A.J. (1998). *Communicating Research*. San Diego: Academic Press. *See* pages 177-194.

review by methods of review[72] under various conditions[73] journal type,[74] and by author perspectives.[75] Consider some of the weaknesses these studies have identified.

Authors and readers complain of long delays between submission and publication,[76] the use of formulaic approaches that reject quality work for trivial reasons,[77] and a lack of relevant expertise by editors or reviewers.[78] Some studies find limited benefits from rejection,[79] in part because nearly 70 per cent are published elsewhere,[80] roughly four in five largely unaltered.[81] Blind review can encourage destructive comments.[82] Some charge peer review "silences" maverick scholars,[83] giving established leaders control of their field's key journals.[84] Closely examining each revision through review, Meyers found authors were pushed toward the "consensus of the field."[85]

Reviewers may compete with authors for limited funds or enjoy a prior association.[86] On the other hand, given the increasingly collaborative nature of research, avoidance of the appearance conflicts may ensure less technically competent reviewers.[87] Evidence of reviewer bias[88] includes ideological bias, age bias, gender bias, geographic bias,[89] and linguistic bias.[90] One study found significant evidence of a "halo effect" with higher evaluations given to work perceived as originating at prestigious institutions.[91] Despite the significant costs of the current peer review process, there are few tangible rewards to participants themselves[92] though some prominent scholars are handsomely compensated as editors.[93]

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[72] Jefferson, T., Wager, E., & Davidoff, F. (2002). Measuring the quality of editorial peer review. *JAMA, 287*(21), 2786-2789.
[73] Godlee F, Gale CR, Martyn C.N. (1997). *The effect on the quality of peer review of blinding reviewers and asking them to sign their reports: A randomized controlled trial*. Presented at the International Congress on Biomedical Peer Review and Global Communications, 17-21 September, Prague, Czech Republic. This study measured the effects of review blind and not blind, author blind and not blind, etc.
[74] Weller, A.C. (2002). Qualitative and quantitative measures of indexed health sciences electronic journals. *JAMA, 287*(21), 2865-2866. Weller's examined processes electronic only, print only, and print and electronic journals.
[75] Webber, E.J., Katz, P.P, Waeckerle, J.F., & Callaham, M.L. (2002). Author perception of peer review: Impact of review quality and acceptance and satisfaction. *JAMA, 287*(21), 2790-2793.
[76] Peters, J. (1996). The Hundred Years War started today: An exploration of electronic peer review. *Management Decision, 34*(1), 54.
[77] *Ibid*, 54.
[78] Gura, R. (2002). Peer review, unmasked. *Nature, 416*(21 March), 258. Pöschl, *supra note* 27.
[79] Grove, L.K. (2003). In pursuit of constructive criticism. *IEEE Transactions on Professional Communication, 46*(4), 257-59.
[80] Ray, J. & Berkwits, M. & Davidoff, F. (2000). The fate of manuscripts rejected by a general medical journal. *American Journal of Medicine, 109*, 131-135.
[81] Wager, E., Jefferson, T. (2001). Shortcomings of peer review in biomedical journals. *Learned Publishing, 14*(2), 261. Peters, *supra note* 77, 54.
[82] Peters, *supra note* 77, 54.
[83] Moran, G. (1998). *Silencing scientists and scholars in other fields: Paradigm controls, peer review, and scholarly communication.* Greenwich, CT: Ablex Publishing Co. O'Reilly, J. (2002). Risk, adventure and the tyranny of peer review. *Engineering Science and Education Journal, 11*(6), 251-253. Horrobin D. (1990). The philosophical basis of peer review and the suppression of innovation. *JAMA*, *263*, 1438–41.
[84] Sullivan, D.L. (2000). Keeping the rhetoric orthodox: Forum control in science. *Technical Communication Quarterly, 9*(2) (Spring), 125-46.
[85] Meyers, G. (1990). *Writing biology: Texts in the social construction of scientific knowledge*. Madison: U. of Wisconsin Press, 53.
[86] van Rooyen, *supra note* 38, 87.
[87] Conversation with Dr. D.E Atkins, University of Michigan, 11 April 2005.
[88] Sharp, D.W. (1990). What can and should be done about publication bias? *JAMA, 263*, 1390–91.
[89] van Rooyen, *supra note* 38, 86-87.
[90] Nylenna, M., Riis, P, & Karlson Y. (1994). Multiple blinded reviews of the same two manuscripts: Effects of referee characteristics and publication language. *JAMA, 272*, 149-51.
[91] Peters & Ceci re-submitted previously published articles with only authors' institutional affiliation changed. Few were recognized as duplicates and eight of twelve were rejected. Peters, D.P, & Ceci, S.J. (1982). Peer review practices of psychological journals: The fate of published articles submitted again. *Behavioral and Brain Science, 5*, 187-195.
[92] Van de Sompel, Payette, et al., *supra note* 59.
[93] Conversation with Dr. D.E Atkins, University of Michigan, 11 April 2005. I have not uncovered examples of compensated reviewers.

Failure to detect and expose fraud [94] by authors and reviewer misconduct[95] are all-too-common. Even serious technical errors are frequently undetected. A study published in the *British Medical Journal* provided a paper with eight major flaws to more than 420 reviewers with a mean number of two flaws identified with no reviewer finding more than five.[96] A systematic study of the outcomes of peer review in information systems field found peer review "little better than chance from the point of view of recommending acceptance or rejection of papers."[97] A meta-analysis of the most rigorous studies of the effects of peer review in biomedical journals found "little evidence peer review actually improves the quality of research papers."[98]

It is one thing to identify weaknesses in current practice but quite another to propose viable alternatives. Translating viable alternatives into broadly acceptable practices is daunting.[99] The central thrust of the most promising alternatives entail disaggregating the individual review stages to improve the quality of treatment at each while making the process of give and take between scholars more transparent.

Closely examining journals in the fields of medicine, physics, and psychology, Dr. Weller discerns three emerging models of peer review in electronic journals.[100] One is little more than an electronic facsimile of traditional processes,[101] the second splits peer commentary and the registering and archiving functions from rigorous review process (arXiv is her exemplar), and the third model, features published peer review commentaries, author responses, as well as reviews of commentaries (she points to Harnad's[102] *Psycoloquy* and we could add *Atmospheric Chemistry and*

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[94] The U.S. Office for Research Integrity uncovers every year instances of fraud published in peer-reviewed journals. The most recent annual was published in 2003. See *Office of Research Integrity Annual Report published by year*. Available: http://ori.dhhs.gov/publications/annual_reports.shtml [1 April 2005]. *Also* Wager & Jefferson, *supra note* 81, 258-59. Lock, S.A. (1991). *Difficult Balance: Editorial Peer Review in Medicine*. London: BMJ Books. Broad W. (1980). Imbroglio at Yale (1): Emergence of a fraud. *Science*, *210*, 38–41.

[95] For an overview of telling cases, *see* Rennie, D. (1999). Misconduct and peer review. In F. Godlee & T. Jefferson, (Eds.), *Peer Review in Health Sciences*. London: BMJ Books.

[96] Smith, R. (1997). Peer review: Reform or revolution? *BMJ, 315*, 759–60.

[97] Wood, M. & Roberts M. (2004). The reliability of peer reviews and papers on information systems. *Journal of Information Science, 30*(1), 10.

[98] Jefferson, T., Alderson, P., Wager, E., & Davidoff, F. (2002). Effects of editorial peer review: A systematic review. *JAMA, 287*(21), 2784-2786. Elsewhere the authors of this meta-analysis report that,

> "peer review is costly in terms of time and resources, and, especially when papers are rejected by a number of journals, does not appear to be particularly efficient. It has the power to improve the quality of submitted articles, yet, in many cases, suggestions from journals that reject a paper are ignored. It does not always detect important work, nor does it reliably protect readers from fraudulent reports. Reviewers do not reliably comment on all the weaknesses of a paper, and a significant proportion of the end-product (i.e. the papers that are published) contains deficiencies that make it hard for the reader to evaluate the research thoroughly or to retrieve cited references. Reviewers may also exhibit bias in relation to authors' identities, professional affiliations, and publication language. In a few cases, reviewers are known to have abused the peer-review system. "

Wager & Jefferson, *supra note* 82, 262. *See also* Enserk, M. (2002). Peer review and quality: A Dubious Connection? *Science, 293*(5538), 21 September, 2187-88. Alderson, P.A., Davidoff, F., Jefferson, T., & Wager, E. (2001). *Editorial peer review for improving the quality of reports of biomedical studies: A Cochrane review*. Fourth International Congress on Peer Review in Biomedical Publication, Barcelona, Spain, September, 2001. Jefferson, T.O., Alderson, P., Davidoff F., Wager, E. (2001). Editorial peer-review for improving the quality of reports of biomedical studies. *The Cochrane Database of Methodology Reviews*, 2001(3). (Art. No.: MR000016). Jefferson, Wager, E & Davidoff, *supra note* 73.
van Rooyen, *supra note* 38, 85-91.

[99] de Vries, J. (2001). Peer review: The Holy Cow of science. In Fredriksen, E.H., (ed.). *A century of science publishing*, (231-244). Amsterdam: IOS Press.

[100] Weller, *supra note* 70, 1328-1333.

[101] This model embraces the "Infelginger rule," named for the long-time editor of the *New England Journal of Medicine*. Under this rule there is no role for visible pre-publication commentary before peer review.

[102] Dr. Harnad expressed strong support for continuing formal peer review, but proposes to break apart the peer commentary and review processes to capture and disseminate greater awareness of the content of exchanges outside the strictures of formal review. Harnad, S. (1990). Scholarly Skywriting and the prepublication continuum of scientific inquiry. *Psychological Science, 1*, 342 - 343. Available: http://www.ecs.soton.ac.uk/~harnad/Papers/Harnad/harnad90.skywriting.html [1 Apr 2005] Harnad, S. (1996). Implementing peer review on the net: Scientific quality control in Scholarly Electronic Journals. In R. Peek & Newby, G. (Eds.). *Scholarly Publication: The Electronic Frontier* (103-108). Cambridge MA: MIT Press. Available:

Physics with its peer discussion board and official journal. While some nettlesome questions remain this mostly open third model appears ascendant since Weller's study.[103] Weller found that electronic review was generally satisfactory, and that most respondents preferred open review (reviewer not blind), but she also found persistent concerns regarding the archiving and rewarding functions.[104]

Proposals for new models of peer review are proliferating because information scientists and librarians recognize both the weaknesses within the current system and the necessity of peer review for quality control.[105] Dr. Pölsch, drawing on his experience as a founder of *Atmospheric Chemistry and Physics* proposes to separate the commentary and review stages, but to also make both more transparent, capturing this interchange, and giving users the ability to set their desired degree of certification.[106] A most intriguing proposal comes from Dr. Stefan Mizzaro at the University of Udine to replace traditional peer review with the judgments and reputations of all stakeholders, including authors, readers, and reviewers, weighted dynamically by their relative experience, skill, and reputation. Stakeholders would receive "reputation scores" updated and producing data for setting certification levels by user-researchers. In the normal functioning of the system the value of stakeholder inputs are recorded and recognized, providing some measure of reward.[107]

The growing number of journals employing open, electronic peer review will produce an expanding body of data about the effectiveness of various approaches. The *Medical Journal of Australia*, for example, assessed the effectiveness of their implementation of electronic peer review in two studies (1996 & 1997), producing three key findings: 1) the process was satisfactory for authors and reviewers; 2) post-publication reader commentary was helpful to reviewers over time; and 3) readers did receive valuable information about the review process under conditions of transparency.[108] Dutch scientist van Royen found open review produces no negative effect on research quality and in some cases produced superior reviews.[109] Additional longitudinal surveys will better assess changing perceptions as new practices become more broadly embraced and familiarity increases.

Information professionals who serve scholars should remain attentive to the emerging models of review. Inducing financial and other support for new library initiatives requires sensitivity to the practices of scholars, including quality assurance practices. Professionals should avoid models that leapfrog over important questions of trustworthiness because what is "technically sweet" is not always socially desirable or readily embraced by intended audiences. Despite the many weaknesses we have seen in current practices, peer review does provide important benefits to scholars and researchers by helping to identify promising works and in assessing the productivity of scholars. Most importantly, whatever specific form it assumes, it is the certain that scholars will continue to demand some acceptable method of quality assurance and critical evaluation of their work. As Ross MacDonald notes,

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http://www.ecs.soton.ac.uk/~harnad/Papers/Harnad/harnad96.peer.review.html [7 Apr 2005]. Harnad, S. (1997). *Learned Inquiry and the Net: the role of peer review, peer commentary and copyright.* Abridged paper of Keynote Address, "Learned Inquiry and the Net," delivered at Beyond Print: Symposium on Electronic Publishing and New Models of Scholarly Communication, Center for Instructional Technology, University of Toronto at Scarborough, September 26-27, 1997. Available: http://www.ecs.soton.ac.uk/~harnad/Papers/Harnad/harnad97.antiquity.html [7 Apr 2005]. Harnad, S. (2000). *The Invisible Hand of Peer Review.* Available: http://www.ecs.soton.ac.uk/~harnad/nature2.html [2 Apr 2005].

[103] Weller, *supra note* 70, 1330-1332. Areas of concern include desirability of blind review, whether to publish review commentary before publication and after publication, how to weight contributions, etc.

[104] *Ibid*, 1330-1332.

[105] Clark, A., Singleton-Jackson, J., & Newsom, R. (2000). Journal Editing: Managing the peer review process for timely publication of articles. *Publishing Research Quarterly, 16*(3), 62-71.

[106] Pöschl, *supra note* 27.

[107] Mizzaro, S. (2003). Quality control in scholarly publishing: A new proposal. *Journal of the American Society for Information Science and Technology, 54*(11), 989-1005.

[108] Bingham C.M., Higgins G, Coleman R, Van Der Weyden M.B. (1998). The Medical Journal of Australia Internet peer-review study. *Lancet*, *352*, 441-445.

[109] van Rooyen, *supra note* 38, 88-89.

> Scholarly publishing is in a state of flux. Odylzko (2002) has described e-publishing as a disruptive technology which has under-performed traditional scholarly communication, but has the potential to enable new applications and eventually outperform the traditional paper-based model. The tradition of credibility through quality control that is inherent in the present-day scholarly publishing will continue to play a role regardless of the exact publishing models used. However, the flexibility and interactivity allowed by the Internet will likely see a greater variety of approaches to peer review in the future.[110]

CASE 2: Institutional repositories

> *"Universities have the necessary critical mass of participants from varied disciplines. University faculty are already well represented on present editorial boards and include many editors; strong representation of university faculty on the new editorial boards established under the auspices of the Scholar's Forum continues this tradition. Universities have close ties to professional societies, have expertise in information technology, and have a large pool of creative student programmers who can contribute to the infrastructure developments that will be needed. Since universities are responsible for most of the work that appears in the scholarly literature, well-defined, committed administrative support can take advantage of major economies of scale to curtail costs as access to the scholarly literature is enhanced. Consensus is growing among scholars that change is desirable, and few would not agree that universities possess the talent required to make it so. However, an individual university will have difficulty redefining the paradigm for scholarly communication on its own."*[111]

Almost unique among recent innovations within the SCS, institutional repositories (IRs) hold the possibility for near-term transformations with respect to all five core communication functions: registration, certification, awareness, archiving, and rewards. While space prohibits any attempt to fully catalog recent activities, in a number of important respects IRs and debates over their design and operation reveal important opportunities to improve the quality of scholarly research. Moreover, by positioning the stakeholders of particular interest (authors, user-researchers, and libraries) to assert greater control of these core functions, IRs can better ensure their interests are optimally served.

While continuing to satisfy invariant functions of scholarly communication, a more effective SCS requires disaggregating core functions now tightly controlled by the scholarly publishing industry. Strategically, authors, user-researchers, and libraries can best leverage their position within the SCS by seeking to break apart the various functions within this model (while retaining the capacity for dynamic content aggregation at the user level) to realize cost and time efficiencies. We have seen that much of the labor and costs of the current model are borne by academic institutions. One cause of this situation is that "bundling together individual functions" in the current model "compromises the market efficiency" maximally achievable at each stage while "fragmenting" them unlocks the potential for greater "value added" services at each.

Effectively disaggregating these core functions, in turn, "presupposes a large body of open access research" useful to scholars, and IRs, "perhaps more than any other type of content source," can generate the "critical mass of open access content necessary to enable the collateral information and knowledge components" of a new SCS. Strategic implementation of IRs creates the potential to better manage the costs and administrative overhead related to the SCS and better and passively

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[110] MacDonald, R. (2002). What are the factors that will shape peer review in e-journals? *Library Hi Tech News, 19*(6) (July), 15.

[111] Buck, A.M., Flagan, R.C., & Coles, B. (1999). *Scholar's forum: A new model for scholarly communication*. California Institute of Technology, Pasadena, CA, March 23, 1999. Available: http://library.caltech.edu/publications/ScholarsForum/scholarsforum.pdf [16 Mar 2005].

capture useful knowledge work presently scattered across journals and hiding in laboratories and offices. Because they can facilitate dis-aggregation they also uniquely support rendering of value added services for each core function. By competing with publishers they will relieve some of the cost burdens of the current system. Finally, because any effective new SCS model must provide rewards to campus-based stakeholders, IRs are well situated to revise incentive structure to facilitate any transition.

At least for campus-based research, IRs can meet the demands of their researchers for *registering* new insights and knowledge. An IR provides a ready and credible registration venue. Even more, the IR provides a mechanism for more powerful institutional registration: A portion of the information objects generated at a given academic institution are so 'registered,' along with some versions faculty work now dispersed across the thousands of journals, are under IRs organized as the collective output of a given institution.[112] By making more transparent the collective output of an institution, offering prestige and perhaps greater funding. "Of potentially greater long term impact to scholarly communication" is capacity of IRs to capture the "body of non-text research and scholarly" materials "growing rapidly and inexorably" in academia.[113] In addition to facilitating pro-active registration, when IRs "move into the background and assume the role of a substrate on which research and scientific communication can be performed," knowledge work of fine granularity can be registered passively.[114]

In principle, IRs will satisfy the *certification* condition. Certification work is typically performed by faculty researchers. This work can continue essentially undisturbed and may be integrated into IRs, for example, certain departments at one institution could 'brand' itself as a source for valuable review for certain subjects. The diverse norms and varying degrees of certification unique to disciplines are supported by IRs, whether implied by association with the university, departments, or key scholars, or more formally through processes analogous to peer review. Given the crucial social process by which disciplines confer 'trustworthiness,' no entity is better positioned to invite trust in new certification processes than faculty themselves working with their institutions. By making certification activities potentially more transparent to host institutions and the scholarly world, IRs may also provide crucial incentives for participation in certification functions.

Institutional repositories can make decisive contributions to the *awareness* function of scholarly communication in both the short and near term. Through hosting e-print servers, producing open access journals, making dissemination of ephemeral or multi-media work products more accessible, providing support for richer faculty and departmental web pages, and so forth, IRs expand the range of interesting materials available to scholars. Discipline-specific norms can be incorporated into IR design and can be operated with the collaboration of a range of stakeholders.[115] They increase competition for commercially published journals, driving down subscription costs, and permitting reallocation of existing resources. Similarly, they give universities more leverage in negotiations over future use and licensing restrictions for valued proprietary content. Perhaps no recent develop holds greater potential to address the SCS 'crisis' factors discussed earlier.

Librarians and information scientists who must play large roles in the design and operation of IRs can impose interoperability standards and meta-data of varying complexity to better satisfy the awareness condition. As part of a "global system of decentralized, distributed

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[112] Crow, *supra note* 19.
[113] Wolpert, A.J. (2002). The future of electronic data: Will universities' own electronic repositories affect traditional publishing? *Nature, 420*(7 November), 18.
[114] Hars, *supra note* 47, 6
[115] Project Euclid sponsored by Cornell is one example for the disciplines of mathematics and statistics. Euclid is a "user-centered initiative to create an environment for the effective and affordable distribution of serial literature in mathematics and statistics" explicitly designed to "address the unique needs of independent and society journals through a collaborative partnership with scholarly publishers, professional societies, and academic libraries.

repositories," related content can be electronically linked to permit users to "search seamlessly across repository types, facilitating interdisciplinary research."[116]

Universities and academic libraries must confront the challenge of long-term preservation of digital objects created by their faculty because no model can effectively function unless the *archiving* condition is satisfied. Because much knowledge work product is generated on campuses, IRs are well situated to integrate into existing practices and locations while maintaining archives.

One important instance in which IRs can better archive while increasing awareness pertain to such faculty work products as pre-prints, conference presentations, discussion boards, dissertations, multi-media products, etc, in short, those materials now rarely captured and not systematically organized for long-term preservation. (Some of this material is considered "grey literature," although the distinction on which the designation rests is increasingly tenuous.)[117] In their early work, Griffith and Garvey documented that formal publication represented an extremely small portion of the total communication among scholars,[118] a situation now more pronounced as new technologies make remote communication routine.[119] The explosion data volume in the sciences, along with heightened interest in repurposing data archives will continue to grow as grid technologies reach their full potential. By imposing or incenting commitment to interoperability standards through the Open Archives Initiative, the objects held in emerging IRs will bear a "core set of metadata that represent a lowest common denominator," thereby reducing "barriers to participation," in ways that make realistic the archiving of "ephemera or other material that might not warrant the expense of extensive metadata tagging, while still adding value in terms of information retrieval."[120] A pilot project of the National Library of Portugal provides some evidence of added value for researchers from the archiving of so-called 'grey literature.'[121]

How well any given IR will serve the archiving functions remains to be seen. Because of importance of this function as a minimum condition of an effective SCS, libraries and other IR sponsors must actively plan and collaborate and ensure funding for long-term preservation, including data migration. As the proportion of digital-only material continues to increase, the issue will become even more pressing. A distributed network of interoperable repositories and mirror sites offers a sound digital preservation framework. An emerging consensus strongly suggests that long-term preservation of digital information is best ensure by distributing copies in many locations (Lots of Copies Keep Stuff Safe), a task for which IRs and federations of IRs are well positioned.[122]

In our discussion of peer review and its alternatives we found that some work is largely unrecognized and poorly rewarded. It is vital to recognize and *reward* the participation of authors, user-researchers, and libraries, and their institutions if they are to participate in IRs. Because of their proximity to researchers and their research, and a closer alignment of interests as compared to publishers, IRs can be inserted into existing reward structures in a non-disruptive and potentially value-adding manner. For example, when initially implemented as complements to existing reward structures tied to impact journals, IRs are less likely to engender faculty resistance

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[116] Crow, *supra note* 19, 10.

[117] The widely-accepted definition produced by at *Luxemburg Convention on GL*, for example, rests on two foundations: poor bibliographic control and material not controlled by commercial publishers. Particularly this last distinction if increasingly blurred by the evolution of the SCS. *See* Thompson, L.A. (2001). Grey literature in engineering. *Science and Technologies Libraries, 19*(3/4), 58-59.

[118] Garvey, W.D. & Griffith, B.C. (1964). Scientific information exchange in psychology. *Science, 146*(3652), 1655-1659.

[119] Schaffner, *supra note* 9, 239-248. Schaffner does caution that the volume of information varies across disciplines and that the substance of these discussions primarily involve formal communication.

[120] Crow, *supra note* 19, 10.

[121] Ramalho Correia, A.M & de Castro, M.N. (2002). The role of e-print archives in the access to, and dissemination of, scientific grey literature: LIZA – a case study by the National Library of Portugal. *Journal of Information Science*, *Vol.28*(3) , 231–241.

[122] *See* the LOCKSS home page: http://lockss.stanford.edu/ [11 Apr 2005]
Rosenthal, D.S.H. & Reich, V. (2000). *Permanent web publishing*. Available: http://lockss.stanford.edu/freenix2000/freenix2000.html [22 Apr 2005].

while growing more appealing.[123] Over time, IRs offer attractive new advantages, such as broader awareness. Evidence of this effect is found in the higher citation rates for open access online articles when "appropriate indexing and search mechanisms [are] in place."[124]

Other ways IRs can satisfy the rewarding function involve new citation-linking analyses that may produce superior metrics of a scholar's contributions by shifting evaluation from crude measures of publishing volume in favor of more valuable measures.[125] In the final analysis, the single most important rewards for participants will relate to the "alternative forms of communication that emerge as faculty begin to exploit" new functionality that supports "the ways they need and want to teach and conduct research."[126]

Significant investments that are a condition for realizing this vision have already been made, or are underway, on many campuses. Indeed, a portion of the investments required to realize this potential is inevitable for reasons unrelated to repositories. Federations of digital repositories permit members to simultaneously specialize and rationalize production and management in particular areas, while retaining access to the collections maintained by associated institutions.[127] Collaboration among those working in libraries, faculty, and administrators is required to maximize the potential positive impact of IRs on the evolution of the SCS requires far greater levels of inter-institutional collaboration.[128] To this end, the D-Space Federation bringing together M.I.T., Hewlett-Packard, and others to create an open source digital repositories software platform can simultaneously reduce transition costs, realize the design advantages of non-proprietary software, and better ensure interoperability across many institutions.[129]

Permutations of potentially useful federations of repositories are endless[130] but university-based repositories that capture the knowledge work of their faculty will be a central actor within any such configuration. The year 2004 was perhaps a tipping point for the open access movement,[131] and major governmental entities have embraced or are considering such models for the research they support, thus ensuring a greater volume of IP-free research. Adding a substantial volume of faculty work will provide even greater return. Free to low cost models do not answer all the technical challenges, pay for migration, or alone fund curatorial processes, but by lowering a crucial cost factor and providing real value to users they may provide a suitable generic economic model for many digital collections.

Areas for Further Research

> *"[T]he trends of distributed computing and open paradigms for scholarly exchange have relaxed the boundaries between stakeholders, allowing more permeable and overlapping roles. Content once fettered by physical constraints has been loosened. The conventions of scholarly communication have been stretched and opened to a wider audience. The products of publication have become more process-like. The roles of libraries have also changed to embrace new opportunities for facilitating and shaping content, communication, and collaboration... the research library's role as archive or steward of information goods is being transformed as a collaborator and potentially a catalyst within interest-based communities."*[132]

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[123] Pinfield, S., Gardner, & MacColl, J. (2002) Setting up an institutional e-print archive. *Ariadne, 31*, np. Available: http://www.arl.org/arl/proceedings/133/phelps.html [22 Apr 2005].
[124] Crow, *supra note* 19, 22.
[125] Van de Sompel, et al, *supra note* 59.
[126] Wolpert, A.J. (2002). The future of electronic data: Will universities' own electronic repositories affect traditional publishing? *Nature, 420*(7 November), 18.
[127] Lesk, M. (2005). *Understanding Digital Libraries*. New York: Elsevier, 247.
[128] Lynch, *supra note* 28.
[129] A visualization of the D-Space model is available at their website: http://dspace.org/introduction/dspace-diagram.pdf [26 April 2005].
[130] The could be linked subject domain, level of interest, geography, or combinations.
[131] O'Reilly, Tim (2004). Open source paradigm shift. *O'Reilly Network: Open Source Paradigm Shift*. June 2004. ONLINE. Tim O'Reilly. Available: http://tim.oreilly.com/lpt/a/4868 [13 Mar 2005].
[132] Lougee, *supra note* 20.

There are many proposed models for a new SCS, including e-print repositories for each discipline, free online peer-reviewed articles (e.g. Public Library of Science), self-archiving (e.g. A.M. Odylzko), hybrid journals (e.g. *Science* and Science Online), pure electronic journals (e.g. the now defunct *JEP: Journal of Electronic Publishing,* institutional repositories, and, more recently, a guild model that looks much like institutional repositories, except it may operate at even smaller institutional units.[133] It is not possible at this juncture to judge which models will emerge as the dominant. What we *can* determine are the minimum conditions any successful SCS model must satisfy for the most important stakeholders. A research agenda sensitive to these findings may help produce new guidance for those charged with sustaining the research enterprise.

Given the challenges humanity will face in the decades ahead, poor resource allocation of sub-optimal efficiency in the production scientific and scholarly knowledge is not acceptable. New SCS models should address identifiable weakness of the current system. Along with the financial investments new models will require, they must be sensitive the diverse work practices of various scholars while supporting navigation across disciplinary boundaries. Most importantly, new SCS models must satisfy the minimum conditions.

The main questions for future research raised here relate to exploring these minimum conditions in various contexts and under various conditions. While most of these areas have received some measure of prior attention, additional studies are required, particularly regarding the operations of these minimum conditions under more fully-digital SCS that will support diverse work practices across seemingly dissimilar disciplines.

This overview points toward several areas for future research:

- The minimum conditions approach permits study of disaggregating the SCS functions at the highest possible level, i.e. logically distinguishable core functions. Designing new models within this framework better exposes this potential while perhaps sustaining cross-discipline flexibility scholars require.
- Existing surveys of authors and user-researchers primarily explore perceptions of *status quo* processes and do not reveal their perceptions of optimal configurations. Using minimum conditions as a framework, additional surveys should explore perceptions about pre-figurative alternative SCS models.
- Existing surveys of discipline-specific practices understandable focus on particularities. Surveys that explore these particularities in light the overarching functionalist model might reveal the differing vocabularies and mechanisms used to describe and serve each of the core functions. For instance, surveys of arts and humanities faculty regarding the operations of the 'certification' function could more clearly reveal their unique requirements.[134]
- Existing satisfaction surveys generally measure author or author group perceptions, occasionally editors and reviewers. More research is needed on perceived minimum conditions from the perspective of the user-researchers. For example, there exist no meta-analyses of the various studies of electronic peer review from the standpoint users not authors.
- Putatively generic models are frequently partisan appeals regarding the asserted universality of a favored approach. More rigorous ethnographic studies drawing on diverse populations of scholars should better ensure that emerging models support research across disciplinary boundaries rather than effacing them.
- There exists little empirical research about the motivations for self-archiving or the reasons for variations in this practice across disciplines.

[133] For a discussion of all these models, *see* Kling, Spector, & McKim, *supra note* 21.

[134] 'Certification' or credentialing within the arts and humanities is widely viewed as a limiting factor explaining, in part, their slower adoption of new SCS models.