Encouraging Software Reuse

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Over the last fifteen years, the primary means of legal protection for computer software has shifted from copyright to patent. In this article, Professor Mark A. Lemley and David W. O'Brien argue that one unanticipated benefit of this trend may be to encourage software reuse. They note that computer programmers traditionally reinvent software components, coding each new program from scratch rather than buying and reusing existing components. This inefficient process operates in stark contrast to common practice in other engineering disciplines. Lemley and O'Brien argue that copyright law encourages reinvention and discourages the development of a market for tradeable software components because it allows competitors to appropriate the value of a new software invention without payment to the original inventor, but forbids competitors from copying the computer code implementing that invention. As a result, competitors copy others' inventions and ideas but write their own code to avoid infringing copyright. By contrast, patent protection forces competitors manufacturing any product incorporating the invention to obtain a license from the patent owner. Lemley and O'Brien maintain that the trend toward reliance on patent law may lead to increased licensing of both patented ideas and their implementing code, paving the way for an expansion of trading and reuse of software components.

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It's like musket making was before Eli Whitney. . . . Before the industrial revolution, there was a nonspecialized approach to manufacturing goods that involved very little interchangeability and a maximum of craftsmanship. If we are ever going to lick this software crisis, we're going to have to stop this hand-to-mouth, every-programmer-builds-everything-from-the-ground-up, preindustrial approach.¹

I. INTRODUCTION

Software developers routinely reinvent the software equivalents of the wheel and the transistor every time they develop a new program.² By contrast, more traditional scientific and engineering disciplines, such as mechanical and

1. W. Wayt Gibbs, *Software's Chronic Crisis*, SCI. AM., Sept. 1994, at 86, 87 (quoting Professor Brad J. Cox of George Mason University).

2. Pamela Samuelson, Randall Davis, Mitchell D. Kapor & J.H. Reichman, *A Manifesto Concerning the Legal Protection of Computer Programs*, 94 COLUM. L. REV. 2308, 2322 (1994) [hereinafter *Manifesto*]. The authors of the *Manifesto* explain:

Typically, a programmer writes every line of code afresh, no matter how large the program is, or how common its tasks. To perceive the impact of this lack of standard building blocks, imagine trying to design an entire car in complete detail, down to the last fastener, without being able to assume the existence of any standard parts at all (not even nuts, bolts, or screws). *Id.* (citations omitted). With classic understatement, the authors note that "[t]his is not a desirable state of affairs." *Id.* at 2322 n.41. One cause of this problem is the "not-invented-here" syndrome, which refers to the general unwillingness of software developers to use software components designed and implemented by others. John Favaro, *What Price Reusability? A Case Study*, ADA LETTERS, Spring 1991, at 115, 116. In a Usenet newsgroup discussion about software engineering, one engineer argued that hardware developers may practice a great deal more reuse than software developers, partly because it is not feasible for an electrical engineer designing a circuit board to make his own integrated circuits. Software developers do not encounter these same conceptual barriers to producing new components from scratch: "This lack of conceptual barrier allows software developers to reinvent the wheel very easily, where this is well nigh impossible for the [electrical engineer]." Usenet posting from Martin Vuille to comp.software-eng newsgroup, *Re: Do OO People Really Understand Software Reuse?* ¶ 3 (Jan. 7, 1995) (on file with the *Stanford Law Review*).

electrical engineering, build upon existing components, structures, and methods with attributes and limitations widely known within these fields. These components, structures, and methods are incrementally improved, reused, and improved again in a constant cycle of innovation. As a result, a robust market exists for components such as gears, transistors, and standard cell semiconductor designs, whereas there is currently little, if any, market for software components.³ Many software cost and reliability problems stem from this software reinvention culture. In the words of one computer science professor, software development "needs to become more of an engineering discipline. . . . It's treated too often as an art form"⁴

Economic and historical factors have shaped the development of the current culture in which reinvention prevails over reuse. Because software represented only a small part of early computer systems,⁵ protection of computer software was lax. In fact, computer vendors often treated software as merely incidental to the sale of the "real" product—the hardware.⁶ Although the value of software rose to forty percent of the value of the computer system by the 1960s,⁷ computer manufacturers continued to bundle hardware, software, operating systems, and technical assistance into an integrated package with a single overall price.⁸ "Custom" software for more specific needs was normally developed in-house by the purchasers.⁹

The legal environment has also played a role in cementing the culture of software reinvention. Intellectual property protection for computer software developed slowly, and initially emphasized trade secret laws against misappropriation and copyright prohibitions against the literal copying of computer

3. See Gibbs, *supra* note 1, at 93-94 (characterizing current software development practices as unsystematic and describing a National Institute of Standards and Technology ("NIST") program aimed at developing standards for interchangeable parts); see also *Stitch Ups: Software*, ECONOMIST, Oct. 29, 1994, at 99 (describing the Oct. 24, 1994 NIST announcement of a "five-year, \$150m project to create a software-component industry" including the development of "new 'architectures', 'semantics', and 'formal languages'"). But cf. Keith Stephens & John P. Sumner, *Software Objects: A New Trend in Programming and Software Patents*, 12 SANTA CLARA COMPUTER & HIGH TECH. L.J. 1, 29 (1996) (concluding that existing object-oriented programming techniques allow software engineers to build upon existing modules and components and not reinvent the wheel each time they develop a new program).

4. Andrew Pollack, *Transforming the Decade: 10 Critical Technologies: Software Writing from an Art To a Science*, N.Y. TIMES, Jan. 1, 1991, at 39 (quoting Victor R. Basili, Professor of Computer Science at the University of Maryland).

5. See CHARLES H. FERGUSON & CHARLES R. MORRIS, *COMPUTER WARS: HOW THE WEST CAN WIN IN A POST-IBM WORLD* 7 (1993) ("Only about 8 percent of the value of the earliest systems was accounted for by software.").

6. See Thomas P. Burke, Note, *Software Patent Protection: Debugging the Current System*, 69 NOTRE DAME L. REV. 1115, 1126 (1994) ("Much as car dealers used to throw in floor mats and a full tank of gas, hardware vendors would include the software to make their systems operational.").

7. See FERGUSON & MORRIS, *supra* note 5, at 7.

8. See THOMAS J. WATSON, JR. & PETER PETRE, FATHER, SON, & CO.: MY LIFE AT IBM AND BEYOND 380-81 (1990) (describing IBM's "bundling" in which computer software, hardware, training, maintenance, and technical assistance were all sold for a single price).

9. See Burke, *supra* note 6, at 1126 (explaining that business applications that didn't come bundled with computer hardware were typically written in-house).

code.¹⁰ Trade secret law remained the dominant form of legal protection of software through the mid-1970s.¹¹ Then, in 1980, Congress amended the Copyright Act to expressly include software, and copyright law became the dominant basis for protection throughout the 1980s.¹² More recently, patent law arrived on the software scene.¹³ Although by 1981 court decisions clearly established the patentability of certain software-related inventions,¹⁴ and the U.S. Patent and Trademark Office ("PTO") issued the first widely acknowledged pure software patent in 1983,¹⁵ it has only recently been widely recognized that patent laws can provide protection for computer software.¹⁶

Both trade secret and copyright law offer effective protection for the tangible embodiments of computer software—the computer code itself. However, they both offer only extremely limited protection for the underlying techniques and ideas embodied in the software. For example, the copyright statute specifically excludes from protection "any idea, procedure, process, system, method of operation, concept, principle, or discovery, regardless of the form in which it is described, explained, illustrated, or embodied in such work."¹⁷ Further, both

10. The term "computer code" includes both source (human readable) and object (machine readable) code. For a discussion of the role of trade secret and copyright protections, see text accompanying notes 99-112, 135-161 *infra*.

11. See David Bender, *The More Things Change, the More They Stay the Same: An Unhurried Reflection on Software Protection Over the Years*, 16 RUTGERS COMPUTER & TECH. L.J. 309, 310, 321 (1990) ("In the area of software protection, the 1970s was the decade of trade secret litigation.").

12. See Act of Dec. 12, 1980, Pub. L. No. 96-517, § 10(a), 94 Stat. 3015, 3028 (1980) (codified as amended at 17 U.S.C. § 101 (1994)) ("A 'computer program' is a set of statements or instructions to be used directly or indirectly in a computer in order to bring about a certain result."); see also § 10(b), 94 Stat. at 3028 (codified at 17 U.S.C. § 117 (1994)) (allowing copying of computer programs for archival or use purposes). In addition, the 1976 Copyright Act treated software programs as literary works. Congress enacted an interim section, Pub. L. No. 94-553, ch. 1, § 117, 90 Stat. 2541, 2565 (1976), regarding copyrightability of computer programs pending the outcome of a report by the Commission on New Technological Uses ("CONTU"). H.R. Rep. No. 94-1476, at 54, 116 (1976), reprinted in 1976 U.S.C.A.N. 5659, 5667, 5731.

13. A patent allows its owner to exclude others from making, using, or selling the patented invention in the United States. See 35 U.S.C. § 271(a) (1994). Unlike copyright law, for which mere originality is the threshold requirement, the availability of patent protection is limited by the statutory requirements of novelty and nonobviousness. See 35 U.S.C. §§ 102, 103 (1994).

14. See *Diamond v. Diehr*, 450 U.S. 175, 187, 192-93 (1981) (holding that a process for curing synthetic rubber was patentable subject matter despite use of a mathematical formula and a programmed digital computer); see also *In re Freeman*, 573 F.2d 1237, 1246 (C.C.P.A. 1978) (holding that a computer-based system for typesetting was patentable subject matter despite use of a computer algorithm).

15. See United States Patent No. 4,398,249 (entitled *Process and Apparatus for Converting a Source Program into an Object Program*). The original patent application was filed on August 12, 1970, but the patent was not issued until August 9, 1983.

16. See, e.g., *In re Alappat*, 33 F.3d 1526, 1542-45 (Fed. Cir. 1994) (en banc) (holding that patentability is not precluded even if program includes mathematical subject matter); see also *In re Trovato*, 60 F.3d 807 (Fed. Cir. 1995) (en banc) (per curiam) (vacating and remanding for reconsideration panel decision that rejected patent application for computer process using a mathematical algorithm).

17. 17 U.S.C. § 102(b) (1994). This section codifies what is known as the idea-expression dichotomy. See *Whelan Assocs. v. Jaslow Dental Lab., Inc.*, 797 F.2d 1222, 1234 (3d Cir. 1986) ("The legislative history of this section, adopted in 1976, makes clear that § 102(b) was intended to express the idea-expression dichotomy," cert. denied 479 U.S. 1031 (1987); see also Julie E. Cohen, *Reverse Engineering and the Rise of Electronic Vigilantism: Intellectual Property Implications of "Lock-Out" Programs*, 68 S. CAL. L. REV. 1091, 1136-44 (1995) (explaining how the idea-expression dichotomy evolved in early cases concerning the scope of copyright protection for computer programs).

trade secrecy and copyright law operate to channel innovation in directions which are not always productive from an engineering or economic standpoint.

As a result, from the beginning of the software era and through much of the 1980s, the formative years for many of today's software professionals, copyright and trade secret law defined the rules for software innovation. While new programming structures and techniques spread quickly as programmers moved from job to job,¹⁸ copyright law punished the transfer of actual code implementations of these structures and techniques. Software developers routinely appropriated others' successful software innovations, but the actual code implementing the innovation was a dangerous commodity. Rather than risk liability for copyright infringement, programmers routinely sacrificed the benefits of successive refinements and bug fixes in existing code in favor of recoding the software themselves from scratch.

While we acknowledge the importance of historical and cultural factors that encouraged software reinvention, in this article we focus on the ways in which legal and economic incentives for software innovation influence the tradeoff between reinvention and reuse. We suggest that successful development of a market for reusable software components is most likely under a legal regime which provides strong protection for innovative components but little or no protection for the interoperability elements of programs and the interconnection of components in particular ways. Recent developments suggest that intellectual property law is moving in this general direction, emphasizing strong patent protection for components and weakening copyright protection for program interfaces and interoperability elements. This trend should encourage the development of a reusable software market.

In Part II, we examine the costs associated with software reinvention and evaluate the benefits of software reuse in both internal and external reuse markets. We conclude that software reinvention is generally inefficient. In Part III, we analyze the role of law in shaping the development of the software market. We also examine various possible methods for ensuring adequate economic incentives to invest in reusable software, and provide a brief overview of the legal protections available to computer programs. Finally, in Part IV, we argue that patent protection is better suited than copyright and trade secrecy to a software components-based market. We explore the implications of the current shift from copyright to patent protection in some detail, suggesting how the law might develop to encourage software reuse.

II. SOFTWARE REINVENTION AND REUSE

The terms "software reinvention" and "software reuse" are stylized descriptions of different organizational approaches to software engineering. Software reuse has become a buzz-word in the government-sponsored software commu-

18. See Burke, *supra* note 6, at 1126 ("new programming techniques were quickly spread by employees switching positions").

nity.¹⁹ In addition to a variety of government research and development programs focused on reuse, the federal government recently undertook an ambitious program to create large national software asset repositories,²⁰ and in 1994 the National Institute of Standards and Technology ("NIST") announced a 5-year, \$150 million program to develop a nationwide external market for tradeable software components.²¹

In contrast, the term "software reinvention" tends to represent all that is inefficient and parochial about the software development process of handcrafting solutions. Most people agree with the simplistic assertion that reuse is good and reinvention bad. However, reuse and reinvention are really only polar extremes on a continuum of approaches. In this Part, we attempt to characterize the poles of this continuum and clarify the role that various software innovation incentives play in the reinvention/reuse tradeoff.

A. The Inefficiency of "Reinventing"

Software reinvention unnecessarily incurs substantial costs by duplicating effort and failing to incorporate the lessons of past mistakes and inefficiencies into future software designs and implementations. These costs include both the direct costs of designing, coding, debugging, documenting, and supporting reinvented software, and the indirect costs associated with bugs and interoperability problems. Precise quantification of such costs is nearly impossible,²² but most experts agree that the aggregate costs are substantial.²³ Rough estimates place the annual aggregate cost of reinvention at between \$2 billion and \$100 billion.²⁴

19. See U.S. GOV'T ACCOUNTING OFFICE, PUB. NO. B-251542, *SOFTWARE REUSE: MAJOR ISSUES NEED TO BE RESOLVED BEFORE BENEFITS CAN BE ACHIEVED* 19-20 (1993) [hereinafter *GAO REPORT ON SOFTWARE REUSE*] (discussing a Defense Department software reuse initiative involving three major reuse programs: the Defense Advanced Research Projects Agency's Software Technology for Adaptable, Reliable Systems ("STARS"), the Air Force's Central Archive for Reusable Defense Software ("CARDS"), and the Defense Information Systems Agency's ("DISA") Software Reuse Program).

20. One example is the Asset Source for Software-Engineering Technology ("ASSET"), which is available on the Internet and provides worldwide access to reusable software components. Detailed information describing ASSET resources is available on the World Wide Web. See *ASSET Welcome Page* (last modified Nov. 11, 1996) <<http://source.asset.com/asset.html>>.

21. See *Stitch Ups: Software*, *supra* note 3, at 99 (describing NIST project).

22. See William B. Frakes & Sadahiro Isoda, *Success Factors of Systematic Reuse*, *IEEE SOFTWARE*, Sept. 1994, at 15, 16-17 ("Reliable data on how much this [reuse] costs and the benefits an organization will derive is insufficient."). Even if researchers had access to life cycle financial records for all U.S. software development projects, they would still have difficulty quantifying these costs because of the lack of an adequate control group.

23. See *GAO REPORT ON SOFTWARE REUSE*, *supra* note 19, at 1 (noting that the Department of Defense estimates that creation and upkeep of its software costs more than \$24 billion annually and asserting that software reuse "offers the potential to greatly reduce the time, cost, and effort needed to develop and maintain high quality software").

24. Such qualitative estimates are typically extrapolated from audit data for extremely large-scale software enterprises, which are not necessarily representative of the scale or complexity of the average software system. See, e.g., J. Margono & L. Lindsey, *Software Reuse in the Air Traffic Control Advanced Automation System*, in *PROC. OF THE SYMPOSIUM ON SOFTWARE REUSE & RE-ENGINEERING* (1991). Differences in scale and complexity between software engineering efforts render the accuracy of such extrapolated estimates questionable. See, e.g., Gibbs, *supra* note 1, at 89 (attributing the skyrocketing cost of the new air traffic control system to the need to rewrite code). On the other hand, program-

1. Direct costs of redesign and redevelopment.

While accurate estimation of the direct costs of designing, coding, debugging, documenting, and supporting reinvented software is difficult, we can gain some insight from examining the Federal Aviation Administration's ("FAA") Advanced Automation System ("AAS"). The AAS was the central component of an effort to replace the nation's increasingly obsolete air traffic control system. The software aspect of the program was estimated to require the design and development of more than a million lines of code—much of it complex, real time, safety critical code.²⁵ The FAA originally estimated that the AAS software would cost \$500 per line of code, but in 1994 was actually paying \$700-900 per line.²⁶ As a result, redesigning, recoding, debugging, and documenting even only 10 percent of the AAS code would have cost tens of millions of dollars. These costs are not atypical for large, mission-critical system developments.

Even much smaller consumer-oriented projects, while not involving such extraordinary expenses, incur significant reinvention costs. For example, reuse studies at Hewlett-Packard ("HP") compared the productivity rate of internal software engineering groups before and after the institution of concerted internal software reuse programs.²⁷ The studies found that reuse significantly enhanced programmer productivity. Before instituting the reuse program, HP's Software Technology Division indicated an average productivity rate of 700 noncomment source statements ("NCSS") per engineering month for software developed from scratch. The productivity rate improved to 1100 NCSS per engineering month (a 57 percent increase) when the division implemented the reuse program.²⁸ HP's Technical Graphics Division reported a similar experience.²⁹ For a typical 50,000 NCSS software project, such productivity differences can translate into savings of hundreds of thousands of dollars.³⁰

mers develop most large-scale software systems from detailed design specifications and test plans; these rigorous design techniques may partially offset scale and complexity differences. However, any estimate of the magnitude of such an effect would be entirely speculative. Recognizing these limitations, we present cost estimates here in order to illustrate the character of the problem, not to precisely quantify its scale.

25. See generally Gary Stix, *Aging Airways*, *Sci. Am.*, May 1994, at 96, 99-101 (describing the problems that accompany the \$36 billion AAS revision effort). The FAA announced its abandonment of the AAS project in 1994, but since then has undertaken a more modest project. See Matthew L. Wald, *Flight to Nowhere: A Special Report; Ambitious Update of Air Navigation Becomes a Fiasco*, *N.Y. TIMES*, Jan. 29, 1996, at A1.

26. See Gibbs, *supra* note 1, at 89. Large scale projects such as the AAS typically involve hundreds of thousands of lines of code. See also Mark Lewyn, *Flying in Place: The FAA's Air-Control Fiasco*, *BUS. WK.*, Apr. 26, 1993, at 87 (reporting that AAS is estimated at nearly two million lines of computer code).

27. See Wayne C. Lim, *Effects of Reuse on Quality, Productivity, and Economics*, *IEEE SOFTWARE*, Sept. 1994, at 23 (reporting the results of case studies involving HP's Software Technology and Technical Graphics Divisions).

28. See *id.* at 25, fig. 2.

29. See *id.* (reporting a 40% improvement per engineering month from 500 NCSS for new code to 700 NCSS for a product made up of 31% reused code).

30. For this calculation, we assume that the amount expended by a software company for one programmer in a typical engineering month is \$10,000, including employee benefits and overhead expenses. Programmers producing software at a rate of 700 NCSS per month would require approximately

Today, even consumer products rely on increasing quantities of software. Television sets may incorporate 25,000 lines of software, and even a simple electric shaver can embed 100 lines.³¹ Power trains in new General Motors cars contain roughly 30,000 lines of code.³² Although they are difficult to quantify precisely,³³ the private costs associated with the practice of software reinvention are substantial simply because so much code needs to be rewritten.

2. Indirect costs of reinvention: errors and bugs.

A system that rewards reinvention rather than reuse also has substantial social costs. The social costs incurred by reinvention rather than reuse include the indirect costs imposed by errors and bugs that go undetected after the implementation of a program. Software reinvention imposes indirect and consequential costs because newly created software modules exhibit much higher error rates than software components used multiple times.³⁴ Some of these costs are predictable; the costs of identifying and correcting design and coding errors (bugs) appear privately as increased production costs and are passed on to the public as higher prices. Other costs are not predictable; latent, undiscovered bugs, and the delays associated with identifying and correcting such errors (debugging), can result in consequential losses. For an example of a project paralyzed by bugs, consider Denver's new international airport, which sat idle for sixteen months after its projected opening date due to bugs in its baggage handling software.³⁵ The delay forced the city to pay more than \$1 million per day,³⁶ and in August 1994 Denver decided to install a "temporary backup" conventional conveyor belt system.³⁷ The backup system itself was only semi-operational by January 1995, and estimates of its cost range between \$50 million and \$62.9 million.³⁸ Such monumental waste might not have occurred were it not the program's first run. A more troubling problem is that most

71.4 man-months to complete a 50,000 NCSS software project. At \$10,000 per man-month this translates into a total expenditure of approximately \$714,000. If programmer productivity increases to 1100 NCSS per month, the total cost drops to \$455,000. Thus, productivity differences like those reported by HP would translate into \$259,000 in savings.

31. See Gibbs, *supra* note 1, at 88 (reporting 500,000 bytes for televisions and 2000 bytes for electric shavers). Although the translation from source statements to bytes of executable code may vary greatly depending on the source language, operating environment, and programming style, a reasonable estimate is 20 bytes per NCSS.

32. See *id.*

33. See notes 22-24 *supra* and accompanying text.

34. See Lim, *supra* note 27, at 24 (analyzing software quality improvements associated with reuse).

35. See *Denver Airport Opens*, ARIZ. BUS. GAZETTE, Mar. 2, 1995, at 13; see also, Gibbs, *supra* note 1, at 86 (discussing delays); *Silich Ups: Software, supra* note 3, at 99.

36. See Mark Eddy, *Webb Mum on Opening Till August*, DENV. POST, June 22, 1994, at B1 (explaining that the \$33.3 million per month includes costs of continuing to run Stapleton International Airport).

37. *United to Take over Denver Baggage System*, L.A. TIMES, Aug. 24, 1994, at D2; see also Mark Eddy, *Feb. 28 Opening for DIA? Webb's Fund Plea Says Yes, But Doubt Lingers*, DENV. POST, Jan. 12, 1995, at B1 (describing continuing delays and backup system installation).

38. See Kevin Flynn, *Bag Tests Better Than Expected; Three Hour DIA Trial Indicates Switching Systems Work Properly*, ROCKY MTN. NEWS, Jan. 14, 1995, at 11A (reporting cost of \$62.9 million); *United to Take over Denver Baggage System, supra* note 37, at D20 (reporting cost of \$50 million).

modern safety, energy and transportation systems rely on software. High error rates can be deadly if they are not corrected up front.³⁹

Reinvention incurs these indirect and consequential costs each time programmers craft software from scratch. Describing ongoing problems with the FAA's AAS, an internal report complained that "on average every line of code developed needs to be rewritten once."⁴⁰ Although reused software is by no means bug-free, various studies have shown dramatic reductions in error rates for reused software compared with new code.⁴¹ An advantage of reused software is that bugs which are identified during prior use can be avoided or corrected in subsequent uses. For example, in a 1991 study of software developed by its Flight Dynamics Division, the National Aeronautics and Space Administration's ("NASA") Goddard Space Flight Center reported an 87 percent reduction in error rates when it engaged in a program of software reuse.⁴² HP demonstrated similar reductions, reporting a 76 percent reduction from 4.1 defects per thousand NCSS for newly written code to 0.9 defects per thousand NCSS for reused code.⁴³ Even considering that reused code must be combined with some newly generated code, HP found that defect rates for programs consisting of combined new and reused code were 51 percent lower than for completely new code.⁴⁴ In essence, software reuse allows software developers to capitalize on mature, rather than unproven, designs and implementations.

The problem of errors in software grows at a nonlinear rate as the size and complexity of new software programs increases.⁴⁵ Several studies indicate that smaller programs are less prone to defects than larger ones.⁴⁶ Not only do smaller programs have fewer total defects, but they also have fewer defects per line of code.⁴⁷ It is therefore harder to write a 100,000 line program without defects than it is to write ten 10,000 line programs without defects.⁴⁸ Large new programs thus have two different problems: new code has more errors than reused code, and large programs have more errors per NCSS than small pro-

39. See Evan I. Schwartz, *Trust Me, I'm Your Software*, DISCOVER, May 1996, at 79, 81 (arguing that the solution to the software reliability problem is to "take steps to ensure that the software is right in the first place and to prove that it works mathematically").

40. Gibbs, *supra* note 1, at 89 (quoting the internal FAA report).

41. See, e.g., GAO REPORT ON SOFTWARE REUSE, *supra* note 19, at 6 (reporting the results of a 1991 study by NASA's Software Engineering Laboratory); see also Lim, *supra* note 27, at 24-26 (reporting the results of two HP studies).

42. See GAO REPORT ON SOFTWARE REUSE, *supra* note 19, at 5-6 (reporting a reduction from 3.9 to 0.5 errors per thousand lines of delivered code and hypothesizing that using components increases reliability).

43. See Lim, *supra* note 27, at 24 (reporting results for HP's Software Technology Division).

44. See *id.* (reporting the defect rates when 68% of the software product was reused code).

45. See KEVIN KELLY, *OUT OF CONTROL: THE NEW BIOLOGY OF MACHINES, SOCIAL SYSTEMS AND THE ECONOMIC WORLD 194-95* (1994) (describing the difficulty of controlling complex and unpredictable software systems).

46. See *id.* at 197-99 (citing examples); see also Jay Dratler, Jr., *Microsoft as an Antitrust Target: IBM in Software?*, 25 SW. U. L. REV. 671, 737 (1996) (noting that more complex programs contain greater numbers of errors).

47. See KELLY, *supra* note 45, at 197.

48. For this reason, many programmers advocate the development of smaller "modular" software programs that can be linked together as needed. See *id.* (citing sources). The current popularity of object-oriented programming is one example of this trend. See *id.* at 197-98.

grams.⁴⁹ The current practice of software reinvention is uniquely inefficient because programmers are encouraged to produce monolithic programs containing exclusively new code, rather than reusable, modular programs containing code that was previously written and debugged.

B. Software Reuse

Software reuse involves integrating software engineering artifacts from existing software systems into the design and development of new software.⁵⁰ Such artifacts may include code, system architecture, documentation, user interfaces, and data.⁵¹ Reuse takes two forms: opportunistic reuse and systematic reuse. Opportunistic reuse is the ad hoc practice of salvaging code from existing systems and modifying it to serve the design goals of a new program.⁵² Individuals and small software companies routinely practice opportunistic reuse.⁵³

We will focus primarily on the systematic reuse of software components within and across organizations. Systematic reuse creates new applications from software designed to be incorporated and reused within other similar programs.⁵⁴ Systematic reuse therefore demands that programmers undergo what some authors call a "paradigm shift," from the creation of unitary, autonomous systems to the creation of families of interlocking, related systems.⁵⁵

Systematic reuse can be either internal or external. Large commercial organizations such as AT&T, Digital, HP, IBM, Microsoft, and Motorola already have internal reuse programs in place.⁵⁶ On the other hand, external reuse is uncommon even in large corporations.⁵⁷ If reuse is to occur across and not only within organizations, this new focus must include the development of a market for software components. In the sections which follow, we discuss the benefits and costs of software reuse.

1. Reuse benefits.

Software reuse is no panacea. Indeed, common usage of the term often belies the vast gulf that exists between its promise and actual documented suc-

49. See *id.* at 194-97.

50. See Frakes & Isoda, *supra* note 22, at 15; see also GAO REPORT ON SOFTWARE REUSE, *supra* note 19, at 3.

51. See GAO REPORT ON SOFTWARE REUSE, *supra* note 19, at 2; Capers Jones, *Economics of Software Reuse*, COMPUTER, July 1994, at 106-07 (identifying ten types of software artifacts that can be reused).

52. See GAO REPORT ON SOFTWARE REUSE, *supra* note 19, at 3.

53. See Frakes & Isoda, *supra* note 22, at 15.

54. See GAO REPORT ON SOFTWARE REUSE, *supra* note 19, at 3.

55. See Frakes & Isoda, *supra* note 22, at 15.

56. See *id.* at 16.

57. Software distributed in the Usenet newsgroups comp.sources includes free source code for a vast array of programs written by individuals and placed in the public domain. Nonetheless, the comp.sources archives represent, at best, an ad hoc collection of application source code without maintenance or support. Although some well-written software is available there, generally software in the archives is of poor quality, and sources are rarely updated with refinements made by subsequent users.

cesses.⁵⁸ Nonetheless, systematic software reuse can improve the quality of components, increase the productivity of the creators, and reduce the time to market of the finished product.⁵⁹ It is well known that the quality of code improves over time as bugs in a program are identified and fixed. Reuse facilitates this quality improvement because each piece of code is used over the life of several applications.⁶⁰ Further, computer companies have a greater incentive to catch and remove defects in reusable components, where the cost of debugging is spread over a longer lifetime, than in software that is used once and thrown away.⁶¹ The dramatic reductions in defect rates reported by HP⁶² and NASA⁶³ demonstrate that reuse can improve software quality. Finally, software reuse may improve consumer information in the market for software programs. Because the public over time develops a body of knowledge about the accuracy of a particular program or component, reuse of that program or component allows consumers to apply that knowledge instead of forcing them to learn about an entirely new program with each new generation of software.⁶⁴

Software reuse also improves programmer productivity by reducing the total number of lines that must be coded and by increasing programmers' familiarity with the lines that are written.⁶⁵ HP and NASA reported productivity improvements of roughly 50 percent.⁶⁶ The increased productivity initially results from the fact that companies develop fewer programs from scratch, but extends beyond the coding phase to corresponding improvements in documentation, testing, and maintenance productivity.⁶⁷ Both vertical reuse of software components within a particular department and horizontal reuse of software components across a large number of unrelated projects may reduce aggregate labor costs.⁶⁸ Reuse may also reduce labor costs by encouraging internal specialization or by capitalizing on external specialists as sources of reuse components, since specialization tends to increase efficiency.⁶⁹

58. See Frakes & Isoda, *supra* note 22, at 15 ("The reuse literature is skewed towards reporting successes; failures are largely unreported."); cf. Favaro, *supra* note 2, at 116-17 (describing human and technical difficulties with implementing software reuse).

59. See GAO REPORT ON SOFTWARE REUSE, *supra* note 19, at 5-6 (describing possible improvements available through reuse); see also Lim, *supra* note 27, at 23-24.

60. See Lim, *supra* note 27, at 24.

61. See *id.*; see also Mitchell D. Lubars, *Affording Higher Reliability Through Software Reusability*, ACM SIGSOFT SOFTWARE ENGINEERING NOTES, Oct. 1986, at 39, 41 ("If the original software was developed to be reusable . . . [t]he cost of debugging could be amortized among the various subscribing products.")

62. See text accompanying notes 43-44 *supra*.

63. See note 42 *supra* and accompanying text.

64. See Lim, *supra* note 27, at 23.

65. See *id.* at 25; see also PAMELA SAMUELSON, TOWARD A REFORM OF THE DEFENSE DEPARTMENT SOFTWARE ACQUISITION POLICY 68 (Carnegie Mellon University Software Engineering Institute No. CMU/SEI-86-TR-1, 1986).

66. See Lim, *supra* note 27, at 25. (reporting 40% and 57% improvements in two divisions); see also GAO REPORT ON SOFTWARE REUSE, *supra* note 19, at 6 (reporting a 53% increase in productivity from 12.4 to 19 lines of code per day).

67. See Lim, *supra* note 27, at 25 ("[I]f the reused work products are already documented and tested, the new product requires less work in these areas.")

68. See GAO REPORT ON SOFTWARE REUSE, *supra* note 19, at 4 (describing horizontal use of components, such as sort and merge procedures, which are useful in a wide variety of programs).

69. See Lim, *supra* note 27, at 24-26.

This potential savings in development and testing time not only translates into a reduction in development costs, but also reduces the time-to-market, which is critical to success in the fast-paced software industry. Although few statistics are available, HP's study of reuse in its graphics software division suggested a 42 percent reduction in time-to-market for printer and plotter firmware.⁷⁰

Of course, the aggregated social benefits of software reuse depend on the amount of software reused and on the costs associated with the reuse. David Fisher, director for NIST's software components program, estimates that building only 5 percent of all software from reusable components would save over \$2 billion per year.⁷¹ And whatever the social benefits are, the existence of internal software reuse programs at large commercial organizations such as HP, IBM, and Microsoft suggests that financial incentives for reuse exist at these companies.

2. Reuse costs.

The creation and maintenance of reusable software components is more costly than the creation of ordinary computer programs.⁷² Some of these additional costs result from efforts to create an infrastructure for reuse. Such infrastructure expenses include costs associated with purchasing reusable components from outside a company, establishing libraries and search techniques for cataloging and retrieving components, maintaining and upgrading components, and educating programmers in the culture of reuse.⁷³ However, the most important costs are the incremental costs of creating reusable software components and of integrating reused components into new products. Scholars examining the federal government's AAS reuse program have shown that reusable software components cost about twice as much to create as components that will be thrown away.⁷⁴ Other findings suggest incremental costs for reusable software that are 111 percent to 450 percent of the cost of nonreusable software.⁷⁵ In each case examined, however, the cost of integrating the reusable software component with other software was only a small fraction of the cost of developing and integrating a comparable new component from scratch.⁷⁶ Therefore, although it costs more to create reusable components ini-

70. See *id.* at 26 (reporting development time reduction from 36 to 21 months).

71. See *Stitch Ups: Software*, *supra* note 3, at 99 (quoting David Fisher).

72. See Lim, *supra* note 27, at 24.

73. See *id.* at 24, 26-27.

74. See *id.* at 26; John Margono & Thomas E. Rhoads, *Software Reuse Economics: Cost-Benefit Analysis on a Large Scale Ada Project*, in INTERNATIONAL CONFERENCE ON SOFTWARE ENGINEERING 338, 347 (1992) ("We anticipate that developing reusable software on AAS will cost twice as much as developing non-reusable software.").

75. See Lim, *supra* note 27, at 26 (reporting that reusable graphics firmware costs 111% the cost of nonreusable code in HP's Technical Graphics Division); Favaro, *supra* note 2, at 123 (producing and integrating components costs 120% to 450% of the cost of nonreusable software).

76. See Lim, *supra* note 27, at 26 (stating that the cost of creating software from existing components is only 19% of the cost of reinvention); Margono & Rhoads, *supra* note 74, at 347 ("the benefits of reuse on AAS have so far outweighed the costs"); Favaro, *supra* note 2, at 115 (reuse costs are 10% to 63% of reinvention costs).

tially, overall the savings offered by reusable components outweigh the initial cost.

3. Reuse economics and the producer perspective.

Commenting on the economics of software reuse, Capers Jones of Software Productivity Research, Inc., put it this way:

[C]onsider what these three activities have in common:

- (1) building a 12-meter yacht to compete in the America's Cup,
- (2) building a Formula 1 racing car, and
- (3) building a software order-entry system.

They all cost more than \$1 million and for the same reason: Each is a custom product designed and constructed manually by skilled and highly paid craftsmen.⁷⁷

Jones suggests that significant cost reductions for any of these goods requires that manufacturers use standardized, compatible parts rather than custom software development.⁷⁸ In this section, we explore the incentives for software developers to create an external market for standardized components.

From the perspective of the consumer of reusable software components, the source of software components—internal or external—is largely irrelevant as long as the components are of equal quality. From the perspective of the producer, on the other hand, the incentives to create reusable software differ greatly depending on whether the consumer and the producer are part of the same organization. Reuse costs money and produces assets. The potential market return to such an investment determines whether it is worthwhile for a developer to create a reusable software component.⁷⁹

If the producer of a reusable software component is also the consumer, the organization's economic return for its investment and efforts can be readily quantified. HP, for example, calculated its return on its reuse programs by estimating the stream of benefits generated by a given reusable component, subtracting the stream of associated costs, and determining the present value of the net benefits (or net costs).⁸⁰ HP's results indicate substantial returns for two reported projects, which have generated net present benefits of \$1.6 million and \$0.9 million.⁸¹ The two projects broke even in their second and sixth years, respectively.⁸² These numbers suggest that internal software reuse is viable in some organizations even without an external market for reusable components.⁸³

77. Jones, *supra* note 51, at 106.

78. See *id.*; see also text accompanying notes 1-4 *supra*.

79. See Frakes & Isoda, *supra* note 22, at 17; Lim, *supra* note 27, at 27-28.

80. See Lim, *supra* note 27, at 27 (applying net present value techniques to calculate the economic returns of software reuse).

81. See *id.* (reporting a net present value \$1.6 million return for manufacturing resource planning software reuse components and a net present value \$900,000 return for printer and plotter firmware reuse components).

82. See *id.*

83. Of course, the returns for reusable software written for internal reuse would be even greater if the producer could also obtain payment for external reuse of components.

However, when the producer and consumer of a reusable component are from different organizations, it is more difficult to produce an integrated accounting of costs and benefits. In such a case, the producer must recover costs (including a reasonable return on investment) directly from external purchasers of his components. Since a user can readily copy and distribute components without payment to the original producer, production incentives boil down to methods for physically, electronically, or legally preventing others from appropriating the benefits of a producer's investment.⁸⁴ In Part III, we consider the efficiency of various software innovation incentives.

III. INVESTMENT IN REUSABLE SOFTWARE COMPONENTS

A. The Public Goods Problem

The external market for reusable software components exhibits all the features of a classic "public goods" problem.⁸⁵ Public goods have two distinguishing features that are well described in the economic literature.⁸⁶ First, costs of exclusion are high, so that once the good has been provided it is very difficult to prevent those who do not pay for the good from benefiting from it. Second, consumption of the good is "nonrivalrous," meaning additional consumers of the good do not deplete the quantity available to others, so the normal economics of scarcity do not apply.⁸⁷ Because producers cannot prevent those who do not pay from benefiting from a public good, they will have difficulty collecting payment from consumers. As a result, absent some mechanism for appropriating their value, the private market will tend to undersupply public goods.⁸⁸ In the software context, because the cost of copying or transmitting software from one person to the next is low, it is difficult to prevent rapid and uncompensated dissemination once the software is created and released.⁸⁹ For this reason, software products in general, whether distributed in object-code

84. See Peter S. Menell, *An Analysis of the Scope of Copyright Protection for Application Programs*, 41 STAN. L. REV. 1045, 1059-65 (1989) (assessing the need for legal protection for software by analyzing the effect of contract, anticopying devices, private arrangements, and public funding as incentives for development of public goods).

85. See ROBERT COOTER & THOMAS ULEN, *LAW AND ECONOMICS* 108-12 (1988) (describing the distinction between private goods and public goods).

86. See, e.g., *id.* at 46-48 (identifying nonrivalrous consumption and high costs of exclusion as the distinguishing characteristics of a public good).

87. See *id.*

88. See PAUL A. SAMUELSON & WILLIAM D. NORDHAUS, *ECONOMICS* 49 (12th ed. 1985) ("Private provision of these public goods will not occur because the benefits of the goods are dispersed so widely across the population that no single firm or consumer has an incentive to provide them.").

89. The same reasoning that Professor Menell used for application programs applies to software generally:

[T]he information comprising innovation in application programs is a prime example of a public good. Given the ease and low cost of copying application programs, it is often impossible to exclude nonpurchasers from an application program's benefits once it is commercially available. Moreover, one person's use of the information does not detract from others' use of that same information. Since application program creators cannot reap the marginal value of their efforts under these circumstances, they will, in the absence of other incentives, tend to undersupply new and better application programs.

Menell, *supra* note 84, at 1059 (citations omitted). Today, complete software libraries can be transmitted around the globe in a matter of seconds.

(computer readable) or source-code (human readable) format, raise substantial public goods issues.

The public goods problem is not unique to the software industry; all developers of intellectual property face the same problem. However, a viable market in reusable components must overcome additional barriers to induce a switch from production of traditional software programs. To the extent that reusable components cost more to develop than comparable, nonreusable programs,⁹⁰ producers must be able to recoup that additional cost if they are to have any incentive to invest in reusable rather than traditional programs. Further, because selling components in source code form to a potential competitor is riskier than selling a complete program in object code form to end users,⁹¹ software developers must have some incentive to sell components rather than full programs.

Because reusable components are designed to be transmitted to intermediary developers who incorporate them as building blocks into a wide variety of software systems marketed to end users, their risk of appropriation may be higher than the risk for ordinary custom or mass market software. Specifically, the risk is greater that a sophisticated software company will incorporate the component into its own integrated program, or alternatively that it will duplicate the component for resale to other integrators.⁹² This is particularly true if the component is given to purchasers in source code as well as object code form. Purchasers who receive the components in source code can adapt the components to make them work well with other components.⁹³ Therefore, absent mechanisms that prevent unauthorized users from appropriating the benefits of a software producer's investments, a rational producer will not invest in creating components for external use because he will be unable to recoup his investment.⁹⁴

90. See notes 74-75 *supra* and accompanying text.

91. Most mass market software producers distribute their programs in object code form, which makes it difficult for competitors or subsequent users to read or modify the program. To do so, a user must first reverse engineer the object code into some reasonable approximation of source code. This is a difficult and time consuming process. See Andrew Johnson-Laird, *Reverse Engineering of Software: Separating Legal Mythology From Actual Technology*, 5 SOFTWARE L.J. 331, 342-43 (1992) ("[D]eciphering computer-executable programs is extremely tedious and error prone"). Programs distributed in source code, however, can be easily read and modified. The risk with software components is that the competitor will make unauthorized use of source code. While it is possible that purchasers will make unauthorized use of object code as well, it is easier to convert source code into new programs than it is to adapt or reverse engineer object code.

92. By contrast, other types of appropriation are more difficult with software components than with integrated systems. It is less likely that purchasers will casually copy the component on a small-scale basis, since a free-standing component has no utility unless it is integrated into a software system.

93. For example, consider programs written in a language like Java script. "[S]oftware that is embodied either in scripts or in at least some interpreted language does not have a separate 'machine-readable' form. Thus, the developer cannot deliver a completed project without revealing the source materials for this type of software." Hank Barry, *The Deal Corner*, CYBERSPACE LAW., May 1996, at 19, 20.

94. Cf. Janusz A. Ordover, *Economic Foundations and Considerations in Protecting Industrial and Intellectual Property*, 53 ANTITRUST L.J. 503, 505-06 (1985) (discussing problems of appropriability when costly information is easily and quickly replicated).

To be sure, certain producers may be able to recoup their investment in reusable components wholly through internal reuse. Indeed, factory scale software enterprises such as Microsoft and HP, which have ongoing internal reuse programs, appear to be doing just that.⁹⁵ However, given the dearth of components on the external market, it appears that producers find sales or licensing of components outside the firm unprofitable in the current legal environment. Even producers with large internal reuse programs, for whom the marginal costs of marketing already developed components externally would be small, generally do not sell their components outside the corporation.

Finally, other concerns may make producers hesitant to market software components even after they have been developed. In particular, the potential for tort liability may have a chilling effect on the external reuse market.⁹⁶ Producers may also believe that sales and licensing will lead to loss of trade secrets or other proprietary information.⁹⁷ However, many reusable components involve no proprietary information of any kind (aside, of course, from the intellectual property in the component itself). For example, a software component which maintains a linked list of generic data structures and manipulates these lists typically contains no proprietary information and is of well-known design.⁹⁸ While a potentially broad external market exists for such a component, programmers routinely code, debug, and test linked list software from scratch. Indeed, one of the authors estimates that he has coded such software from scratch five to ten times during his career as an engineer.

The rest of this article will focus on the incentives for external software reuse. We consider two approaches to enabling producers of reusable software components to recoup their investments: (1) those based on *de facto* or *de jure* restrictions on access to the software and (2) those premised on dissemination of the software under protection of the federal intellectual property laws.

B. Access Restrictive Methods for Appropriating Returns

Conceptually, the simplest way to prevent unauthorized users from appropriating the benefits of a producer's investment in a component is to keep the component secret. Secrecy is relatively easy to achieve for a producer of components for internal reuse, since the source code does not leave the company. By contrast, disseminating components for external reuse creates a risk of appropriation by nonpaying users. Trade secrecy, encryption, and to a lesser ex-

95. See Frakes & Isoda, *supra* note 22, at 16.

96. See GAO REPORT ON SOFTWARE REUSE, *supra* note 19, at 13 (stating that the uncertain extent of software producers' liability for harm attributable to software components is a major concern of software companies). There is a large market for standard electronic and mechanical hardware components which are used in life/safety critical systems, however, and it is hard to imagine why a similar market could not develop in software.

97. The fear that collateral proprietary information will be lost is distinguishable from the fear that the component itself will be copied. The latter problem is discussed in notes 89-94 *supra* and accompanying text.

98. For a discussion of linked list data structures, see Marci A. Hamilton & Theodore M. Sabety, *Computer Science Concepts in Copyright Cases: The Path to a Coherent Law*, 11 HARV. J.L. & TECH. (forthcoming 1997).

tent, first mover advantages each restrict access (either physically, electronically, contractually, or *de facto*) and therefore potentially limit the risk of appropriation by nonpaying users.

1. Trade secret protection.

Unlike patents and copyrights, which are controlled by federal law, trade secrets are governed by the laws of the individual states. Despite this potential for variation among states, modern trade secret law is relatively uniform because its development has been dominated by two major sources, the Restatement of Torts⁹⁹ and the Uniform Trade Secrets Act.¹⁰⁰ Under the Uniform Act,

"Trade secret" means information, including a . . . program . . . that . . . derives independent economic value, actual or potential, from not being generally known to, and not being readily ascertainable by proper means by, other persons who can obtain economic value from its disclosure or use, and . . . is the subject of efforts that are reasonable under the circumstances to maintain its secrecy.¹⁰¹

The Restatement definition, adopted by courts in a number of states, differs primarily in its requirement that the confidential information be in "continuous use" in the trade secret owner's business.¹⁰²

In either case, it is well established that trade secret law protects the secrets contained in a software program from misappropriation, provided the source code remains secret.¹⁰³ Once the information contained in the software becomes common knowledge to those programmers for whom it has economic value, it ceases to be a trade secret.¹⁰⁴ Therefore, software may not be freely disseminated as source code and still retain its trade secret protection.¹⁰⁵ In

99. See generally RESTATEMENT OF TORTS §§ 757-58 (1939) (setting forth the basic principles of trade secret law).

100. See UNIF. TRADE SECRETS ACT § 1 (amended 1985), 14 U.L.A. 438 (1990). Forty states and the District of Columbia have enacted the Uniform Trade Secrets Act in one form or another. See 14 U.L.A. 433 (Supp. 1996) (listing jurisdictions where the act has been adopted). United States participation in bilateral and multilateral agreements also encourages trade secret uniformity by obligating the United States to provide a minimum level of trade secret protection nationwide. See, e.g., GATT Agreement on Trade-Related Aspects of Intellectual Property Rights Including Trade in Counterfeit Goods, 33 I.L.M. 84, 98 (Dec. 15, 1993) (providing for the legal protection of "undisclosed information"); *Litton Sys. v. Sangyong Cement Indus. Co.*, No. C-89-3832 VRW, 1993 U.S. Dist. LEXIS 12198, at *1-2 (N.D. Cal. Aug. 19, 1993) (implying a federal trade secret cause of action under Lanham Act Section 44 in order to comply with United States treaty obligations to South Korea), *dismissed by agreement of parties* 1996 U.S. App. LEXIS 8445 (Fed. Cir. Mar. 26, 1996). Finally, in 1996 Congress passed a federal criminal trade secrets statute. 18 U.S.C. §§ 1831-39 (1996).

101. UNIF. TRADE SECRETS ACT § 1(4) (amended 1985), 14 U.L.A. 438 (1990) (emphasis added).

102. See RESTATEMENT OF TORTS § 757, cmt. b (1939) ("A trade secret may consist of any formula, pattern, device, or compilation of information which is used in one's business, and which gives him an opportunity to obtain an advantage over competitors who do not know or use it. . . . [I]t is not simply information as to single or ephemeral events . . . but rather a trade secret is a process or device for continuous use in the operation of the business.").

103. See, e.g., DONALD S. CHISUM & MICHAEL A. JACOBS, UNDERSTANDING INTELLECTUAL PROPERTY LAW § 3C(1) (1992).

104. See note 101 *supra* and accompanying text.

105. *Bur. of Data Gen. Corp. v. Digital Computer Controls Corp.*, 297 A.2d 433, 436 (Del. Ch. 1971) (holding that a company which distributed multiple copies of its program was allowed to protect

order to maintain its trade secret status, access to source code must be restricted, whether physically, by contract, or by a duty of confidentiality.¹⁰⁶

Physical control over the code is impractical if producers of reusable components ultimately want to sell (or license) their components to software developers for incorporation in applications and systems. They must reveal their source code to facilitate such incorporation.¹⁰⁷ Distribution of components in object code format, when viable,¹⁰⁸ may preserve the secrecy of the underlying source code, particularly if the code is accompanied by enforceable contractual restrictions on reverse engineering and disclosure of the trade secrets contained in the code. In *Data General Corp. v. Grumman Systems Support Corp.*,¹⁰⁹ the court held that the contents of a computer program distributed only in object code format were protectable trade secrets.¹¹⁰

Reverse engineering a publicly distributed product to identify the secrets contained therein does not violate the trade secret laws.¹¹¹ Instead, it is usually considered proper to use reverse engineering techniques to regenerate source code from the distributed object code. Despite popular misconceptions, however, software reverse engineering methods are time-consuming and labor-intensive.¹¹² As a result, distribution in object code format, if feasible, does provide the producer with some level of confidence that source code will remain a trade secret.

Trade secret protection does not enable a component producer to fully appropriate the benefits of his investment for three reasons. First, under *Data General* the authorized distribution of object code does not itself disclose trade secrets contained therein. Unauthorized further distribution of the object code

the program code as a trade secret, where each of the recipients was in a contractual relationship with the vendor), *aff'd*, 297 A.2d 437 (Del. 1972).

106. *See id.*

107. *See* note 93 *supra*. Electronic security via encryption is an alternative to physical security. Some have even suggested that encryption will make intellectual property obsolete as a means for defining property rights in cyberspace. However, encryption of a program is only of limited value to vendors of software components, since purchasers must be able to decrypt the program; the purchasers are then able to misappropriate the decrypted program. We discuss this issue in more detail in the next section.

108. Computer programs are typically distributed to customers only as machine readable object code, while human readable source code is retained by the developer. Statically linkable and dynamically linkable libraries are good examples of reusable software components that might be distributable in object code form.

109. 825 F. Supp. 340 (D. Mass. 1993), *aff'd*, 36 F.3d 1147 (1st Cir. 1994).

110. *See id.* at 359 (holding that distribution in object code successfully preserved secrecy, and therefore trade secret status). *But see* *Trandes Corp. v. Guy F. Atkinson Co.*, 996 F.2d 655, 663 n.8 (4th Cir. 1993) (noting that widely distributing object code destroys trade secrecy of the object code, even though the secrecy of the source code may remain intact).

111. According to the Uniform Trade Secrets Act, proper means includes:

[d]iscovery by "reverse engineering", [sic] that is, by starting with the known product and working backward to find the method by which it was developed. The acquisition of the known product must, of course, also be by a fair and honest means, such as purchase of the item on the open market for reverse engineering to be lawful.

UNIF. TRADE SECRETS ACT § 1 cmt. (amended 1985), 14 U.L.A. 438 (1990).

112. *See* Johnson-Laird, *supra* note 91, at 343 (explaining that reverse engineering techniques require up to a minute to decipher a single computer instruction and that a typical program may contain hundreds of thousands of instructions); *Manifesto*, *supra* note 2, at 2389 n.333 (explaining that purchasers are free to decompile a product containing a software innovation but decompilation is difficult and time-consuming).

by others therefore does not "misappropriate" those trade secrets, which remain undisclosed.¹¹³ To protect the object code itself against further copying and distribution, the component producer must either rely on the federal copyright laws or create separate contractual restrictions on dissemination.¹¹⁴

Second, because programmers must integrate many components into a larger system, distribution of only the object code of a component may not be a feasible alternative. Unlike complete software systems, where the purchaser is generally an end user who simply wants the program to work, many software components must come with "assembly instructions" to be fully useable. As a general matter, this means that some source code will have to be distributed along with the component.

Finally, disclosure of a trade secret to the public—for example by placing it on the Internet—forever destroys the secrecy of the program.¹¹⁵ Thus, widespread distribution of a computer program under an assumption of secrecy is fragile protection indeed. One significant act of misappropriation can destroy the secret by exposing it to the entire consuming public. While the trade secret owner will likely have a cause of action against the person who discloses the program, that fact may provide small solace for the loss of the secret itself.

2. Encryption.¹¹⁶

Of late, two very popular topics of discussion in certain circles on the Internet have been encryption technology and the undesirability of using patent and copyright law to cover software and digital works. Some have even synthesized the two, suggesting that encryption, or "crypto-bottling," replace patent and copyright as the means for defining intellectual property rights in cyberspace.¹¹⁷ We argue that while cryptography is extremely useful in estab-

113. Under the Uniform Trade Secrets Act, "misappropriation" is defined as: acquisition of a trade secret of another by a person who knows or has reason to know that the trade secret was acquired by improper means; or . . . disclosure or use of a trade secret of another without express or implied consent by a person who . . . used improper means to acquire knowledge of the trade secret . . .

UNIF. TRADE SECRETS ACT § 1(2) (amended 1985), 14 U.L.A. 438 (1990) (emphasis added). "'Improper means' includes theft, bribery, misrepresentation, breach or inducement of a duty to maintain secrecy, or espionage through electronic or other means." *Id.* § 1(1), 14 U.L.A. 437; *see Trandes Corp.*, 996 F.2d at 660 ("The significant difference of fact between trade secrets and processes or devices which are not secret is that knowledge of the latter is available to the copier without the use of improper means to procure it, while knowledge of the former is ordinarily available to him only by the use of such means.").

114. For an example of the latter approach, see *ProCD, Inc. v. Zeidenberg*, 86 F.3d 1447 (7th Cir. 1996) (holding that a telephone directory publisher could protect its noncopyrightable database with a shrinkwrap license). For further discussion of contract protection, see note 279 *infra* and accompanying text.

115. *See, e.g., Religious Technology Ctr. v. Lerma*, 908 F. Supp. 1362, 1368 (E.D. Va. 1995) ("Once a trade secret is posted on the Internet, it is effectively part of the public domain, impossible to retrieve.").

116. Encryption is a process whereby data, including software programs, are encoded so as to be unreadable without the appropriate decoding key. *See* A. Michael Fromkin, *The Metaphor is the Key: Cryptography, the Clipper Chip, and the Constitution*, 143 U. Pa. L. Rev. 709, 718-64 (1995) (explaining encryption and its various uses).

117. *See, e.g., John P. Barlow, The Economy of Ideas: A Framework for Rethinking Patents and Copyrights in the Digital Age (Everything You Know About Intellectual Property Is Wrong)*, WIRED,

lishing security barriers to unauthorized access, it is not a new paradigm destined to supplant intellectual property law. Rather, it simply establishes more effective barriers to reverse engineering (decryption) than does embedding a program in object code. Even assuming that it provided perfect security, which it does not, encryption merely shifts the focus of trade secret misappropriation to the end user. Software components must be decrypted to be valuable to purchasers and end users of an integrated software system. While encryption better protects against unauthorized access to the component, it can not prevent unauthorized use or disclosure of the encrypted ideas by those who have legitimately acquired and decrypted them.

3. First mover advantages.

Innovators who are first to market often enjoy substantial advantages over later imitators even when access is not physically, electronically, or legally restricted.¹¹⁸ This first mover advantage is not premised on any direct effort to restrict access to proprietary information; it results from practical limitations on access and delays associated with incomplete knowledge. Empirical data shows that such first mover advantages function as innovation incentives. For example, one study of large corporations in various industries concluded that head start advantages, including the establishment of production and distribution facilities, was more effective than the use of patents in enabling firms to reap returns from innovation.¹¹⁹ In fact, Nancy Dorfman argues that first mover advantage has been the primary reason for innovation in the computer and semiconductor industries.¹²⁰

The first mover advantage is not as great a factor in the production of software components for external reuse markets as it is in the software industry more generally. The magnitude of first mover advantages in an industry is directly related to the cost of transmitting an innovation to others.¹²¹ Low transmission costs allow first mover advantages to dissipate quickly, while high transmission costs allow a first innovator to appropriate much of the value of his innovation.¹²² Software copying, particularly exact duplication of object

Mar. 1994, at 84, 129 (suggesting that "Crypto Bottling" will replace patent and copyright as a means of intellectual property protection in the digital age); David Friedman, *A World of Strong Privacy: Promises and Perils of Encryption*, 13 Soc. Phil. & Pol'y 212, 220 (1996).

118. Strictly speaking, this is not an "access-restrictive" method of appropriating returns. We have placed the first mover advantage in this category, however, because it depends on competitors' inability to discover and duplicate an innovation in a short period of time.

119. Richard C. Levin, Alvin K. Klevorick, Richard R. Nelson & Sidney G. Winter, *Appropriating the Returns from Industrial Research and Development*, 1987 BROOKINGS PAPERS ON ECON. ACTIVITY 783, 815-16 (concluding that the patent system and related institutions "improve the appropriability of returns from innovation," but "are not the only nor necessarily the primary barriers that prevent general access to what would otherwise be pure public goods"); see also Edwin Mansfield, *Patents and Innovation: An Empirical Study*, 32 Mon. Sci. 173, 176 (1986) (examining the extent to which various firms and industries rely on the patent system to protect their innovations).

120. See NANCY S. DORFMAN, *INNOVATION AND MARKET STRUCTURE: LESSONS FROM THE COMPUTER AND SEMICONDUCTOR INDUSTRIES* 235-39 (1987).

121. See Ordover, *supra* note 94, at 505-06 (discussing the effect of transmission costs on appropriability).

122. See *id.*

code, is quick and easy. The first mover advantage is therefore probably less significant in the software industry than in the stable industries in which survey data has typically been gathered.

A related problem in markets characterized by rapid technological change is the ability of an imitator to incorporate a rival's innovations into its own leapfrogging innovations.¹²³ The software industry is made up of a small number of dominant firms, such as Microsoft and IBM-Lotus, and a large number of comparatively small firms.¹²⁴ This market structure places dominant firms, with their large development, marketing, and distribution resources, in a strong position to imitate and capitalize at a worldwide level on the innovations of their smaller rivals.¹²⁵

Further, a market for commodity-type software components is likely to develop around the attributes of durability and reliability. These attributes require repeated use and testing of the component over time. Copying of a successful component can prevent its developer from recouping additional money invested in such long-term attributes. Thus, an external market for reuse is even more vulnerable to rapid imitation than the traditional software market.

From a software reuse perspective, the first mover advantage appears to create incentives for *internal* software reuse. Organizations striving to be first to market will attempt to build on proven software implementations, rather than incur the delays and risks associated with developing code from scratch. The development of extensive internal reuse programs at AT&T, Digital, HP, IBM, Microsoft, and Motorola supports this conclusion.¹²⁶ It is less likely, however, that first mover advantages will result in significant dissemination of software components in the external reuse market; indeed, it is likely that producers perceiving an opportunity to exploit first mover advantages will develop software components for internal reuse and attempt to protect those components as trade secrets. By encouraging a short-run focus, first mover advantage, like trade secret and encryption, may encourage the climate of reinvention.

4. Disadvantages of access restrictive approaches.

A principal drawback associated with trade secret, encryption, and first mover advantages is the high risk that these access restrictions will fail. Trade secrecy may be lost through reverse engineering or unlawful dissemination by a

123. See Joseph Kattan, *Antitrust Analysis of Technology Joint Ventures: Allocative Efficiency and the Rewards of Innovation*, 61 ANTITRUST L.J. 937, 942-43 & n.32 (1993) ("imitators can incorporate rivals' innovations in their own innovations that leapfrog the originators' technological advantage").

124. See JOYCE PLOTKIN, MASSACHUSETTS COMPUTER SOFTWARE COUNCIL, INC., *SOFTWARE INDUSTRY BUSINESS PRACTICES SURVEY* 8, 9 (1991) (75% of software firms have fewer than 100 employees and 49% have less than 30).

125. See Kattan, *supra* note 123, at 943 (citing William L. Baldwin & Gerald L. Childs, *The Fast Second and Rivalry in Research and Development*, 36 S. ECON. J. 18, 21 (1969), for the proposition that first mover advantage may not necessarily hold for markets in which dominant firms are well situated to enter quickly with imitations of smaller rivals' innovations).

126. See Lim, *supra* note 27, at 26 (noting time to market advantages associated with software reuse); Frakes & Isoda, *supra* note 22, at 15-16 (listing companies that have implemented software reuse programs to gain competitive advantage).

judgment-proof defendant. Even if a solvent defendant can be identified, proving loss from dissemination of a secret on the Internet to recover consequential damages may be a daunting task. Encryption algorithms may be "cracked,"¹²⁷ or a program may be disseminated after authorized decryption. First mover advantages may be unsustainable and can be lost through reverse engineering. In each of these cases, once disclosed, the secret cannot be retrieved from the public domain.

Access-restrictive approaches are also problematic from a social perspective because they disfavor dissemination of technical ideas. Progress in computer science, the useful arts, and programming, as in other fields, depends on the ability of innovators and researchers to build up on earlier advances. Sir Issac Newton made this observation in a letter to a friend: "If I have seen further it is by standing on ye shoulders of Giants."¹²⁸ Unlike copyright and patent law, which encourage dissemination¹²⁹ and contain mechanisms for separating out portions of the disseminated material as unprotected,¹³⁰ access restrictive approaches encourage secrecy. Dissemination is antithetical to the goals of trade secret law and encryption. Finally, secrecy is largely incapable of differentiating between that which must be protected to ensure that the component developer retains control of his innovation and that which need not be. Thus, it may encourage *too much* secrecy.¹³¹

C. Exclusive Rights Under the Federal Intellectual Property Laws

Intellectual property protection presents an alternative method of solving the public goods problem presented by reusable software components. By providing a limited opportunity for exclusive control over products, intellectual property protection enhances the expected reward to those who create protected works.¹³² At the same time, the law requires public disclosure and registration. This economic incentive fosters a climate of innovation and product develop-

127. See Steven Levy, *Wisecrackers*, WIRED, Mar. 1996, at 128, 128 (suggesting that encryption algorithms are more vulnerable to attack than previously supposed).

128. ROBERT K. MERTON, ON THE SHOULDERS OF GIANTS: A SHANDEAN POSTSCRIPT 31 (1965) (quoting Feb. 5, 1675/1676 letter from Sir Isaac Newton to Robert Hooke); see *Lotus Dev. Corp. v. Paperback Software Int'l*, 740 F. Supp. 37, 77 & n.3 (D. Mass. 1990) (commenting on the "on the shoulders of giants" principle in relation to software).

129. Copyright law encourages dissemination through publication. See Robert A. Kreiss, *Accessibility and Commercialization in Copyright Theory*, 43 UCLA L. Rev. 1, 4-5 (1995). Patent law requires disclosure by the inventor to the public sufficient to enable one skilled in the art to which it pertains to make and use the invention. See 35 U.S.C. § 112 (1994).

130. Under copyright law only expression is protected; ideas may be freely copied. Patent law distinguishes between the claimed subject matter (which is protected) and the subject matter disclosed but not claimed (which is donated to the public domain). See *Maxwell v. J. Baker, Inc.*, 86 F.3d 1098, 1106-08 (Fed. Cir. 1996) (holding that matter disclosed in a patent but not claimed is dedicated to the public).

131. See Edmund W. Kitch, *The Law and Economics of Rights in Valuable Information*, 9 J. LEGAL STUD. 683 (1980).

132. See Menell, *supra* note 84, at 1059. ("Enhancing the scope of intellectual property protection (by increasing the duration or breadth of production) increases the expected reward to those engaged in intellectual work by enhancing the opportunity for monopolistic exploitation of any products created.")

ment.¹³³ Patent and copyright law are the principal sources of intellectual property rewards for software, although trade secret law may also play an important role.¹³⁴

1. Copyright law.

Copyright subsists in "original works of authorship," including computer software, which are "fixed in any tangible medium of expression."¹³⁵ Copyright protection arises automatically upon fixation of the work on paper, magnetic tape, magnetic disk, semiconductor chip or any other permanent medium. The work must be original to the author,¹³⁶ but copyright protection does not require that a work be novel or that it be a substantial change from what was done before.¹³⁷ Moreover, copyright, unlike patent, does not require government examination or approval. The owner of a copyrighted work has the exclusive right to reproduce the work and to prepare derivative works therefrom (or authorize others to do the same).¹³⁸

Because patent and trade secret law have traditionally been associated with utilitarian works, the historical view of copyright law as the proper means of protecting computer software is somewhat surprising. Copyright law protects only the *expression* of a particular idea, not the idea itself.¹³⁹ The Copyright Act specifically excludes from protection "any idea, procedure, process, system, method of operation, concept, principle, or discovery."¹⁴⁰ The scope of copyright protection for software has ebbed and flowed over the years. In its report on software reuse, the General Accounting Office cited the uncertain scope of copyright protection for software components as a major impediment to cooperation among suppliers, repositories, and users of reusable software components.¹⁴¹

Software copyright infringement law has developed over several generations of cases, each redefining the scope of copyright protection for elements of program code.¹⁴² The first generation of cases established that direct copying

133. See *id.* ("These increased rewards encourage inventive activity, which in turn spurs the discovery of new and better products."); see also Louis Kaplow, *The Patent-Antitrust Intersection: A Reappraisal*, 97 HARV. L. REV. 1813, 1823-24 (1984).

134. See notes 99-115 *supra* and accompanying text (discussing trade secret law).

135. 17 U.S.C. § 102(a) (1994).

136. See *Feist Publications, Inc. v. Rural Tel. Serv. Co.*, 499 U.S. 340, 437-49 (1991) (mandating originality as a prerequisite for copyright protection).

137. See *CHISUM & JACOBS*, *supra* note 103, § 1B[3].

138. See 17 U.S.C. § 106(1)-(2) (1994).

139. See *Mazer v. Stein*, 347 U.S. 201, 217 (1954) (construing *Baker v. Selden*, 101 U.S. 99 (1879)); 1 MELVILLE B. NIMMER & DAVID NIMMER, *NIMMER ON COPYRIGHT* (1996) § 2.03[D], at 2-34 to -35.

140. 17 U.S.C. § 102(b) (1994).

141. See GAO REPORT ON SOFTWARE REUSE, *supra* note 19, at 12-13 ("[A] major challenge facing software reuse is to balance these [intellectual property] rights between software suppliers, repositories, and users.")

142. For a more detailed discussion of this historical development, see Mark A. Lemley, *Convergence in the Law of Software Copyright?*, 10 HIGH TECH. L.J. 1 (1995).

of the precise coding of computer software constituted infringement.¹⁴³ Under this line of cases, copyright protection extended to only an innovator's specific implementation of a software component in code. The innovator could prohibit others from directly copying that code, but not from duplicating organization or programming techniques.

*Whelan Associates v. Jaslow Dental Laboratories*¹⁴⁴ ushered in a second generation of cases in which courts began to protect application program code on the basis of nonliteral infringement—the duplication of a program's organization without the literal copying of any significant portions of the code.¹⁴⁵ The *Whelan* court adopted an expansive definition of expression within the structure, sequence, and organization of a computer program.¹⁴⁶ The court reasoned that "everything that is not necessary to the purpose or function [of a utilitarian work] would be part of the [protectable] expression."¹⁴⁷ This broad scope of protection conflicted with the Copyright Act's express prohibition of copyright for ideas, procedures, processes, systems, methods of operation, concepts, principles, and discoveries,¹⁴⁸ and most commentators criticized *Whelan's* extension of copyright scope as inconsistent with the statute.¹⁴⁹

More recently, in the third generation of software copyright cases, courts have refused to apply the *Whelan* standard. Led by *Computer Associates International v. Altai, Inc.*¹⁵⁰ in 1992, these courts have advanced a much narrower "abstraction-filtration-comparison" test to determine whether two programs are substantially similar.¹⁵¹ The *Altai* analysis limits the scope of copyright protection of nonliteral expression by requiring that elements of the program that are dictated by efficiency or external factors and elements taken from the public

143. See, e.g., *Apple Computer, Inc. v. Franklin Computer Corp.*, 714 F.2d 1240, 1253 (3d Cir. 1983); *Williams Elec., Inc. v. Artic Int'l, Inc.*, 685 F.2d 870, 877 (3d Cir. 1982). Unauthorized, direct copying of computer code, in whole or in part, constitutes literal infringement of the copyright holder's exclusive rights to reproduce the copyrighted work and to prepare derivative works based on the copyrighted work. See 17 U.S.C. § 106 (1988).

144. 797 F.2d 1222 (3d Cir. 1986).

145. See *id.* at 1248 ("copyright protection of computer programs may extend beyond the programs' literal code to their structure, sequence, and organization").

146. See Lemley, *supra* note 142, at 10-12; Menell, *supra* note 84, at 1074 (examining the *Whelan* court's expansive view).

147. *Whelan*, 797 F.2d at 1236.

148. See 17 U.S.C. § 102(b) (1994).

149. See, e.g., 3 NIMMER & NIMMER, *supra* note 139, § 13.03[A][1][d], at 13-45 to -48; Menell, *supra* note 84, at 1074, 1082; Steven R. Englund, Note, *Idea, Process, or Protected Expression?: Determining the Scope of Copyright Protection of the Structure of Computer Programs*, 88 MICH. L. REV. 866, 881 (1990); Thomas M. Gage, Note, *Whelan Associates v. Jaslow Dental Laboratories: Copyright Protection for Computer Software Structure—What's the Purpose?*, 1987 WIS. L. REV. 859, 860-61, 881, 884, 891-93; Mark T. Kretschmer, Note, *Copyright Protection for Software Architecture: Just Say No!*, 1988 COLUM. BUS. L. REV. 823, 837-39; Peter G. Spivack, Comment, *Does Form Follow Function?: The Idea/Expression Dichotomy in Copyright Protection of Computer Software*, 35 UCLA L. REV. 723, 747-55 (1988); cf. Pamela Samuelson, *CONTU Revisited: The Case Against Copyright Protection for Computer Programs in Machine Readable Form*, 1984 DUKE L.J. 663, 732-36 (arguing that copyright should not protect computer programs).

150. 982 F.2d 693 (2d Cir. 1992).

151. See *id.* at 706 ("We think that *Whelan's* approach to separating idea from expression in computer programs relies too heavily on metaphysical distinctions and does not place enough emphasis on practical considerations.").

domain be filtered out.¹⁵² Virtually all courts issuing opinions in software copyright cases since 1992 have followed *Altai*.¹⁵³ However, while courts agree on using the *Altai* test, they do not always agree on how to apply that test.¹⁵⁴

Courts and litigators also disagree about whether copyright law prevents reverse engineering by a competitor in order to develop compatible systems. One early case held that a user could not justify copying a copyrighted program in order to achieve compatibility with that program.¹⁵⁵ More recently, however, courts have been uniformly receptive to arguments that copying certain portions of copyrighted programs is justified either to reverse engineer the program or to build interoperable programs.¹⁵⁶

A final set of disagreements over software copyright law came to the fore in 1995, when the First Circuit reversed a series of related lower court decisions concerning the menu command structure of the Lotus 1-2-3 spreadsheet program.¹⁵⁷ The First Circuit declined to follow *Altai's* abstraction-filtration-comparison test, instead holding that the Lotus 1-2-3 menu command hierarchy is an entirely unprotectable "method of operation" under 17 U.S.C. § 102(b).¹⁵⁸ The majority did not treat the case as an issue of compatibility between programs, as Judge Boudin advocated in his concurrence.¹⁵⁹ This decision placed the First Circuit at odds with several other circuits that had read the "method of operation" language more narrowly.¹⁶⁰ While the Supreme Court granted certi-

152. See *id.* at 707-10.

153. See, e.g., *Apple Computer, Inc. v. Microsoft Corp.*, 35 F.3d 1435 (9th Cir. 1994), cert. denied, 115 S. Ct. 1176 (1995); *Engineering Dynamics, Inc. v. Structural Software, Inc.*, 26 F.3d 1335 (5th Cir. 1994); *Gates Rubber Co. v. Bando Chemical Indus.*, 9 F.3d 823 (10th Cir. 1993). For a complete list, see Lemley, *supra* note 142, at 15.

154. See Lemley, *supra* note 142, at 21-25 (discussing areas of confusion that remain in applying the *Altai* test).

155. See *Apple Computer, Inc. v. Franklin Computer Corp.*, 714 F.2d 1240, 1253 (3d Cir. 1983); see also *Digital Communications Assoc. v. Softklone Distrib. Corp.*, 659 F. Supp. 449, 462-63 (N.D. Ga. 1987); Anthony L. Clapes, *Confessions of an Amicus Curiae: Technophobia, Law and Creativity in the Digital Arts*, 19 U. DAYTON L. REV. 903 (1994); Arthur R. Miller, *Copyright Protection for Computer Programs, Databases, and Computer-Generated Works: Is Anything New Since CONTU?*, 106 HARV. L. REV. 977, 1029-32 (1993) (arguing against promotion of interoperability as a justification for a copyright exception for reverse engineering).

156. See, e.g., *DSC Communications v. DGI Tech.*, 81 F.3d 597, 601 (5th Cir. 1996); *Bateman v. Mnemonics, Inc.*, 79 F.3d 1532, 1539 n.18 (11th Cir. 1996); *Lotus Dev. Corp. v. Borland Int'l, Inc.*, 49 F.3d 807, 821 (1st Cir. 1995) (Boudin, J., concurring), *aff'd*, 116 S. Ct. 804 (1996); *Sega Enter. v. Accolade, Inc.*, 977 F.2d 1510, 1527-28 (9th Cir. 1992); *Atari Games Corp. v. Nintendo of Am. Inc.*, 975 F.2d 832, 843-44 (Fed. Cir. 1992); *Vault Corp. v. Quaid Software Ltd.*, 847 F.2d 255, 270 (5th Cir. 1988); *Mitel Inc. v. Iqtel Inc.*, 896 F. Supp. 1050 (D. Colo. 1995); JONATHAN BAND & MASANOBU KATON, *INTERFACES ON TRIAL: INTELLECTUAL PROPERTY AND INTEROPERABILITY IN THE GLOBAL SOFTWARE INDUSTRY* (1995); Cohen, *supra* note 17, at 1091; Lawrence D. Graham & Richard O. Zerbe Jr., *Economically Efficient Treatment of Computer Software: Reverse Engineering, Protection, and Disclosure*, 22 RUTGERS COMPUTER & TECH. L.J. 61 (1996); Dennis S. Karjala, *Copyright Protection of Computer Documents, Reverse Engineering, and Professor Miller*, 19 U. DAYTON L. REV. 975, 1016-18 (1994); David A. Rice, *Sega and Beyond: A Beacon for Fair Use Analysis . . . At Least as Far as It Goes*, 19 U. DAYTON L. REV. 1131, 1168 (1994).

157. See *Lotus Dev. Corp.*, 49 F.3d at 807.

158. See *id.* at 815.

159. See *id.* at 821 (Boudin, J., concurring).

160. See, e.g., *Engineering Dynamics, Inc. v. Structural Software, Inc.*, 26 F.3d 1335, 1345-46 (5th Cir. 1994) (finding that "the command format and sequence structure in an original word processing

orari to resolve the split in the circuit opinions, one week after oral argument the Court issued an affirmance without opinion.¹⁶¹

In short, in each of the three main computer software copyright issues, the courts have cut back the scope of protection rather dramatically in the last five years.

2. Patent law.

This limitation of software copyright has coincided with a trend towards using patent law to provide protection for software. Section 101 of the Patent Act defines patentable subject matter as "any new and useful process, machine, manufacture, or composition of matter."¹⁶² To qualify for a patent, an invention must meet the requirements of utility, novelty, and nonobviousness.¹⁶³ Unlike copyright, which arises automatically, a patent may be obtained only by filing an application in the PTO.¹⁶⁴ The application must describe both the subject matter of the invention and the metes and bounds of the invention claimed.¹⁶⁵ Only if the PTO determines that the claimed invention is novel and nonobvious will it issue a patent.¹⁶⁶ An issued patent gives the patent owner the right to prevent others from "making, using, or selling" the product or process claimed by the patent in the United States.¹⁶⁷ Unlike copyright infringement, independent creation is no defense to a claim of patent infringement.

It is a fundamental proposition of patent law that any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may be patented if it meets the requirements set forth in the statute.¹⁶⁸ However, the courts have held that the discovery of a law of nature, an abstract idea or principle, or mathematical relationships, operations, or functions cannot be patented.¹⁶⁹ Historically, the PTO viewed software components as mere mathematical formulations existing independently of func-

or computer spreadsheet should be copyrightable because as a whole, the interface's structure and hierarchy constitute a high degree of original expression"); *Autoskill Inc. v. National Educ. Support Sys.*, 994 F.2d 1476, 1495 n.23 (10th Cir. 1993) ("As we have stated, we must go beyond the literal language of [§ 102(b)] and apply the idea/expression distinction to resolve the issue."); *Brown Bag Software v. Symantec Corp.*, 960 F.2d 1465, 1477 (9th Cir. 1992) (holding that computer programs are subject to the same "substantial similarity" test for copyright protection used in literary works).

161. *Lotus Dev. Corp. v. Borland Int'l, Inc.*, 116 S. Ct. 804 (1996), *aff'd* by an equally divided Court, 49 F.3d 807 (1st Cir. 1995).

162. 35 U.S.C. § 101 (1994).

163. See CHISUM & JACOBS, *supra* note 103, at § 1B[1].

164. See *id.*

165. See *id.*

166. See *id.*

167. 35 U.S.C. § 271(a) (1994).

168. See *In re Alappat*, 33 F.3d 1526, 1542 (Fed. Cir. 1994). The court went on to say: The use of the expansive term "any" in § 101 represents Congress's intent not to place any restrictions on the subject matter for which a patent may be obtained beyond those specifically recited in § 101 and the other parts of Title 35. Indeed, the Supreme Court has acknowledged that Congress intended § 101 to extend to "anything under the sun that is made by man." *Id.* at 1542 (quoting *Diamond v. Chakrabarty*, 447 U.S. 303, 309 (1980) (quoting S. Rep. 82-1979, at 5 (1952); H.R. Rep. 82-1923, at 6 (1952))).

169. See *Diamond v. Diehr*, 450 U.S. 175, 191 (1981) (noting that "[a] mathematical formula [in the abstract] is not accorded the protection of our patent laws").

tional structures or processes, and thus refused to extend patent protection to such components. Similarly, in the 1980s, courts and the PTO regularly rejected patent claims directed to software unless the claim included an accompanying physical structure.¹⁷⁰

Since software components are in essence software application building blocks that are independent of physical structure, patent protection has historically been unavailable for them.¹⁷¹ More recent opinions of the Court of Appeals for the Federal Circuit raise the possibility that software per se will be patentable subject matter.¹⁷² These opinions, as well as patent attorneys' skill in characterizing software patent claims as possessing physical structure, prompted a flood of software patents in recent years.¹⁷³

Nonetheless, courts since *Alappat* have not clearly determined whether certain types of software components, notably data structures, are now eligible for patent protection. In *In re Lowry*, the Federal Circuit held that an electronic memory with an internal data structure is patentable subject matter even though the requisite novelty resides in the organization of the data structure.¹⁷⁴ The court reasoned that the organization of data objects in Lowry's invention constituted a form of "electronic structure" which served as the basis for patentability.¹⁷⁵ *Lowry* is important for software components because the "electronic structure" rationale may apply equally to the organization of data structures and relations among instructions, code modules, and objects.¹⁷⁶ However, it is not

170. The two-part test used by courts in the 1980s for analyzing mathematical algorithm cases was set out in *In re Freeman*, 573 F.2d 1237 (C.C.P.A. 1978), and modified by *In re Walter*, 618 F.2d 758 (C.C.P.A. 1980):

First, the claim is analyzed to determine whether a mathematical algorithm is directly or indirectly recited. Next, if a mathematical algorithm is found, the claim as a whole is further analyzed to determine whether the algorithm is "applied in any manner to physical elements or process steps," and, if it is, it "passes muster under § 101."

In re Pardo, 684 F.2d 912, 915 (C.C.P.A. 1982) (quoting *In re Walter*, 618 F.2d at 767). Under the second part of the court's test, the claims may be considered without the algorithm to determine whether the remainder is otherwise statutory. See *In re Abele*, 684 F.2d 902, 907 (C.C.P.A. 1982) ("[I]f the claim would be 'otherwise statutory,' albeit inoperative or less useful without the algorithm, the claim likewise presents statutory subject matter when the algorithm is included.") (quoting *In re Walker*, 618 F.2d at 767).

171. See *Parker v. Flook*, 417 U.S. 584 (1978) (holding unpatentable software for setting alarm limits); *Gottschalk v. Benson*, 409 U.S. 63 (1972) (holding unpatentable software for converting binary numerals to binary-coded decimal numerals).

172. See *Alappat*, 33 F.3d at 1545 (holding that a computer programmed to perform particular functions pursuant to instructions from program software becomes a "new machine, because a general purpose computer in effect becomes a special purpose computer"). But see Jonathan N. Geld, Note, *General Does Not Mean Generic—Shedding Light on In re Alappat*, 4 TEX. INTELL. PROP. L.J. 71 (1995) (arguing that the *Alappat* court maintained that structure is necessary to support software patents and does not extend patent protection to all software implemented on a general purpose computer).

173. By the end of 1994, there were approximately 14,000 United States patents in existence that covered software. See Steve G. Steinberg, *Growth of U.S. Software Patents*, WIRED, Jan. 1995, at 54. In 1994, Gregory Aharonian estimated that the patent office was issuing approximately 4000 new software patents per year. See Simson L. Garfinkel, *Patently Absurd*, WIRED, July 1994, at 104, 106.

174. See *In re Lowry*, 32 F.3d 1579, 1584-85 (Fed. Cir. 1994).

175. *Id.* at 1583.

176. See Stephen C. Durant, *Patents in Cyberspace: Impact of Recent Federal Circuit Decisions*, 12 COMPUTER LAW. 1, 3 (1995) (considering whether courts will interpret instructions, code modules, and objects as sufficiently structural).

clear whether other Federal Circuit panels agree with *Lowry's* holding. For example, in *In re Warmerdam* the court affirmed the rejection of claims directed to data structures, describing the structures as "nothing more than the manipulation of basic mathematical constructs, the paradigmatic 'abstract idea.'" ¹⁷⁷ The *Warmerdam* court came to its decision because it found that the software aspect of the patent claim lacked physicality, thus apparently rejecting the "electronic structure" approach.¹⁷⁸

The most recent developments in this ongoing debate are the *In re Beauregard*¹⁷⁹ appeal and the PTO's issuance of proposed¹⁸⁰ and final¹⁸¹ guidelines for examining computer related inventions. In *Beauregard*, the Board of Patent Appeals and Interferences rejected a claim covering software on a floppy disk. While the case was pending on appeal to the Federal Circuit, the PTO declared that it no longer objected to the claim as nonpatentable, and that it would shortly issue guidelines to that effect.¹⁸² The PTO published a *Request for Comments on Proposed Examination Guidelines for Computer-Implemented Inventions* ("Proposed Guidelines") on June 2, 1995,¹⁸³ and issued a detailed legal analysis supporting the claims in October 1995, which significantly altered the original guidelines.¹⁸⁴ This legal analysis was subsequently supplanted by the *Examination Guidelines for Computer-Related Inventions* ("Revised Guidelines"), published February 28, 1996.¹⁸⁵

The *Revised Guidelines* take the position that data structures which are not embodied in computer readable media and computer programs claimed as mere descriptions of the programs are not physical "things" nor patentable processes. Thus, such data structures and computer programs "do not define any structural and functional interrelationships between [themselves] and other claimed aspects of the invention which permit [their] functionality to be realized."¹⁸⁶ By contrast, the *Revised Guidelines* suggest that a computer readable medium encoded with a data structure or computer program is patentable because it "defines structural and functional interrelationships between the computer program [or data structure] and the medium which permit [their] functionality to be real-

177. *In re Warmerdam*, 33 F.3d 1354, 1360 (Fed. Cir. 1994). The *Warmerdam* court did, however, allow a claim for a "machine" which included a memory containing the data structure. See *id.* 178. See *id.* at 1361-62.

179. 53 F.3d 1583 (Fed. Cir. 1995).

180. Request for Comments on Proposed Examination Guidelines for Computer-Implemented Inventions, 60 Fed. Reg. 28,778 (proposed June 2, 1995) [hereinafter Proposed Guidelines].

181. Examination Guidelines for Computer-Related Inventions, 61 Fed. Reg. 7478 (1996) [hereinafter Revised Guidelines].

182. See *Software Embodied on Diskette is Patentable Subject Matter, PTO Declares*, 50 Pat. Trademark & Copyright J. (BNA) 3 (May 4, 1995).

183. See Proposed Guidelines, *supra* note 180, at 28,778.

184. See PATENT AND TRADEMARK OFFICE, U.S. DEPT. OF COMMERCE, LEGAL ANALYSIS TO SUPPORT PROPOSED EXAMINATION GUIDELINES FOR COMPUTER-IMPLEMENTED INVENTIONS (1995) (on file with the Stanford Law Review).

185. See Revised Guidelines, *supra* note 181, at 7478. According to the PTO, the Revised Guidelines are final and replace the Proposed Guidelines and associated Legal Analysis. See *id.* at 7487 n.1. However, because the Revised Guidelines do not constitute substantive rulemaking and thereby do not have the force and effect of law, "any failure of Office personnel to follow the [Revised] Guidelines is neither appealable nor petitionable." *Id.* at 7479.

186. *Id.* at 7481-82.

ized."¹⁸⁷ The formalism of this distinction should make clear that artful drafting by patent lawyers (emphasizing the physicality of the data structure or computer program) may turn supposedly "nonstatutory" computer programs into patentable subject matter.

The *Revised Guidelines*, in an attempt to chart a course between what is and what is not patentable, introduce the concepts of "functional" and "nonfunctional" descriptive material. According to the PTO, "'functional descriptive material' consists of data structures and computer programs which impart functionality when encoded on a computer-readable medium."¹⁸⁸ "Non-functional descriptive material," on the other hand, "includes but is not limited to music, literary works and a compilation or mere arrangement of data."¹⁸⁹ Descriptive material is not patentable when claimed for itself;¹⁹⁰ it is patentable when claimed in a way that "structurally and functionally interrelate[s]" the descriptive material to other claimed aspects of the invention.¹⁹¹

The PTO reasons, somewhat persuasively, that nonfunctional descriptive material, even when encoded on a computer readable medium, defines no structural or functional interrelationships. For example, music does not become patentable merely because it is recorded on a computer readable medium such as a compact disc. As the PTO points out, "[s]uch a result would exalt form over substance."¹⁹² Yet in the context of functional descriptive material, the PTO is prepared to do just that. The PTO explains that "[d]ata structures not claimed as embodied in computer-readable media are descriptive material per se and are not statutory because they are neither physical 'things' nor statutory processes,"¹⁹³ but adds that "[w]hen functional descriptive material [such as a data structure] is recorded on [a] computer-readable medium it becomes structurally and functionally interrelated to the medium and will be statutory in most cases."¹⁹⁴ Since any software program will likely be recorded on some computer readable medium, it is not clear how much this distinction will accomplish in practice.

The reasoning of the *Revised Guidelines* tracks the inconsistent contours of *Warmerdam* and *Lowry*. Additionally, the PTO's analysis advances "structural and functional interrelationships" between a data structure or computer program and other claimed aspects of an invention as a useful rubric for discriminating among patentable and nonpatentable subject matter. However, analytical reliance on a mere recitation of encoded computer readable media, even in the context of "functional descriptive material," may result in a subject matter inquiry which is both over- and underinclusive. Perhaps as the surrounding jurisprudence develops, both the PTO and the courts will continue to

187. *Id.* at 7482.

188. *Id.* at 7481. The PTO's choice of the verb "consists" in describing functional descriptive material is notable given its well established meaning in patent law as defining a closed set of elements.

189. *Id.*

190. See *id.*

191. *Id.*

192. *Id.*

193. *Id.*

194. *Id.*

recognize that it is these structural and functional interrelationships, whether between other aspects of an invention (i.e., with tangible, physical media or computer structures) or within the programs or data structures themselves, which distinguish patentable computer related subject matter from nonpatentable abstract ideas. Certainly, many patents issued by the PTO already reflect these structural and functional interrelationships among software components.¹⁹⁵

In short, there is good reason to believe that the PTO and the courts will allow patents on software components in many circumstances.¹⁹⁶ Further, it appears that other countries may be following suit.¹⁹⁷ However, greater confusion surrounds the details of exactly which software-implemented inventions are patentable, and exactly what their inventors must claim to comply with the PTO's guidelines for patentable subject matter. This confusion is particularly evident in the area of reusable software components, both because of the Lowry-Warmerdam disagreement¹⁹⁸ and because under the Revised Guidelines patentability appears to turn on the relationship between a software object and its physical implementation in a particular case.¹⁹⁹

IV. INTELLECTUAL PROPERTY RIGHTS AND THE FUTURE OF SOFTWARE COMPONENT TRANSACTIONS

Currently, no viable external market exists for software components. The reasons for this are both technical and economic. On the technical side, a viable market requires some means of evaluating products and transacting business. Several government projects, including NIST's software components program²⁰⁰ and the Defense Advanced Research Projects Agency's ("DARPA") Asset Source for Software Engineering Technology ("ASSET") national software repository,²⁰¹ have been established to deal with this problem. For example, the ASSET system, which went online in August of 1994, plans to develop an electronic marketplace for reusable software products by providing an Internet accessible software reuse library for software developers

195. See, e.g., United States Patent No. 5,414,701 (entitled Method and Data Structure for Performing Address Compression in an Asynchronous Transfer Mode (ATM) System) (disclosing a data structure consisting entirely of software components); United States Patent No. 5,386,375 (entitled Floating Point Data Processor and a Method for Performing a Floating Point Square Root Operation Within the Data Processor) (claiming a method for executing a square root operation).

196. See generally Keith Stephens & John P. Sumner, *Patenting Software Objects and Other Aspects of Object-Oriented Programs Under the New PTO Guidelines*, 23 AIPLA Q.J. 221 (1995) (arguing that software objects are patentable and that patenting software is efficient).

197. See, e.g., *International Developments: Japan, Following U.S., Decides to Allow Patents for Memory Devices*, BNA'S ELECTRONIC INFO. POL'Y L. REP. 466 (Aug. 16, 1996) ("[t]he Japan Patent Office has decided to allow patenting of CD-ROMs, floppy disks, and other memory devices storing proprietary software").

198. See notes 176-178 *supra* and accompanying text.

199. See Revised Guidelines, *supra* note 181, at 7483, 7492.

200. See *Stitch Ups: Software*, *supra* note 3, at 99 (reporting the first awards, totaling \$40 million, of NIST's five-year, \$150 million project to create a software computer industry).

201. See Frakes & Isoda, *supra* note 22, at 16 ("The federal government is attempting to build large national software-asset repositories, such as ASSET"); see also *ASSET Welcome Page*, *supra* note 20.

in government, industry, and education.²⁰² Other private repositories have developed similar projects.²⁰³

While these projects address many important technical issues, such as the development of architectures, semantics, and formal languages,²⁰⁴ as well as practical issues such as design and implementation of interoperable reuse libraries for storage and retrieval of software artifacts,²⁰⁵ they only minimally enhance producers' incentives to sell reusable software components to external consumers. We suggest that the legal shift from copyright to patent protection for software may encourage such transactions. We first describe the economics of a hypothetical software component market and then examine the incentives that various legal regimes provide to software developers who engage in external software reuse.

A. Economics of Software Components Markets

A market for software components requires both willing buyers and willing sellers. The buyers of software components are presumably not end users in most cases,²⁰⁶ but are resellers who will integrate the components into useful products for the consuming public. While the technology for software integration is available today,²⁰⁷ integrators must be able to obtain adaptable components to create useful products. As noted above, the initial development of modular reusable software is more expensive than the development of code from scratch. While those additional costs are outweighed by the savings from reuse of the software, the developer herself will benefit only if she is able to capture some or all of the benefit from the consumers who reuse the software. Without legal protection for the design of reusable software components, producers will not be able to capture sufficient profits to justify the cost of the design refinements essential to the creation of reusable software components.²⁰⁸ Further, software developers who do not want to sell components to integrators can continue to "self-integrate" by writing their own code for an entire integrated program and selling it directly to end users. While self-inte-

202. See *ASSET Electronic Marketplace* (last modified Oct. 30, 1996) <<http://source.asset.com/WSRD/electronic-marketplace.html>>.

203. See, e.g., *Softbank Web Market*, INFO. WK., May 27, 1996, at 26 (reporting the unveiling of an online software component marketplace).

204. See *Stitch Ups: Software*, *supra* note 3, at 99 (reporting that these issues are the near term focus of the first \$40 million of projects under NIST's software components program).

205. See generally GAO REPORT ON SOFTWARE REUSE, *supra* note 19 (discussing the need for interoperable software repositories).

206. In some cases, end users who use a large amount of software may buy components and assemble them for their own use. The Defense Department considered such a program, for example. See SAMUELSON, *supra* note 65, at 70-71.

207. For one example, see Sabra Chartrand, *Patents: Computer Code Has Kept at Bay Many People Who Wanted to Create Their Own Programs. No More.*, N.Y. TIMES, July 15, 1996, at D2 (describing new technology of "elastic objects," adaptable bundles which permit the integrator to combine objects without writing code of her own).

208. See SAMUELSON, *supra* note 65, at 70-71 (explaining that software developers would not have an incentive to develop "perfect" code if the Department of Defense had unlimited rights to reuse their software because the developers would not benefit from the extra effort necessary to make the code reusable).

gration is less efficient for society than external software reuse, software developers will produce and sell their components to others for reuse only if they have a good reason to do so.

One approach to solving this public goods problem is to give strong intellectual property protection to software developers. For example, one might confer on the first developer of an idea or piece of code a perpetual right to exclude others from using that code or anything similar to it in any way and for any purpose. However, every scheme of intellectual property protection has costs as well as benefits. Legal protection that is too broad or too long lasting may have a detrimental effect on subsequent innovation. If, for example, the owner of intellectual property rights in a software component refused to grant others a license,²⁰⁹ the inability of programmers to exploit data structures, program sequences, and algorithms would have a significant chilling effect on the development of future generations of reusable software components.²¹⁰ Hence, intellectual property law strives to balance the aims of encouraging innovation and creation with the goals of protecting competition and encouraging the wide dissemination of information.²¹¹ Both patent and copyright law maintain this balance by limiting the scope and duration of protection and by setting minimum hurdles which an innovator must clear before she can obtain protection.²¹²

Several characteristics of the market for software in general, and for reusable software components in particular, affect how this balance should be struck.²¹³ First, because reliability from repeated testing and use provides much of the marginal value of reusable software,²¹⁴ standardization is more important in software components markets than in other software markets. Since it is more efficient to use existing software than to develop new software, the number of competitive options for accomplishing a particular task should be smaller than in other markets. This means that the effect of legal rules

209. On the reasons why such licensing might not occur, see Mark A. Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 *Tex. L. Rev.* (forthcoming 1997) (suggesting that the high costs and uncertainty associated with intellectual property licensing might result in an inefficient failure to license).

210. See Levin et al., *supra* note 119, at 788 (noting that "strong protection of individual achievements may slow the general advance" because such protection "may preclude competitors from making socially beneficial innovations"); see also Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, *J. ECON. PERSP.*, Winter 1991, at 29, 31 (explaining that a first innovator may not expect to profit by licensing to others and thus broad patent protection could inhibit future innovation and undermine the entire research line); cf. Menell, *supra* note 84, at 1094-95 (making an analogous argument with respect to protection of user interfaces).

211. For a general discussion of these tradeoffs, see *White v. Samsung Elec. Am., Inc.*, 989 F.2d 1512 (9th Cir. 1993) (Kozinski, J., dissenting from denial of rehearing en banc).

212. For a brief discussion of some of these limitations on intellectual property, see notes 10-18 *supra* and accompanying text.

213. Professor Menell reminds us that "legal protection for computer software should be approached within a rich economic framework emphasizing the cumulative nature of innovation; the broad range of legal and non-legal methods for appropriating revenues from innovation; network effects; and the limitations and costs of comprehensive legal rules for appropriating returns to innovation . . ." Peter S. Menell, *The Challenges of Reforming Intellectual Property Protection for Computer Software*, 94 *COLUM. L. REV.* 2644, 2648 (1994).

214. See notes 60-63 *supra* and accompanying text.

against copying is stronger in software component markets than elsewhere, since much of the value resides in the reused code itself.²¹⁵

Second, the software market features strong "network externalities" because the total social value of a software program increases as more consumers use it.²¹⁶ The three types of network externalities are discussed here in decreasing order of strength. The strongest are interconnection externalities, in which connection to other users is itself the product being sold. The prototypical example of such interconnection externalities is the telephone network, where the product is nothing more than the ability to connect to other customers of the network. The Internet shares strong interconnection externality characteristics, for the same reason.²¹⁷ The second strongest are interoperability externalities, which emerge where a product's value is a function of its compatibility with other products in the market. For example, in the household appliances market, an electric power plug is useless unless it connects firmly with most wall outlets. Thus, the design of electric plugs is significantly contained by the design of wall outlets (and vice versa). The third strongest are convenience externalities, which exist where a product becomes more desirable as more consumers learn to use it, since they become less willing to learn how to use new products. For example, the typewriting industry has used the QWERTY keyboard design for over a century even though it is allegedly inferior to competing designs, arguably because training typists on a new keyboard would be too difficult and costly an undertaking for companies.²¹⁸

In general, software exhibits strong interoperability characteristics. This is particularly true for operating systems.²¹⁹ In the market for operating systems,

215. The effect of this factor may be to counteract to some extent the problem identified in the *Manifesto*, *supra* note 2, at 2330-64, that much of the value of a computer program resides in "know-how" which is not copyrightable but which is evident upon detailed inspection of the program.

216. See DOUGLAS G. BAIRD, ROBERT H. GERTNER & RANDALL C. PICKER, *GAME THEORY AND THE LAW* 208-13 (1994) (stating that the software industry exhibits significant network externalities); Joseph Farrell & Garth Saloner, *Standardization, Compatibility, and Innovation*, 16 *RAND J. ECON.* 70, 71 (1985) ("consumers value a product more highly when it is 'compatible' with other consumers' products"); Michael L. Katz & Carl Shapiro, *Systems Competition and Network Effects*, *J. ECON. PERSP.*, Spring 1994, at 93, 98 (asserting that consumers will choose hardware according to their predictions about available software because they anticipate being "locked-in" to the corresponding hardware/software system).

217. See Mark A. Lemley, *Antitrust and the Internet Standardization Problem*, 28 *CONN. L. REV.* 981 (1996) (explaining that the Internet's value lies in its ability to connect people to other people). Even Liebowitz and Margolis acknowledge the existence of network externalities of this sort, though they generally caution against the argument that network externalities constitute market failure. See S.J. Liebowitz & Stephen E. Margolis, *Network Externalities: An Uncommon Tragedy*, *J. ECON. PERSP.*, Spring 1994, at 133, 134.

218. See Paul A. David, *Clio and the Economics of QWERTY*, 75 *AM. ECON. REV.* 332, 335-36 (1985) (discussing the history and present-day economic rationale for the widespread use of the QWERTY keyboard design). But see S.J. Liebowitz & Stephen E. Margolis, *The Fable of the Keys*, 33 *J.L. & ECON.* 1, 4, 19 (1990) (arguing that if another keyboard design were superior to QWERTY, manufacturers would internalize the externality of converting typists to the superior product and would ultimately realize a profit).

219. "[T]he operating system serves as a compatibility nexus for a particular computer network. Application software products will develop more programs for systems that are widely used; hardware producers will develop more configurations of disk drives, memory, and other features for popular operating systems." Peter S. Menell, *Tailoring Legal Protection for Computer Software*, 39 *STAN. L. REV.* 1329, 1341 (1987).

standardization is essentially inevitable. Even where a competing operating system is technically superior to the standard, consumers will not purchase the computer unless it is compatible with a wide variety of application programs. This behavioral trend depends on a large user base. Consequently, once a program becomes the standard, it remains in that position for a long time.²²⁰ Even in the computer software applications market, where network externalities are not so noticeable, interoperability both with operating systems ("vertical interoperability") and with competing programs ("horizontal interoperability") affects consumer product selection.

There are many possible ways to meet consumer demand for interoperability. First, competitors could agree to establish a standard of compatibility among their products, or the government could require such a standard. Joint standard setting organizations are relatively common in the computer industry, although they have achieved only sporadic success.²²¹ Second, individual companies could sell or give away "open platform" systems to encourage competitors to write programs that run on this platform. In markets exhibiting particularly high interoperability externalities, a number of companies have had some success with this approach.²²² If consumers have to choose between competing "closed" systems, however, the market gravitates toward a single, de facto standard for operating systems.²²³

Reusable software components should exhibit even stronger externalities than the general software industry—particularly in the context of vertical interoperability. To sell a software component, as opposed to an integrated software system, producers must persuade buyers that the components will be interoperable with at least one set of complementary components, and preferably with many different complementary components.²²⁴ To achieve vertical integration, vendors of different components must not only share their interface specifications,²²⁵ but they must also standardize their interfaces.²²⁶ In a market that favors interchangeable software components, vendors who design their prod-

220. The continued prevalence of the MS-DOS operating system and its derivatives in spite of its technological inferiority may be attributable to these externalities. See Lemley, *supra* note 217 (explaining that once a standard has been established, consumers are hesitant to embrace new products because of switching costs).

221. The failures of joint standard setting groups such as X-OPEN and the Open Software Foundation demonstrate that the participation of large industry players does not guarantee the success of a joint standard.

222. Sun Microsystems and Netscape have both done remarkably well by adopting open platforms: Netscape with its Web browser and Sun with both the UNIX operating system code and the Java Internet programming language. See, e.g., Lawrence M. Fisher, *The Executive Computer: Microsoft's Operating System Rivals Get a Boost, Sort Of*, N.Y. TIMES, July 24, 1994, § 3, at 7 (describing the market for personal computer operating systems).

223. For example, Microsoft has demonstrated a relatively durable dominance of the operating systems market with its MS-DOS standard and subsequent refinements to that standard. See note 220 *supra*.

224. See David J. Teece, *Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy*, 15 RAS. POL'Y 285, 288 (1986) (describing how software innovators may exploit their products' compatibility with other computer components to appropriate returns on their creations).

225. See *Manifesto*, *supra* note 2, at 2321 ("Software interfaces are the information equivalents of the gear teeth, levers, pulleys, and belts that physical machines use to interoperate.").

ucts according to the industry standard benefit not only from consumer interest but also from cheaper and more accessible parts and servicing.²²⁷ Thus, Matutes and Regibeau have persuasively shown that product compatibility encourages the development of component systems, allowing consumers to assemble their own products from interchangeable components.²²⁸

A market for interchangeable software components, then, requires two conditions. First, producers of software components must hold relatively strong intellectual property rights in the individual components themselves. Otherwise, they risk losing their profits to free riders by selling their components to software integrators on the open market.²²⁹ This follows the discussion in Part III.A,²³⁰ where we noted that reusable components may cost more to produce than normal code. Free riders could exploit reusable components, because vendors will likely distribute them in source as well as object code form. If intellectual property protection is relatively weak, vendors will not be willing to license their source code to potential competitors. Second, purchasers of software components must be able to use them with complementary components from other producers. Software components must either have "plug and play" compatibility, or purchasers must have the right to adapt the components to work with complementary goods.²³¹ Absent interoperability, the interconnection between software components will remain a rarity outside single, vertically integrated companies.

226. See generally JOSEPH FARRELL, HUNTER K. MONROE & GARTH SALONER, *THE VERTICAL ORGANIZATION OF INDUSTRY: SYSTEMS COMPETITION VERSUS COMPONENT COMPETITION* (U.C. Berkeley Program in Law & Econ., Working Paper No. 94-12, 1994) (describing the economic considerations that determine whether competition in an industry will occur at the component level or at the integrated system level).

227. See Farrell & Saloner, *supra* note 216, at 70-71 ("[A] complementary good (spare parts, servicing, software . . .) becomes cheaper and more readily available the greater the extent of the (compatible) market.").

228. See Carmen Matutes & Pierre Regibeau, "Mix and Match": *Product Compatibility Without Network Externalities*, 19 RAND J. ECON. 221, 222 (1988).

229. "Relatively strong" refers to intellectual property rights that enable a producer to appropriate much of her component's returns. See Levin et al., *supra* note 119, at 799 ("when patents effectively prevent competitors from duplicating processes and products, they tend also to be effective in securing royalty income"); Thomas M. Jorde & David J. Teece, *Innovation, Cooperation and Antitrust: Striking the Right Balance*, 4 HIGH TECH. L.J. 1, 6-7 (1989) (defining the strength of various "appropriability regimes"). Where the essential value of the software component is contained in the literal code itself, a rule prohibiting literal copying would be sufficient to satisfy this "relatively strong" criterion.

230. See notes 90-94 *supra* and accompanying text.

231. The *Manifesto* authors are particularly eloquent on the complexity of this interoperability process:

Where physical machines are built from physical structures like gears, wires, and screws, programs are built from information structures, such as algorithms and data structures. In software, these components must work together in a very carefully orchestrated way that resembles nothing so much as an intricate mechanical device consisting of thousands of delicate gears and levers. In a mechanical device, the gear teeth must mesh exactly, and levers must move at just the right moments. If a single component of either a hardware or software machine fails to work as intended, disastrous effects can propagate through the rest of the machine in the blink of an eye.

Manifesto, *supra* note 2, at 2321.

B. The Impact of Legal Rules

Unfortunately, the traditional legal rules protecting computer programs—trade secret and copyright—do not exhibit these characteristics. Under trade secret rules, designers must make “reasonable efforts” to conceal their trade secrets from competitors.²³² If the producer discloses the secret, or if his competitors generally know or can readily ascertain the secret, the producer loses trade secret protection. Consequently, trade secret laws encourage designers to build “fences” around their secrets.²³³ Producers build these fences by disclosing information sparingly and imposing stringent conditions on a licensee’s right to use or further disclose the secret, particularly to the producer’s competitors. These are not the characteristics likely to lead to a market in tradeable software components. Ultimately, by discouraging designers from sharing interface information with each other, trade secret laws retard the software industry’s move toward market-wide vertical interoperability.²³⁴

Copyright law also discourages the development of a market in tradeable software components for two reasons. First, strong copyright protection, like that generated by the decision in *Whelan Associates v. Jaslow Dental Laboratories*,²³⁵ extends to both literal and nonliteral aspects of a completely integrated computer program. According to some courts and commentators, this means that the developer can protect the program interface elements,²³⁶ and possibly the program languages,²³⁷ as well as the code itself. Further, courts do not uniformly permit competitors to copy vertical interoperability interfaces, even where an interface constitutes an industry standard.²³⁸ Thus, if broadly inter-

232. See notes 103-110 *supra* and accompanying text (discussing strategies for disseminating software without sacrificing its trade secret status).

233. However, trade secret laws may enable producers to build smaller “fences” than they would need to in the absence of any intellectual property protection. Under trade secret laws, to bring an action for misappropriation a producer need only demonstrate “reasonable efforts” to protect secrecy. Thus, trade secrets law arguably helps prevent wasteful overspending on secrecy measures. See ROBERT P. MERGES, PETER S. MENELL, MARK A. LEMLEY & THOMAS M. JORDE, *INTELLECTUAL PROPERTY IN THE NEW TECHNOLOGICAL AGE* (forthcoming 1997) (“Legal protection is essentially equivalent to some benevolent third party—e.g., the government—adding on to your [imperfect] fence to make it totally effective.”). Nonetheless, relative to other forms of intellectual property protection, trade secrets discourage rather than encourage dissemination of information.

234. Trade secret law does permit reverse engineering to obtain the secrets contained in commercial products. However, because of its technical difficulty, reverse engineering is a less than desirable means of accessing information necessary to achieve interoperability. See notes 111-112 *supra* and accompanying text.

235. 797 F.2d 1222 (3d Cir. 1986).

236. See, e.g., *Apple Computer, Inc. v. Franklin Computer Corp.*, 714 F.2d 1240, 1253 (3d Cir. 1983) (holding that copyright is available to an operating system unless there is no other way to express the idea behind the operating system). As noted above, however, most courts and commentators reject granting nonliteral expression such broad copyright protection. See notes 145-151 *supra* and accompanying text.

237. See *Lotus Dev. Corp. v. Paperback Software Int'l*, 740 F. Supp. 37, 54 (D. Mass. 1990) (suggesting programming languages may be copyrightable as long as the language is “merely an original expression of an idea, method, or process but not an idea, method, or process itself”). But see *Lotus Dev. Corp. v. Borland Int'l, Inc.*, 49 F.3d 807, 815 (1st Cir. 1995) (rejecting District Court’s conclusion in a related case), *aff’d by an equally divided Court*, 116 S. Ct. 804 (1996).

238. For example, in *Sega Enterprise Ltd. v. Accolade, Inc.*, 977 F.2d 1510 (9th Cir. 1992), often cited as the leading decision favoring interoperability, the court actually addressed only the legality of intermediate copying to facilitate reverse engineering, leaving open the question of whether the copying

preted, copyright law may empower owners to control who designs interoperability interfaces compatible with their components.

Broad copyright protection for interfaces increases the transaction costs of building integrated programs from purchased components.²³⁹ To build an integrated program a manufacturer must not only license use of the components that constitute the system, but also the rights to adapt the interfaces associated with each component. Where two components from different manufacturers were being integrated, the integrator would need permission from both manufacturers to adapt the components so they worked together. Furthermore, original software developers may use strong copyright protection to control data’s migration path by forbidding transfer of the original program data to subsequent, improved programs.²⁴⁰ Original developers may be unwilling to freely license use of their data, especially to a company whose program might compete with theirs.²⁴¹ Thus, strong copyright law protection is likely to inhibit component interoperability.

This problem is compounded by the relatively harsh rules governing derivative works, which are “recast, transformed, or adapted” versions of preexisting works.²⁴² Section 106(2) empowers the copyright owner to prevent purchasers from integrating copyrighted materials into their own original works.²⁴³ Not only is it infringement of the original copyright for a purchaser to alter her copy or to create an improved version of the work without permission,²⁴⁴ but any

interface components in a final work violates copyright laws. See Cohen, *supra* note 17, at 1135-36 (“It makes little sense to allow intermediate copying where necessary to understand the requirement for interoperability, only to withhold permission to incorporate the copied work’s functional features to the extent necessary to make the reverse engineered product interoperable.”); Graham & Zerbe, *supra* note 156, at 120-21 (arguing that without reverse engineering copyright law not only grants owners control over original expression but also over the ideas behind the expression).

239. See, e.g., Frederick R. Warren-Boulton, Kenneth C. Baseman & Glenn A. Woroch, *The Economics of Intellectual Property Protection for Software: The Proper Role for Copyright* (1995) (unpublished manuscript, on file with the *Stanford Law Review*) (arguing that overly broad protection of interface specifications is especially pernicious and costly to society); JOSEPH FARRELL, *ARGUMENTS FOR WEAKER INTELLECTUAL PROPERTY PROTECTION IN NETWORK INDUSTRIES* (U.C. Berkeley Program in Law & Econ., Working Paper No. 94-11, 1994) (explaining that protection is particularly costly when strong network effects exist).

240. See Hamilton & Sabety, *supra* note 98, at 5, 32 (illustrating how strong copyright protection can impede migration of data from old programs to new ones).

241. This is arguably what was at issue in *Lotus Development Corp. v. Borland International, Inc.*, 799 F. Supp. 86 (D. Mass. 1992), *rev’d* 49 F.3d 807, 816 (1st Cir. 1995) (holding that Borland did not infringe Lotus’ copyright because it copied Lotus’ “method of operation” which was unprotected by copyright).

242. 17 U.S.C. § 101 (1994).

243. See 17 U.S.C. § 106(2) (1994) (granting the copyright owner the exclusive power to authorize the right “to prepare derivative works based upon the copyrighted work”); see also Paul Goldstein, *Derivative Rights and Derivative Works in Copyright*, 30 J. COPYRIGHT SOC’Y 209, 236-39 (1983). Pamela Samuelson identifies this as one of the critical barriers to purchaser-encouraged software reuse. See SAMUELSON, *supra* note 65, at 69-70.

244. In the computer software context, 17 U.S.C. § 117 does provide purchasers with a limited right to copy and make adaptations as an “essential step” in the use of the program, provided the adaptation is used for no other purpose. This exception is unlikely to support adaptation or improvement for purposes of commercial resale, although at least one court has read it broadly. See *Vault Corp. v. Quaid Software Ltd.*, 847 F.2d 255, 261 (5th Cir. 1988) (construing 17 U.S.C. § 117 to mean a copy does not have to serve the purpose intended by the copyright owner, and thus defendant could use the copy to dismantle the protective function of plaintiff’s program).

purchaser who creates such an improvement loses copyright protection for her own original expression if it is effectively integrated with infringing material.²⁴⁵ Ultimately, the derivative works rule discourages software designers using purchased interface components from rewriting, debugging, and generally improving software, since such alterations can potentially create an infringing derivative work.²⁴⁶ It therefore impedes vertical interoperability in the software market.²⁴⁷

It is conceivable that owners of copyrighted interface elements would voluntarily license interoperability interface elements to other developers in order to sell their products in a components market. Nonetheless, licensing the right to copy and adapt a preexisting interface still poses problems. First, because copyright law recognizes a right to reverse engineer programs to achieve interoperability in some circumstances, developers may choose to reverse engineer the underlying program and develop their own code to save the cost and complication of licensing. Second, licensing interface components may prove difficult where interoperability requirements are complex, since a purchaser may need to acquire rights to both copy and adapt the interface from a number of different copyright owners. And third, copyright owners of interfaces retain a limited "veto" power over any integration of their components with other manufacturers' components. This veto power will likely reinforce the reign of powerful companies over markets in which they are already vertically inte-

245. Because section 103 of the Copyright Act denies copyright only in the "part of the work" that incorporates infringing material, some infringing derivative works may nonetheless be copyrightable in part. This is particularly true in the case of compilations, where the infringing material can be separated easily from other parts of the work. Thus, the House Report accompanying the 1976 Act provides that the author of "an anthology of poetry could sue someone who infringed the whole anthology, even though the infringer proves that publication of one of the poems was unauthorized." H.R. Rep. No. 94-1476, at 57-58 (1976), reprinted in 1976 U.S.C.A.N. 5659, 5671.

However, where copyrighted material is intertwined with that contributed by the infringer, the infringer loses any rights in the resulting product, even if most of the value of the work is attributable to her contribution. "[I]f the pre-existing material used without permission 'tends to pervade the entire derivative work,' copyright protection is denied to the derivative work entirely." *Dynamic Solutions, Inc. v. Planning & Control, Inc.*, 646 F. Supp. 1329, 1340 (S.D.N.Y. 1986) (quoting 1 NIMMER, NIMMER ON COPYRIGHT, § 3.06 (1985)); see *Pamfiloff v. Giant Records, Inc.*, 794 F. Supp. 933, 938 (N.D. Cal. 1992) (quoting this *Dynamic Solutions* language); 1 NIMMER & NIMMER, *supra* note 139, § 3.06, at 3-34.5 to -34.6 (1996); Anastasia P. Winslow, *Rapping on a Revolving Door: An Economic Analysis of Parody and Campbell v. Acuff-Rose Music, Inc.*, 69 S. CAL. L. REV. 767, 779 (1996) ("Thus, when the preexisting material pervades the derivative work, the derivative author acquires no copyrights at all, no matter how creative or inventive the derivative use.").

246. See J.H. Reichman, *The Know-How Gap in the TRIPS Agreement: Why Software Fared Badly, and What Are the Solutions*, 17 HASTINGS COMM/ENT. L.J. 763, 780 (1995) (software developers might use the right to prepare and authorize derivative works to claim ownership over the functional aspects of subsequent computer programs); Pamela Samuelson, *The Need for Reform of the Software Licensing Policy of the Department of Defense*, 27 JURIMETRICS J. 9, 34-35 (1986) ("Because of its adaptability, software is generally in a state of continual development, 'new' or updated versions replacing 'old' versions every year, or even every several months.").

247. See Lemley, *supra* note 209 (arguing for a change in the derivative works rule to bring it in line with the rule in patent cases).

grated.²⁴⁸ Finally, various complications, from transaction costs to uncertainty to strategic behavior, may preclude an efficient licensing transaction.²⁴⁹

The second problem with copyright law is that it only protects the code of a copyrighted component and permits competitors to copy the ideas underlying that component. It therefore encourages competitors to write their own code to implement the basic ideas behind another's program. This amounts to re-creating code, precisely the result we would like to avoid in creating a reusable software market. If subsequent developers can capture the know-how of a program by observing it and then writing a competing program, and if that know-how (rather than the code itself) is the most valuable part of the program,²⁵⁰ competitors will write their own programs incorporating that know-how and save the cost of purchasing the component.²⁵¹ Arguably, prohibiting direct copying but permitting redesign, as copyright does, encourages software reinvention.

In sum, copyright law stunts the development of a reusable software market in two related ways. First, copyright law vests control over derivative works in the author of the original copyright program, and threatens to give the copyright owner complete control over the creation of compatible programs. This makes it difficult for integrators to alter purchased components to make them compatible with a variety of different systems.²⁵² While original developers might license the right to adapt their components, copyright supplies powerful incentives for those developers to keep a tight rein on the subsequent use of their components.²⁵³

Second, one does not necessarily need a license to capture the bulk of a component's value. One can achieve this goal by reverse engineering the program or analyzing it to uncover and copy its unprotected ideas and functional aspects. Understandably, subsequent users generally choose to write their own program code and capture this value rather than license the original. Unfortunately, this means that competitors must engage in software reinvention rather than reuse.

248. See, for example, *Atari Games Corp. v. Nintendo of America, Inc.*, 975 F.2d 832, 845-46 (Fed. Cir. 1992), and *Sega Enterprise Ltd. v. Accolade Inc.*, 977 F.2d 1510, 1527-28 (9th Cir. 1992), both involving an effort by a dominant game box and game cartridge manufacturer to use intellectual property rights to prevent competition in their market for game cartridges. See also Samuelson, *supra* note 246, at 44 (expressing skepticism that reuse would be easy to achieve because of copyright owners' relative position of power).

249. For more detail on this issue, see generally Lemley, *supra* note 209.

250. See *Manifesto*, *supra* note 2, at 2332-33 (concluding that most program value does in fact stem from know-how unprotected by copyright law).

251. Specifically, they will do so if a license for the component is unavailable or is costlier than reverse engineering.

252. See Joseph Farrell, *Standardization and Intellectual Property*, 30 JURIMETRICS J. 35, 47 (1989) (arguing that portions of a program necessary to achieve software interoperability should remain unprotected so that more software developers will design with an eye toward compatibility).

253. In fact, copyright law may also encourage software developers to sell integrated systems rather than individual components by giving protection to a compilation of components which are individually uncopyrightable. See, e.g., *Apple Computer, Inc. v. Microsoft Corp.*, 35 F.3d 1435, 1439, 1446-47 (9th Cir. 1994) (stating that a collection of uncopyrightable user interface elements could as a whole receive minimal protection against virtually identical copying), cert. denied, 115 S. Ct. 1176 (1995).

C. Software Patents and Components Markets

Patent law is more consistent with the development of a components market. Unlike copyright and trade secrecy, patent rights are "strong" in an absolute sense. They do not depend on limited disclosure or on proof of copying, but extend to *any* use of the claimed invention. Because of their strength, patents eliminate a major problem with copyright protection: the incentive to reinvent software in order to appropriate the ideas in the software component without infringing the original producer's copyright.²⁵⁴ If an integrator wants to use the ideas in a patented software component, he must license the patent from the producer of the component.²⁵⁵ And once the existence of patent rights for components forces the parties to the bargaining table, the transaction costs of licensing the code itself drop dramatically. Why should the integrator license only the idea and then reinvent the code from scratch, when he could license the whole thing in one transaction?

254. Certain proposals for sui generis legal protection of computer programs could also solve this problem. See *Manifesto*, *supra* note 2, at 2312; cf. Richard H. Stern, *On Defining the Concept of Infringement Of Intellectual Property Rights in Algorithms and Other Abstract Computer-Related Ideas*, 23 AIPLA Q.J. 401, 519-23 (1995) (proposing unification of software infringement tests under a "petty patent" system). However, because as a practical matter such proposals are unlikely to be adopted, we have chosen to focus on patent law. See Jane C. Ginsburg, *Four Reasons and a Paradox: The Manifest Superiority of Copyright Over Sui Generis Protection of Computer Software*, 94 COLUM. L. REV. 2559, 2565-66 (1994) (arguing that software proprietors will resist replacing satisfactory copyright protection with the *Manifesto*'s proposed compulsory license registration). See generally Paul Goldstein, *Comments on A Manifesto Concerning the Legal Protection of Computer Programs*, 94 COLUM. L. REV. 2573 (1994) (articulating attacks on its foundational premises and its operational details that the *Manifesto* would need to withstand if it entered the legislative marketplace).

255. See Mark Aaron Paley, *A Model Software Patent Act*, 12 SANTA CLARA COMPUTER & HIGH TECH. L.J. 301, 328 (1996) (explaining that Microsoft OLE technology allows applications based on prebuilt components which "increases the need for mandatory licensing because it is so easy to put a little program inside another program"). Classic economic literature suggests that vesting strong property entitlements in a single party will encourage that party to make efficient use of the property. See, e.g., Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. 347, 354-56 (1967); Trotter Hardy, *Property (and Copyright) in Cyberspace*, 1996 U. CHI. LEGAL F. (forthcoming 1996). Rob Merges has explored this issue in detail in the context of intellectual property. See Robert D. Merges, *Intellectual Property and the Costs of Commercial Exchange: A Review Essay*, 93 MICH. L. REV. 1570 (1995) [hereinafter Merges, *Commercial Exchange*]. When the property is part of a larger package in which entitlements are owned by different parties, the problem becomes more complex. Compare Ian Ayres & Eric Talley, *Solomonic Bargaining: Dividing a Legal Entitlement to Facilitate Coasean Trade*, 104 YALE L.J. 1027, 1029-30 (1995) (noting that in the context of imperfect bargaining, dividing entitlements to property through liability rules may reduce the incentives for strategic behavior and induce each bargainer to reveal more information) with Louis Kaplow & Steven Shavell, *Do Liability Rules Facilitate Bargaining?: A Reply to Ayres and Talley*, 105 YALE L.J. 221, 228-29 (1995) (arguing that strong property entitlements result in greater bargaining-related welfare gains than divided entitlements in the context of imperfect bargaining). On the development of market mechanisms that mimic liability rules, compare Robert P. Merges, *Contracting into Liability Rules: Institutions Supporting Transactions in Intellectual Property Rights*, 84 CAL. L. REV. 1293 (1996) [hereinafter Merges, *Liability Rules*] (arguing that establishing property entitlements is the only way to get parties to bargain over the value of intellectual property rights) with Richard R. Nelson, *Intellectual Property Protection for Cumulative Systems Technology*, 94 COLUM. L. REV. 2674, 2676 (1994) (claiming that strong intellectual property protection in multiparty bargaining environments may slow innovation). Cf. Lee Hollar, *Justice Douglas Was Right: The Need for Congressional Action on Software Patents*, 23 AIPLA Q.J. (forthcoming 1996) (suggesting that buying commercial components, rather than reinventing them, may serve as a form of insurance against patent infringement claims).

Properly interpreted, patent law should also help solve the interoperability problem.²⁵⁶ Most patentable inventions in computer science are not whole software programs but particular ideas or approaches to specific problems. Entire software programs are unlikely to be protected by patent law, but the components themselves (and even smaller "subcomponents") will probably qualify for patent protection. Under patent law, the "invention" of putting two components together should ordinarily fail to satisfy the requirement of nonobviousness, at least if the patent office evaluates obviousness using the standard of a reasonable programmer skilled in the relevant art.²⁵⁷ Thus, patent protection for innovative components should provide both of the basic requirements for the development of an interchangeable components market: strong protection for each component itself and little or no protection for vertical interoperability elements.²⁵⁸ Licensing should be easier under a pure patent system than under a pure copyright system, since patent law precludes the overlapping claims to interface elements that copyright law produces. Over the longer term, patent protection will also help solve the problem of secret code, since patent owners will have to disclose their inventions to the public to obtain a patent, and those inventions will be free for all to use once the patent expires.²⁵⁹

Further, dividing property entitlements by patenting software components may leave the developers of integrated software programs no choice but to negotiate licensing agreements with others in the industry. Because programming inventions tend to be directed toward particular techniques for solving defined problems, one company will likely not possess all of the rights it needs to produce an integrated software system. It is more likely that different software developers will patent different techniques, algorithms, or program routines, and companies will have to obtain licenses from different developers in the process of producing an integrated system. For this reason, the concern that software patents will allow large companies to "lock up" rights to produce integrated software systems²⁶⁰ should be alleviated by the distributed owner-

256. See text accompanying notes 155-156 *supra*.

257. In practice, patent law has been lenient toward seemingly obvious combinations in the software industry. See notes 287-292 *infra* and accompanying text.

258. As Professor Merges explained:

Without the security of a property right granted by the government, software suppliers in Japan would be loathe to leave the protective contractual sphere they shared with their captive customer/patrons. But with such a right, enforceable outside the context of an individual contract . . . these firms are free to sell to other customers. Thus the establishment of the property right . . . mak[es] such transactions feasible.

Robert P. Merges, *A Comparative Look at Property Rights and the Software Industry*, in THE INTERNATIONAL COMPUTER SOFTWARE INDUSTRY: A COMPARATIVE STUDY OF INDUSTRY EVOLUTION AND STRUCTURE 272, 282 (David C. Mowery ed., 1996); see also Merges, *Commercial Exchange*, *supra* note 255, at 1589-90.

259. See 35 U.S.C. § 112 (1994) (providing that the patent specification must describe the invention so that a person skilled in the art to which it pertains can make or use the invention); see also Hollar, *supra* note 255. Those who maintain code as a secret may lose their rights to that code to subsequent patentees. Regarding the problem of secret prior art, see note 286 *infra*.

260. See John Swinson, *Copyright or Patent or Both: An Algorithmic Approach to Computer Software Protection*, 5 HARV. J.L. & TECH. 145, 168-69 (1991) ("[E]xisting firms can stifle competition, and therefore innovation, by obtaining licenses over many different kinds of inventions, and keep rivals

ship of software patents and the consequent routine licensing of those patent rights.²⁶¹

Finally, in some respects patent law provides initial developers with less control over others' derivative works than does copyright law.²⁶² While improving a patented invention still requires a license from the owner of the original invention, substantial improvers can obtain their own patents for their improvement. Substantial improvers may thus take advantage of the rule of "blocking patents," under which either party can prevent the other from using the improved invention unless the parties negotiate a license.²⁶³ The reverse doctrine of equivalents, which excuses literal patent infringement in certain cases of radical improvement, may also benefit some improvers.²⁶⁴ The additional bargaining power which these rules give the improver should encourage others to improve on prior inventions. This patent law rule contrasts with the copyright rule, under which the improver loses the value of his unauthorized improvements if they are integrated with infringing material. Further, patent law should encourage licensing between original software developers and those who adapt or improve the original code,²⁶⁵ a critical element in the development of a software components market.

We therefore believe that a pure patent-based system is more conducive than a copyright-based system to the development of a market for reusable software components. Indeed, industries which have characteristics similar to computer software but which already rely primarily on patent protection (such as the semiconductor industry) have actually developed in this fashion.²⁶⁶ An-

out of the market by refusing to license, by charging excessive license fees, or by forcing rivals to waste resources inventing inferior processes that accomplish similar results in less efficient ways.").

261. See generally Merges, *Liability Rules*, *supra* note 255 (arguing that firms mitigate the effect of property rules in intellectual property cases by "contracting into" group licensing systems).

262. See Samuelson, *supra* note 246, at 34-35. This result may seem odd, given that patent rights are in most respects stronger than copyright rights. Patent law's leniency toward derivative works may stem from the different goals and origins of copyright and patent law. While patent law has traditionally sought to provide incentives for new innovation to improve products sold, copyright has generally focused more attention on the "moral" rights of authors over their creations. See generally Edward J. Damich, *The Right of Personality: A Common-Law Basis for the Protection of the Moral Rights of Authors*, 23 GA. L. REV. 1 (1988) (providing a rationale for greater protection of moral rights based on the right of personality in case law); Roberta Rosenthal Kwall, *Copyright and the Moral Right: Is an American Marriage Possible?*, 38 VAND. L. REV. 1 (1985) (arguing that the 1976 Copyright Act should include provisions protecting a creator's moral rights as distinct from the economic rights of copyright holders). Cf. Margaret Jane Radin, *Property and Personhood*, 34 STAN. L. REV. 957 (1982) (suggesting that fungible property rights should yield to personhood interests where the two conflict). But see Lemley, *supra* note 209 (rejecting the moral rights justification for different rules regarding improvements in patent and copyright law).

263. See Robert Merges, *Intellectual Property Rights and Bargaining Breakdown: The Case of Blocking Patents*, 62 TENN. L. REV. 75, 78-91 (1994) (discussing the bargaining breakdown that may occur when a pioneer and a radical improver hold patents that block each other).

264. See *id.* at 91-99 (suggesting the reverse doctrine of equivalents as a solution to the bargaining impasse).

265. See *id.* at 76 (stating that "the promise of a liberalized reverse doctrine will encourage more voluntary licensing in these cases").

266. See ANNALÉE SAXENIAN, *REGIONAL ADVANTAGE: CULTURE AND COMPETITION IN SILICON VALLEY AND ROUTE 128*, at 45 (1994). Saxenian writes:

Semiconductor firms, following the model set by AT&T's Bell Labs with the transistor, liberally cross-licensed their patents to competitors during the industry's first three decades. This

naLee Saxenian attributes the relative success of the Silicon Valley computer and semiconductor industries to their greater willingness to shift from internal self-sufficiency to reliance on purchasing hardware components from external sources, often from competitors.²⁶⁷

For the sake of argument, we have drawn a sharp contrast between copyright and patent regimes. In practice, however, the role of legal incentives in the software industry is more complex. In the first place, not every new software component is eligible for patent protection. Because of the strong rights patent law provides, the standards for obtaining a patent are higher than those for obtaining a copyright or a trade secret.²⁶⁸ Some, perhaps most, new components will fail to meet these standards because they are obvious to one skilled in the art.²⁶⁹ These will be essentially commodity components—interchangeable components produced by a variety of "manufacturers," which do not typically exploit advances in the state of the art. The linked list manipulation component suggested earlier,²⁷⁰ which presumably could be implemented by any moderately skilled programmer using a first semester computer science text as a guide, exemplifies such commodity type components. Because the linked list component is probably unpatentable, the analysis in this part would not apply to that component.

Even if many software components cannot be patented, patent law may still create powerful incentives for component licensing. If a typical integrated program contains six software components, a competitor with a patent on any one of those components can withhold permission to use his component and thus prevent development of the program. Integrators thus will have to negotiate with such patent holders to obtain permission to use the patented component. Even a modest number of software patents will force licensing in a significant number of cases over time. And as noted above, the number of software patents in force is already quite substantial.²⁷¹

The fact that patent rights to software techniques are likely to be owned by many different companies triggers the "blocking patents" situation, further encouraging licensing. It also helps allay concerns that software patents will simply perpetuate market dominance among companies that have controlled the copyright-driven software industry. Single firm market dominance is much harder to achieve when many companies control different (albeit small) pieces

pooling of inventions and devices ensured that technical advances diffused quickly and the industry as a whole progressed, regardless of the fate of any individual firm. In Robert Noyce's words: "Without [cross-licensing patents], no firm could be using the latest technology in all areas. One might be using epitaxy without diffusion, another oxide masking but not planar techniques, yet another making MOS transistors without the possibility of making integrated circuits."

Id.

267. See *id.* at 141-42 (discussing Sun Microsystems' use of outside suppliers for hardware, such as integrated circuits and disk drives).

268. See notes 135-138, 162-171 *supra* and accompanying texts.

269. See 35 U.S.C. § 103(a) (1994).

270. See text accompanying note 98 *supra*.

271. See note 173 *supra*.

of an industry. The decentralization achieved by dividing the property entitlement will drive software companies to license components to each other.

A second complicating factor is that the increase in the availability of patent protection for computer software has not eliminated the availability of copyright protection.²⁷² We do not argue that it should. At a minimum, public goods analysis calls for copyright protection against literal and near-literal copying for commodity type components that do not qualify for patent protection. Without such minimal protection, an imitator could immediately copy the component and enter the software component market at a lower cost than the initial producer of the code. In the case of many reusable software components, copyright protection against literal copying provides sufficient reassurance to producers creating reusable components. The market does not value commodity-type components for the new design concepts they contain; by definition, they merely implement well-known ideas in code. Thus, one of the primary reasons why copyright protection discourages reuse—the ability of competitors to take the design concept without taking the code—does not apply in the case of commodity type components, since their value resides entirely in the copyrighted code. In short, literal protection of source code and object code creates a sufficient incentive for producers to provide some commodity type reusable components in the external market. Indeed, such components are starting to be disseminated over the Internet.²⁷³ Limiting copyright protection also prevents the developer from controlling program interoperability interfaces, and therefore avoids some of the problems associated with stronger copyright protection.

A third factor is that a surprisingly large amount of code is produced as "freeware" or "shareware." This software is intended to be shared and distribution over computer networks is encouraged. Shareware is particularly common early in the development of any given software market, such as the market for computer games in the early 1980s and the current market for Internet "applets," executable programs written in Java, Sun Microsystems' new programming language. Because of freeware and shareware, we can reasonably assume that some software components will be free for anyone to use in producing integrated software systems. Such free components will be particularly valuable to entrepreneurs building new programs.

In sum, we do not suggest that computer software should switch from a pure copyright to a pure patent system, or that the relationship between legal

272. The new patent guidelines governing computer software make "functional" aspects of programs patentable, and "functional" elements of a work are theoretically unprotected by copyright. See *Computer Assocs. Int'l, Inc. v. Altai, Inc.*, 982 F.2d 693, 714 (2d Cir. 1992). Thus, the particular aspects of a computer program eligible for patent protection are arguably uncopyrightable. See also Lemley, *supra* note 142, at 26-27 (arguing that patent protection for functional software elements should preclude copyright protection for the same elements). Under this argument, only the functional elements which were eligible for patent protection would be uncopyrightable, not the entire computer program.

273. One factor that has favored the development of such components in the Internet programming environment is the development of the Java programming language, which is in some respects more amenable to component integration than standard programming languages such as C++. See Gus Venditto, *Java: It's Hot, but Is It Ready to Serve?*, *INTERNET WORLD*, Feb. 1996, at 76, 77.

incentives and the reuse of software is a linear one. We do believe that, for the reasons given, patent law is better suited than copyright law to an economy in which software components with a significant inventive aspect are externally traded, and that one effect of the current trend towards software patents will be to encourage reuse of such components. Further, we contend that weak copyright protection for software components will better encourage a software component market than would strong copyright protection. In the next section, we examine the consequences of developing patent protection for software components markets.

D. The Outlook for Developing a Reusable Component Market

Modern intellectual property protection demonstrates encouraging trends from the perspective of a market for reusable software components. A more limited form of copyright protection for software has replaced the strong copyright protection evident in a number of court decisions in the 1980s.²⁷⁴ Courts are much more skeptical of broad copyright claims to the "look and feel" of a computer program. Moreover, virtually all courts that have considered the issue have taken steps towards creating a right to copy program interface elements, at least when necessary to achieve vertical interoperability.²⁷⁵ Finally, although a competitor who copies portions of a producer's program occupies a more precarious position under the law than a downstream user, at least two courts have suggested that copyright in program components cannot be used to block either horizontal or vertical interoperability efforts by competitors.²⁷⁶

As the scope of copyright protection has diminished, the scope of patent protection has expanded.²⁷⁷ While uncertainty surrounding the patentability of software components has not entirely disappeared, both the PTO and the Federal Circuit have allowed software patents in a wide variety of circumstances. That decision would be hard to reverse at this point, even if the PTO or the Federal Circuit were willing to do so.

Despite this trend away from broad copyright protection toward expanded patent protection, some problems remain. Some large integrated computer software firms are seeking both to reexpand copyright protection for

274. See generally Lemley, *supra* note 142 (discussing this development); see also notes 149-161 *supra* and accompanying text.

275. See note 156 *supra* and accompanying text.

276. See *DSC Communications Corp. v. DGI Tech., Inc.*, 81 F.3d 597, 601 (5th Cir. 1996) (holding that the district court properly declined to issue preliminary injunction against company that booted up its competitor's microprocessor card); *Lotus Dev. Corp. v. Borland Int'l, Inc.*, 49 F.3d 807, 818-19 (1st Cir. 1995) (holding that defendant did not infringe competitor's copyright by copying menu command hierarchy for spreadsheet program), *aff'd by an equally divided Court*, 116 S. Ct. 804 (1996). The unsettled nature of the law with regard to horizontal copying arises from the conflicting goals of competition and intellectual property. Resolution of this conflict requires a court to consider not only relevant intellectual property law, but also antitrust law. For an argument that horizontal copying to achieve interoperability is necessary where the copied program has become a *de facto* standard, see Pamela Samuelson, *Software Compatibility and the Law*, *COMMUNICATIONS OF THE ACM*, Aug. 1995, at 15, 16.

277. See notes 149-162, 196 *supra* and accompanying texts.

software²⁷⁸ and to circumvent the rules of copyright altogether by expanding contract doctrine to cover shrinkwrap licenses which prohibit copying or adaptation.²⁷⁹ Either or both of these developments may cause the industry to return to a reliance on expansive copyright-like protection.

Further, the trend towards allowing software patents has not been coupled with a robust mechanism in the PTO to distinguish between obvious and non-obvious inventions. This problem has several parts. First, because it long considered software unpatentable, until recently the PTO did not employ examiners experienced in the software arts. As a result, many of the patents issued during the 1980s were not examined by those most skilled in the subject matter of the applications.²⁸⁰ Second, very little of the relevant prior art is cited in software patent applications.²⁸¹ Professor Julie Cohen explains:

[I]n the field of computers and computer programs, much that qualifies as prior art lies outside the areas in which the PTO traditionally has looked—previously issued patents and previous scholarly publications. Many new developments in computer programming are not documented in scholarly publications at all. Some are simply incorporated into products and placed on the market; others are discussed only in textbooks or user manuals that are not available to examiners on line. In an area that relies so heavily on published, "official" prior art, a rejection based on "common industry knowledge" that does not appear in the scholarly literature is unlikely. Particularly where the examiner lacks a computer science background, highly relevant prior art may simply be missed. In the case of the multimedia data retrieval patent granted to Compton's New Media, industry criticism prompted the PTO to reexamine the patent and ultimately to reject it because it did not represent a novel and non-obvious advance over existing technology. However, it would be inefficient, and probably impracticable, to reexamine every computer program-related patent, and the PTO is unlikely to do so.²⁸²

278. The likely test case for this effort, *Lotus v. Borland*, fizzled when an equally divided U.S. Supreme Court affirmed the First Circuit Court of Appeals' judgment in January 1996. *Lotus Dev. Corp. v. Borland Int'l, Inc.*, 116 S. Ct. 804 (1996).

279. Shrinkwrap licenses are license provisions that vendors package and "shrinkwrap" with their products, intending to bind customers to those terms through their opening of the plastic wrap and use of the product. Such shrinkwrap licenses are typically included in software products. See Mark A. Lemley, *Intellectual Property and Shrinkwrap Licenses*, 68 S. CAL. L. REV. 1239, 1241-42 (1995). In 1996, a court held for the first time that shrinkwrap licenses were enforceable, and could provide copyright-like protection even to uncopyrightable works. See *ProCD, Inc. v. Zeidenberg*, 86 F.3d 1447, 1452-53 (7th Cir. 1996). A draft proposal to create a new Article 2B to the Uniform Commercial Code would validate such shrinkwrap license provisions by statute. Both *ProCD* and the Article 2B draft run counter to the prevailing trend among courts to refuse to enforce shrinkwrap licenses. See Lemley, *supra*, at 1243 & n.23 (discussing cases). For a proposal on how to treat shrinkwrap licenses that alter federal intellectual property rights, see Merges, *Commercial Exchange*, *supra* note 255, at 1612-13.

280. For the somewhat surprising argument that this lack of examiner expertise has hurt rather than helped patent applicants, see Stuart P. Meyer, *Obtaining and Enforcing Patents for Software-Related Inventions: Avoiding the Pitfalls*, 5 SOFTWARE L.J. 715 (1992).

281. "Prior art" is any relevant knowledge, act, description, or patent which predates the invention in question. See *Mooney v. Brunswick Corp.*, 663 F.2d 724, 733 (7th Cir. 1981) (citing 35 U.S.C. § 102).

282. Cohen, *supra* note 17, at 1178 (citations omitted). Professor Cohen's argument is supported by a recent study of software patents, which concluded that "the most relevant art is not being considered by the Patent Office when issuing a software patent." David R. Syrowik, *United States Software Patents—An In-Depth Look*, 11:2 COMPUTER L. ASS'N BULL. 3, 4 (1996) (emphasis omitted); see also

A new approach to this problem is the creation of private "prior art" databases designed to make available for search those software techniques that have not been patented and are not otherwise available.²⁸³ In addition, database groups such as the Software Patent Institute propose to address complaints about the quality of software patent examinations by offering educational services to patent examiners.²⁸⁴ Online collections of software prior art may help to alleviate some, but not all, of the problems Professor Cohen describes.

The amount of prior art will increase as the large numbers of software patents that are currently being issued become prior art themselves, and can be cited against newer patent applications. Unfortunately, these software patents can be cited as prior art only if they can be found, and current classification techniques within the PTO make locating software patents difficult.²⁸⁵ In addition, much of the prior art which does exist, particularly source code manufactured by competing developers, is still maintained as a trade secret. There may be no way for the PTO to find and cite this material to oppose a patent claim.²⁸⁶

Finally, the patent laws are extraordinarily lenient towards inventions that consist of combining two different, previously known ideas to produce a new invention.²⁸⁷ This lenience results in the issuance of thousands of patents for the seemingly obvious idea of taking well-known physical world practices and

Garfinkel, *supra* note 173, at 105 (discussing the difficulty of searching for prior art involving software patents).

283. For a list of sources of prior art in the software industry, see GREGORY A. STOBBS, *SOFTWARE PATENTS* 122-147 (1995).

284. *Id.* at 141.

285. See *id.* at 121-22 (noting that current classification of software is too large to be useful). A study by one of the authors discovered that software patents were scattered throughout the PTO classification scheme. See Mark A. Lemley, *An Empirical Study of the Twenty-Year Patent Term*, 22 AIPLA Q.J. 369, 404-05 & n.100 (1995).

286. Cohen, *supra* note 17, at 1170. Secret prior art causes other problems for the patent process. For example, exploiting an invention by treating it as a trade secret can amount to concealment under section 102(g) of the patent code. If so, the "concealed" invention cannot be offered as prior art to bar a later inventor from patenting the same invention. 35 U.S.C. § 102(g); see Albert C. Smith & Jared A. Slosberg, *Beware! Trade Secret Software May be Patented by a Later Inventor*, COMPUTER LAW., Nov. 1990, at 15, 15 (discussing the problem of the status of secret prior art under 35 U.S.C. § 102(g)); see also George H. Gates III, *Trade Secret Software: Is It Prior Art?*, COMPUTER LAW., Aug. 1989, at 11, 11. In the era after *Gottschalk v. Benson*, 409 U.S. 63 (1972), this was not much of a threat, since patents for software were generally not available. See Himanshu S. Amin, *The Lack of Protection Afforded Software Under the Current Intellectual Property Laws*, 43 CLEV. ST. L. REV. 19, 24-25 (1995). Now, however, assuming an inventor is clever enough to phrase her patent claims in accordance with cases such as *In re Alappat*, 33 F.3d 1526 (Fed. Cir. 1994), and *In re Iwahashi*, 888 F.2d 1370 (Fed. Cir. 1989), patent protection is available. The result is that later inventors may be able to claim patent priority over earlier inventors of the same software. See Smith & Slosberg, *supra*, at 21-22. Section 102(g) not only makes it impossible for the first inventor to obtain a patent, but also directs the Patent Office and courts to disregard the first inventor's secret use when evaluating the validity of the second inventor's patent. In short, the combination of the section 102(g) rule and the growing role of patents creates a serious threat to established software vendors who have been relying on trade secret protection for a long time. In some such cases, the second inventor will have barred the first inventor from using her own invention, especially if the first inventor invented long before the second. See *id.*

287. To prove that such a combination invention is obvious, the Patent Office must show that a single prior art reference suggested that the ideas be combined, and that the combination is easily accomplished. See *In re Vaeck*, 947 F.2d 488 (Fed. Cir. 1991) (holding that a combination of prior art is obvious if "the prior art would have suggested to those of ordinary skill in the art that they should make

implementing them on computers using standard programming techniques.²⁸⁸ The problem with combination patents is particularly significant for the software components market. One advantage of using patents to encourage such a market is that they should give strong protection to the components themselves, but little if any protection to obvious combinations of preexisting components. In practice, however, the PTO allows these obvious software combination patents. If the PTO does not pay more detailed attention to patent applications,²⁸⁹ the practice of trading components will become more difficult, because a single firm will be able to patent and therefore control the integration of multiple components into a software program.²⁹⁰ Even worse, patents may issue on the integration or translation of software components, preventing any unauthorized combination of components.²⁹¹

A number of commentators have suggested that we curtail the issue of obvious combination patents by redefining the obviousness test to whether a programmer of ordinary skill in the art who desired to achieve a particular result using a computer could write such a program using standard programming techniques. If a programmer of ordinary skill in the art could do so, the new program should be *prima facie* obvious and therefore unpatentable.²⁹² This suggestion is both workable and consistent with patent cases in other contexts. Its adoption would help discourage the PTO from issuing overbroad patents which preclude the development of subsequent programs using standard programming techniques well known to those skilled in the art.

the claimed combination," and if the "prior art would also have revealed that in . . . making or carrying out [the combination] . . . those of ordinary skill would have a reasonable expectation of success").

288. See Cohen, *supra* note 17, at 1168-70. As one example, consider United States Patent No. 5,530,752 (entitled Systems and Methods for Protecting Software from Unlicensed Copying and Use), issued in July 1996 for a system that encrypts software by means of an existing encryption algorithm. But see *In re Raynes*, 7 F.3d 1037 (Fed. Cir. 1993) (affirming the Patent Board's determination that a simple patent for providing video information at a gasoline pump was obvious).

289. Alternatively, such patents may continue to be issued but will be invalidated by the courts. However, judicial review is not a perfect substitute for real examinations by the Patent Office. Litigants face a heavy burden of proof in showing that an issued patent is invalid. See *Intel Corp. v. U.S. Int'l Trade Comm'n*, 946 F.2d 821, 829 (Fed. Cir. 1991) (explaining that a patent is presumed valid, and invalidity must be proven by clear and convincing evidence). In addition, most licensed patents are never litigated. Thus, issuing such obvious patents could result in a myriad of unnecessary licenses.

290. By contrast, a patent system in which software patents are only issued to innovative software components is less likely than the old copyright system to enable one firm to capture a market for a particular type of integrated software program. When different companies own the patents for the components necessary for an integrated software program (a reasonable assumption in most software markets), a developer of an integrated program will need to license the patents from different parties. Dividing the legal entitlement into parts should reduce the threat that any one firm will dominate a particular market. For a discussion of the effects of such a divided entitlement, see Ayres & Talley, *supra* note 255, at 1027 (examining the effects of a divided entitlement through game theory analysis); Merges, *supra* note 263 (discussing ways to encourage voluntary transactions between patent holders).

291. See, e.g., United States Patent No. 5,530,852 (entitled Method for Extracting Profiles and Topics from a First File Written in a First Markup Language and Generating Files in Different Markup Languages Containing the Profiles and Topics for Use in Accessing Data Described by the Profiles and Topics) (claiming an SGML-HTML converter).

292. This is known as the "innovative programmer" standard. See Cohen, *supra* note 17, at 1169 (describing the standard suggested by Richard H. Stern, *Tales From the Algorithm War: Benson to Iwahashi, It's Deja Vu All Over Again*, 18 AIPLA Q.J. 371, 395 (1991)).

To be sure, the development of software components markets requires more than simply a properly designed intellectual property regime. Other legal rules and norms must exist for such a market to develop. For example, some mechanism must exist to permit parties to license their components at low cost to others and to divide profits made from multicomponent systems. Some recent evidence suggests that, left to themselves, industry participants may develop innovative solutions to this problem.²⁹³ Software companies' increasing tendency to conduct business transactions over the Internet also has the potential to improve component licensing, both because information about component capabilities and pricing is easily disseminated on the World Wide Web, and because parties can negotiate contract terms electronically.²⁹⁴ Both of these mechanisms require that antitrust law treat such cooperation among competitors more leniently than it has in the past.²⁹⁵ Some evidence demonstrates that antitrust law is willing to permit cooperative arrangements among competitors where such arrangements serve a market-making function.²⁹⁶

There are also nonlegal prerequisites for a successful software components market. Computer scientists who think of program writing as "art" and companies that are used to producing software entirely in-house will have to change their approaches to producing integrated software programs. Established companies and experienced programmers may resist a shift towards writing software incorporating components developed by someone else because they will have less control over the final product. While such resistance may delay the transition to software components markets, it will not prevent the development of such markets. Already, the newest generation of programmers and companies is adapting to the decentralized, component based world of the Internet. Interchangeable, plug-compatible applications and system software components including Web browsers, FTP, email and news clients, Internet protocol implementations, image and motion picture viewers, and audio players compete for places in the application suites of end users. Design innovation and implementation refinement in the market for such component applications

293. See Merges, *Liability Rules*, *supra* note 255 (describing the development of patent pools in innovative industries, and copyright collectives to license music); Stanley M. Besen, Sheila M. Kirby & Steven C. Salop, *An Economic Analysis of Copyright Collectives*, 78 VA. L. REV. 383 (1992) (describing copyright collectives). The development of such licensing programs among competitors may actually be more likely in industries characterized by strong network externalities, where users want to buy products compatible with those bought by others, such as the software components market. See Stanley M. Besen & Joseph Farrell, *Choosing How to Compete: Strategies and Tactics in Standardization*, J. ECON. PERSP., Spring 1994, at 117, 124-25 (explaining that companies in network markets are more likely to license their technology to competitors because of the company's desire to achieve the "industry standard").

294. On the potential for the Internet to reduce transactions costs, see I. Trotter Hardy, *The Proper Legal Regime for "Cyberspace"*, 55 J. PATT. L. REV. 993, 1033-36 (1994); Mark A. Lemley, *Shrink-wraps in Cyberspace*, 35 JURIMETRICS J. 311, 323 (1995).

295. See Jorde & Teece, *supra* note 229, at 36-55 (explaining how traditional antitrust laws can hinder innovation).

296. See *Broadcast Music, Inc. v. Columbia Broad. Sys., Inc.*, 441 U.S. 1 (1978) (holding that formation of "copyright collectives" by musicians to collect copyright royalties did not violate section 1 of the Sherman Act). For more detail on this subject, see Lemley, *supra* note 217. Cf. Dratler, *supra* note 46, at 736, 738 (suggesting that antitrust in some cases may encourage or even mandate the unbundling of compiled software products into their component parts).

is progressing at a rapid rate, with major releases occurring several times a year.²⁹⁷ In addition, Java "applets" promise a paradigmatic shift in both programming and software distribution methods, allowing components to be transparently and incrementally delivered on demand across the network.²⁹⁸ Peter Lewis predicts that "the shrink-wrapped packages that contain individual, monolithic applications are eventually going to disappear, to be replaced by object-oriented software components that are downloaded from the network."²⁹⁹

V. CONCLUSION

There are powerful reasons to encourage software reuse. Reusable software is more reliable than reinvented software, and reuse is much cheaper than reinvention once the reusable component has been written. A software components market will encourage competition among producers of components as well as among integrators of different components. This will be a great improvement over the current vertically integrated firms' monopoly of the market for de facto standards.

Traditional intellectual property rules discourage the development of such a market, both because they discourage the dissemination of new inventions (thus encouraging internal integration) and because they encourage reinvention as a means of circumventing copyright protection. The shift from copyright to patent as the dominant mode of protection for computer software is encouraging, however, because it promises to couple strong protection for novel components with a free market in interoperability. Up until now, legal doctrine has not optimally encouraged software reuse. In this article, we offer suggestions as to how the law can encourage the creation of a tradeable software components market. As legal barriers to software reuse continue to disappear, the trend toward component based software will accelerate, to the benefit of the industry.

297. Many such application components are updated monthly, even weekly, during periods of rapid development. The current release (version 2.1f) of Trumpet Winsock, a SLIP/PPP interface for connecting Windows PC to the Internet over dialup lines available from Trumpet Software, International, incorporates the refinements of nearly 50 minor releases over the last two years. Netscape Communications Corporation has brought three major releases of its popular Web browser, Netscape Navigator, to market in the past 12 months, and Microsoft's Internet Explorer is keeping pace.

298. According to Java developers at Sun Microsystems, "[t]here is no such thing as 'installing' software. It just comes when you need it Content developers for the World Wide Web don't have to worry about whether or not some special piece of software is installed in a user's system; it just gets there automatically." *The HotJava Browser: A White Paper*, (on file with the Stanford Law Review); see also David Bank, *The Java Saga*, WIRE, Dec. 1995, at 166, 240 (describing the functionality of an early Java prototype).

299. Peter H. Lewis, *Personal Computers: New World Brought to You by . . .*, N.Y. TIMES, July 30, 1996, at C7.