
Managing Intellectual Capital:

LICENSING AND CROSS-LICENSING IN SEMICONDUCTORS AND ELECTRONICS

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One of the most significant emerging business developments in the last decade has been the proactive management of intellectual capital by innovating firms. While firms have for decades actively managed their physical and financial assets, until quite recently intellectual property (IP) management was a backwater. Top management paid little attention and legal counsel did not participate in major managerial decisions. This is changing. High-technology firms now often have "IP" managers as well as "IT" managers.¹ In some firms considerations of intellectual capital management have expanded from the mere licensing of residual technology to become a central element in technology strategy. This development is spurred by the increasing protection afforded IP worldwide and by the greater importance of technological know-how to competitive advantage. These developments herald a new era for management.

Patents and trade secrets have become a key element of competition in high-technology industries. In electronics and semiconductors, firms continually make large investments in R&D in their attempts to stay at the frontier and to utilize technological developments external to the firm. Fierce competition has put a premium on innovation and on defending IP from unlicensed imitators. As IP owners have taken a more active stance regarding their patent portfolios, industry participants increasingly find it necessary to engage in licensing and cross-licensing.² Moreover, and relatedly, royalty rates have risen. The effect has been positive for firms with strong portfolios, who are now able to capture considerable benefit from their patent estates. Firms that are high net users of others' patents have a choice. They must increasingly pay royalties, or they must develop their own portfolios so as to bring something to the table in cross-licensing negotiations.

The new environment affords new challenges. If a firm is to compete with advanced products and processes, it is likely to utilize not only its own technology, but also the patents of others. In many advanced products, the range of technology is too great for a single firm to develop its entire needs internally. In cumulative technology fields such as electronics and semiconductors, one innovation builds on another. There are inevitably overlapping developments and mutually blocking patents. It is likely that firms will need to cross-license patents from others to ensure that they have freedom to manufacture without infringement. Thus in many industries today, firms can generate value from their innovation not only by embedding it in new products and processes, but also through engaging in licensing and cross-licensing.

In electronics and semiconductors, cross-licensing is generally more complex than the exchange of individual patent rights. The size of the patent portfolios of some firms is often too great for it to be feasible to identify individual infringements. Companies may own thousands of patents, used in literally tens of thousands of products, and may add hundreds more each year. With this degree of overlap of technology, companies protect themselves against mutual infringement by cross-licensing portfolios of all current and future patents in a field-of-use, without making specific reference to individual patents. It is simply too cumbersome and costly to license only the specific patents you need for specific products. The portfolio approach reduces transactions costs and allows licensees freedom to design and manufacture without infringement.³

An important dimension of field-of-use cross-licensing is the calculation of balancing royalty payments, according to the relative value of the patent portfolios of each party. This calculation is made prospectively, based on a sample of each firm's leading patents. Weight is given to the quality and market coverage of the patents. Desirable portfolios have excellent patents covering technology widely used in the industry. A quality portfolio is a powerful lever in negotiating access to required technology and may lead to significant royalty earnings or, at a minimum, to reduced payments to others. Obviously, a firm which is a large net user of other firms' patents, without contributing comparable IP in exchange, is likely to have to pay significant royalties.

Many managers now understand the use of licensing and cross-licensing as part of business strategy as well as the importance of a valuable patent portfolio. The key to successful cross-licensing is a portfolio of quality patents that covers large areas of the partner's product markets. Significantly, for the balancing process, the firm should not necessarily emulate the portfolio of its cross-licensing partner. Rather it should concentrate R&D in those areas in which it does best and has the most comparative advantage to develop patents that its partners need. This will give maximum leverage in negotiating access and balancing royalties. This might be in product design, software, or manufacturing processes, wherever the firm's R&D is most effective and its IP most widely used. In this sense, cross-licensing has a double positive effect on innovation. It allows firms greater means of earning a return on innovation (to help fund further

R&D), while allowing firms to concentrate their innovation and patenting activities according to their comparative advantage. In this way, firms can develop complementary rather than duplicative technology, thereby benefiting the public interest.

The unprecedented rates of technological development in the electronics industries have been made possible by a combination of the ability to capture value from innovation and the freedom to design and manufacture. Cross-licensing has been crucial. A key lesson for managers is to be aware of the value of developing a strong, high-quality IP portfolio and the effect this can have on licensing and cross-licensing strategies. This protects the firm's innovations and may significantly reduce royalty payments and fund further R&D.

The Licensing Legacy

Background—The Formation of RCA

Cross-licensing is not a new phenomenon in electronics; it goes back almost to the beginning of the industry. Cross-licensing is typical of industries involved in "cumulative systems technologies," where one innovation builds on another and products may draw on several related technologies. Multiple firms develop patented innovations in the same technological fields, and the "state of the art" of the technology tends to be covered by a large number of different patents held by different firms. Because of the potential for mutually blocking patents, firms typically cross-license all patents in a field-of-use to ensure adequate access to technology. The strongest examples of cumulative systems technologies are in electronics, including computers and semiconductors, where extensive cross-licensing ensures "design freedom" or "freedom-to-manufacture."⁴ Note that this is a different situation than in some other industries not characterized by cumulative systems technologies, such as chemicals and pharmaceuticals, where cross-licensing, or, rather, reciprocal licensing, is typically aimed at exchanging technology rather than avoiding patent interference.⁵

An important instance of field-of-use cross-licensing is the development of radio in the first quarter of this century.⁶ It epitomizes the complexities surrounding intellectual property arrangements that may be encountered with cumulative systems technologies. Also, many of the cross-licensing ideas used later by the electronics industry were pioneered during the early days of radio.

The commercialization of radio required a number of basic inventions. The scientific basis for wireless was developed by university scientists such as Maxwell, Hertz, and Lodge in the 19th century. Their discoveries were first applied to practical communication with the development of wireless telegraphy by Marconi in Britain in 1896. The first speech transmissions were made in the U.S. by Fessenden in 1900, using a high-frequency alternator. Further basic innovations were made over the next two decades.⁷

Many of these inventions were initially developed by individuals working independently of each other. Indeed, many carry the name of the inventor, such as the Poulsen arc, the Fleming valve, and the de Forest triode.⁸ As the potential for radio became apparent, and the need for large-scale R&D and investment grew, large corporations entered the field. The pace of development accelerated and the number of patents multiplied. The companies involved included Marconi, General Electric (GE), Westinghouse, AT&T, Telefunken, and others. In addition to their considerable R&D effort, these corporations also acquired key patents where appropriate.⁹ There was considerable competition, and with research teams in different companies working in parallel, patent interferences were common.¹⁰ By 1918, it was apparent that several technologies were needed to manufacture radio systems, and each of these technologies itself involved multiple patents from different firms. In the words of Armstrong, one of the pioneers of radio, "It was absolutely impossible to manufacture any kind of workable apparatus without using practically all of the inventions which were then known."¹¹

The result was deadlock. A number of firms had important patent positions and could block each other's access to key components. They refused to cross-license each other. It was a "Mexican standoff," with each firm holding up the development of the industry.¹² The situation arose in large part as a result of the way radio had developed. Key patent portfolios had been developed by different individuals and corporations, who were often adamant about refusing to cross-license competitors. Also, in a new industry in which large scale interference was a novel problem, there was no well developed means of coordinating cross-licensing agreements between these groups.

The situation was resolved in the U.S. only when, under prompting by the U.S. Navy, the various pioneers formed the Radio Corporation of America (RCA) in 1919.¹³ This broke a key source of the deadlock. RCA acquired the U.S. rights to the Marconi patents, and cross-licensed the U.S. rights for other major patent portfolios.¹⁴ The major U.S. patent holders became shareholders in RCA. In this way, RCA acquired the U.S. rights to all the constituent radio patents under one roof—amounting to over 2,000 patents.¹⁵ It established RCA as the technical leader in radio, but also enabled the other cross-licensees to continue their own development of the technology for use in other fields or as suppliers to RCA. The RCA cross-licensing agreements became a model for the future.¹⁶

The case shows that because of the reluctance of the parties to cross-license, technological progress and the further commercialization of radio was halted. In this case, the debacle was resolved only by the formation of RCA, a rather radical organizational solution. However, it became clear from the experience that the same ends—namely design freedom—may be achieved more simply, without such fundamental reorganization, by cross-licensing alone. This helped set the stage for further development of cross-licensing in electronics.

AT&T's Cross-Licensing Practices

The need to achieve design freedom was soon experienced in other fields of electronics and resulted in patent cross-licensing agreements. One of the most influential firms in shaping the industry practices was AT&T, whose licensing and cross-licensing policy, especially from the 1940s until its breakup in 1984, has been crucial to the development of similar practices in U.S. electronics and semiconductor industries.

Over its long history, AT&T's licensing policy has had three phases, reflecting changes in its overall business strategy. First, from AT&T's establishment in 1885 until its first antitrust-related commitment in 1913, it used its IP rights in a forthright fashion to establish itself in the service market.¹⁷ In the second phase, from 1914 until 1984, AT&T became a regulated monopoly. Its policy (as a matter of law under the 1956 antitrust consent decree) was to openly license its IP to everyone for minimal fees. Reasons of technology access similar to those in radio led to patent cross-license agreements between the major producers of telephone equipment, starting in the 1920s. This developed into a more widespread policy. It was during this period that the transistor was invented at Bell Labs. This and other breakthroughs laid the foundation for the semiconductor industry and shaped the development of the telecommunications, computer, and electronics industries. In the current phase, dating from divestiture in 1984, AT&T is no longer bound by the consent decree, and its IP licensing can be aligned with its proprietary needs.¹⁸

The 1956 antitrust consent decree required AT&T to openly license all patents controlled by the Bell System to any applicant at "reasonable royalties," provided that the licensee also grant licenses at reasonable royalties in return. AT&T was also required to provide technical information with the licenses on payment of reasonable fees; licensees had the right to sublicense the technology to their associates.¹⁹ The impact of AT&T's liberal licensing on the industry was considerable, especially when considered in parallel with that at IBM.²⁰

To a large extent, the licensing terms in AT&T's 1956 decree simply codified what was already AT&T policy. As an enterprise under rate-of-return regulation, it had little reason to maximize royalty income from its IP. Instead, it used its technology and IP to promote new services and reduce costs. It procured a tremendous amount of equipment and materials on the open market and apparently figured that its service customers would be better off if its technologies were widely diffused amongst its actual and potential suppliers, as this would lower prices and increase the performance of procured components.²¹ It was the first company we are aware of to have "design freedom" as a core component of its patent strategy. It did not see licensing income as a source of funds for R&D, as Bell Labs research was largely funded by the "license contract fee," assessed on the annual revenues of the Bell operating companies. This very stable source of research funding supported a constant stream of basic innovations.²² Using its own portfolio as leverage, AT&T was able to obtain the (reciprocal) rights it

needed to continue to innovate, unimpeded by the IP of others. It successfully accomplished this limited objective.

An interesting aspect of AT&T's IP strategy was that technologies (though not R&D programs) were often selected for patent protection based on their potential interest to other firms generating technology of interest to AT&T. Since the legal requirement for open licensing specifically did not extinguish all of AT&T's intellectual property rights, the company was able to gain access to the external technology that it needed, while contributing enormously to innovation in telecommunications, computers, and electronics worldwide.²³

The terms of AT&T's licenses set a pattern that is still commonplace in the electronics industries. The "capture model" was defined in the consent decree.²⁴ Under this arrangement, the licensee is granted the right to use existing patents and any obtained for inventions made during a fixed capture period of no more than five years, followed by a survivorship period until the expiration of these patents and with subsequent agreement renewals. The open licensing regimes this led to were persistent, since with the long survivorship period on many of the basic patents, there was limited scope to introduce more stringent conditions for new patents.

AT&T's licensing policy had the effect of making its tremendously large IP portfolio available to the industry worldwide for next to nothing. This portfolio included fundamental patents such as the transistor, basic semiconductor technology, and the laser, and included many other basic patents in telecommunications, computing, optoelectronics, and superconductivity. Shaped under antitrust policy reflecting the needs and beliefs of an era in which U.S. firms did not have to worry much about foreign competition, such a liberal policy appears quite anachronistic today. However, there is no doubt that it provided a tremendous contribution to world welfare. It remains as one of the most unheralded contributions to economic development—possibly far exceeding the Marshall Plan in terms of the wealth generation capability it established abroad and in the United States.

The traditional cross-licensing policy of AT&T was greatly extended following the invention of the transistor. Widespread "field-of-use" licenses in the semiconductor industry is a legacy, as the industry was founded on the basic semiconductor technology developed by AT&T. In the early days of semiconductor technology, AT&T controlled most of the key patents in the field. It soon realized that, given the importance of semiconductor technology, other electronics companies were developing their own technologies and could eventually invent around the AT&T patents. Cross-licensing ensured that AT&T would have reciprocal access to this technology and be able to develop its own technology without risking patent interference.²⁵

AT&T's liberal licensing allowed the semiconductor industry to grow rapidly, and members of the industry did not care much about individual patents. The culture of the industry still reflects this, with a tradition of spin-outs

and new ventures, open communications and frequent job changes.²⁶ The continued speed of technological progress in the industry and the difficulty of monitoring technological use are reasons why there is still a need for the transactional simplicity associated with “lump-sum” or bundled licensing.²⁷ With individual product life cycles short compared with the long patent lives, any new innovation is likely to infringe several existing patents. Licensing thus typically involves clusters of patents.

Not surprisingly, AT&T now uses its IP more strategically. No longer bound by the consent decree, and with R&D funding no longer guaranteed by the telephone subscribers, its IP policy is necessarily linked more closely to individual business opportunities. This is especially true of trade secret licensing, which is often a key component of international joint ventures, involving omnibus IP agreements combining patents, trademarks, and know-how.

Cross-Licensing in the Computer Industry—IBM

A second major influence on licensing practice across the electronics industry has been IBM. It has long been heavily involved in licensing and cross-licensing its technology, both as a means of accessing external technology and to earn revenues. In many ways, it has been in a similar position to AT&T in that it has been a wellspring of new technology but was also subject to a consent decree in 1956 that had certain compulsory licensing terms. Under the IBM consent decree, IBM was required to grant non-exclusive, non-transferable, worldwide licenses for any or all of its patents at reasonable royalties (royalty free for existing tabulating card/machinery patents) to any applicant—provided the applicant also offered to cross-license its patents to IBM on similar terms. The provision covered all existing patents at the time of the decree (i.e., as of 1956) plus any that were filed during the next five years. The rights lasted for the full term of the patents.²⁸

IBM's cross-licensing activity continues today. IBM states that it is “exploiting our technology in the industry through agreements with companies like Hitachi, Toshiba, Canon, and Cyrix.” Patent and technology licensing agreements earned \$640 million in cash for IBM in 1994.²⁹ IBM is one of the world's leading innovators, with more U.S. patents granted in each of the three years from 1993 to 1995 than any other company (see Table 1).

The central importance IBM attaches to its patent portfolio in providing an arsenal of patents for use in cross-licensing and negotiating access to outside technology has been borne out in public statements by the company.³⁰ For IBM, the main object of its licensing policy has been “design freedom,” to ensure “the right to manufacture and market products.” To be able to manufacture products, IBM needs rights to technology owned by others:

Market driven quality demands that we shorten our cycle times. This means we have to speed up the process of innovation. And that means there is less time to invent everything we need. We can't do everything ourselves. IBM needs to have access to the inventions of others.³¹

TABLE I. Top Ten U.S. Patent Recipients (1990-1995)

Company	US Patents Received					
	1990	1991	1992	1993	1994	1995
IBM	608	684	851	1,088	1,305	1,383
Canon	868	831	1,115	1,039	1,100	1,088
Motorola	396	614	662	731	839	1,012
NEC	448	441	462	602	901	1,005
Mitsubishi	862	964	977	944	998	971
Toshiba	891	1,031	1,036	1,064	985	970
Hitachi	902	962	973	949	1,002	909
Matsushita	351	467	616	722	782	852
Eastman Kodak	720	863	778	1,008	890	772
General Electric	785	818	943	942	973	757

Source: IFI/Plenum Data Corp., USPTO

It acquires these rights “primarily by trading access to its own patents, a process called ‘cross-licensing’.”³² IBM has often had the reputation of being a “fast follower” in some areas of technology, and it has used the power of its patent portfolio to negotiate the access needed. The company notes that:

You get value from patents in two ways: through fees, and through licensing negotiations that give IBM access to other patents. Access is far more valuable to IBM than the fees it receives from its 9,000 active [U.S.] patents. There is no direct calculation of this value, but it is many times larger than the fee income, perhaps an order of magnitude larger.³³

The effect of the consent decree for IBM, as for AT&T, was in large part to formalize policies that were already partly in effect. While IBM already used cross-licensing for design freedom where appropriate, the consent decree expanded the scope and in a sense prodded IBM into treating licensing and cross-licensing as a central aspect of its business.

Impact of Consent Decrees on Industry Development

The combined cross-licensing of basic technology by the technologically leading firms—AT&T, IBM, and others—had a profound influence on the development of the post-war electronics industry. The effect of the 1956 AT&T and IBM consent decrees was to make a huge range of basic semiconductor and telecommunications technology widely available for next to nothing to domestic and foreign firms. Even so, for AT&T and its existing cross-licensing partners, the AT&T 1956 consent decree merely formalized what was already established corporate policy. This was exchanged for rights to related technology where this was available; otherwise it was offered at low royalty payments. The availability

of the basic technology formed the basis for the rapid growth of the semiconductor industry. Given the common technological base, firms relied on the rapid development and introduction of new products to succeed.

Yet the very prevalence of AT&T, IBM, and others in licensing at low royalties also created a mind set in the industry that became accustomed to artificially low royalties. This contributed to some initial agitation, if not outrage, in some quarters when in the 1980s some intellectual property owners such as Texas Instruments began to seek market returns on their IP.³⁴

Licensing Practice at a Semiconductor Company— Texas Instruments³⁵

Licensing Objectives

In the semiconductor industry, IP licensing is an integral and essential element of competition, and a corollary of innovation. As noted above, the industry was launched with the invention of the transistor by Bell Laboratories in 1947. First commercial transistor production took place in 1952. By 1995, worldwide sales of the industry were over \$150 billion. Like other parts of the electronics industry, the semiconductor industry is characterized by wide use of cross-licensing. The main purpose of cross-licensing is to ensure “freedom-to-operate” or “design freedom” in an industry where there are likely to be large numbers of overlapping patents. Given rapid technological development and many industry participants, the probability is high that any new product or process will overlap technology developed by other firms pursuing parallel paths. Also, the technology often overlaps that developed in related industries, such as computers and telecommunications.

The licensing procedures and royalty rate determination process at Texas Instruments (TI) illustrates the ways in which cross-licensing agreements are used in practice. TI has two main licensing objectives. The first and primary objective is to ensure freedom to operate in broad areas of technology supporting given product markets, without running the risk of patent infringement litigation by other firms with similar technology. Agreements cover groups of patents within designated “fields-of-use,” including existing and new patents developed within the fixed term of the agreement. The second objective is to obtain value from the firm’s IP, in the form of its patent portfolio, by generating royalty income. The purpose and result of royalty payments received under cross-licensing agreements is “competitive re-balancing,” which equalizes the net cost and profit advantage for imitators who otherwise might free-ride on technology TI developed.

Buying “freedom-to-operate” is vital in the semiconductor industry, with its rapid innovation, short product life cycles, and ubiquity of patents. In a typical technological field, there may be as many as a half dozen other firms with patents that an innovator could potentially infringe while implementing its

independent research strategy. In semiconductor devices and manufacture, there are huge numbers of patents to consider, with many more generated each year, as seen in Table 2. Bear in mind that a particular product can utilize technology from several other technology fields, such as computers, software, materials, communications, and general systems, each with large patent establishments.

At the start of an R&D program, possible infringements cannot be easily predicted, as firms are quite ignorant of the R&D and product development plans of competitors. Yet a firm investing in R&D and product development needs to be confident that patents developed through independent R&D efforts by others will not hinder commercialization of its technology. Consider that a wafer production facility now costs \$1 billion.³⁶ The facility may have a five-year life or longer, and it is not known in advance what products will be developed for manufacture during that time. R&D is similarly becoming more expensive. Companies need to be able to develop new products to fill the wafer fabrication facilities without being concerned that startup may be blocked by patents owned by competitors and other companies inside and outside the industry.

One approach for a developer to deal with the IP rights of others would be simply to identify all infringements as they arise, and negotiate separate licenses for each. However, the transactions costs of such an approach would be inordinate.³⁷ Moreover, it would expose the potential licensee to large risks.

A typical cross-license includes all patents that licensees may own in a given field-of-use, giving each firm the freedom to infringe the other's existing and future patents for a given period, typically five years. Such licenses are typically non-exclusive and rarely include any trade-secret or know-how transfer or sublicensing rights.³⁸

In a cross-license, technology is not usually transferred, as the parties each are capable of using the technology in question without assistance. Firms will usually gain access to the relevant technology either by developing it

TABLE 2. U.S. Patents Granted in Semiconductor Devices and Manufacture (1969-1994)

Company*	Patents granted (1969-94)	Patents granted (1994)
IBM	3,435	220
Toshiba	2,492	245
Texas Instruments	2,366	231
AT&T	2,342	110
Hitachi	2,218	170
Motorola	1,882	210
Mitsubishi	1,691	275
RCA	1,601	0
Siemens	1,518	46
U.S. Philips	1,482	61
General Electric	1,446	48
NEC	1,360	261
Fujitsu	1,335	125

* Companies with over 1,000 semiconductor patents granted (1969-94). Source: USPTO, 1995

themselves, or by other means such as reverse engineering, hiring consultants, other technical agreements, or technical publications.³⁹ In either case, the cross-license primarily confers the right to use the patented technology without being sued for infringement. This avoids monitoring costs and adjusts royalty payments to reflect overall contributions to the stock of IP currently in use.⁴⁰

In the semiconductor industry, licensing agreements sometimes go further, and may include transfer of trade secrets and know-how. However, trade secret licenses are quite different, typically involve technology transfer, and often accompany a joint venture or strategic alliance. Technology transfer involves significant costs and managerial effort, and often "creates competitors", as it frequently transfers to the licensee important technological capabilities otherwise inaccessible.⁴¹

Types of Cross-Licenses

There are two main models for cross-licensing agreements in the semiconductor industry: "capture" and "fixed period." In the "capture" model the licensee has rights to use, in a given field-of-use, all patents within a technological field which exist or are applied for during the license period, usually five years, and, importantly, retains "survivorship" rights to use the patents until they expire, up to 20 years later. The agreement does not generally list individual patents, but some patents of particular strategic importance to the licensor may be excluded. In the "fixed period" model the licensee has similar rights to use patents existing or applied for during the license period, but with no survivorship rights once the license period has expired. This requires full renegotiation of the cross-license for succeeding periods.

TI has been a leader in the use of fixed period licensing, which is becoming more widely used. The capture model became widespread through the industry following its use by AT&T and IBM. It gives broad rights to patents for a long period. The fixed period model allows more flexible commercialization of patent portfolios, since licensing terms can be periodically adjusted to account for changes in competitive conditions and the value of the technology. This increases strategic flexibility and allows the parties more freedom to negotiate royalty terms so that they more closely mirror the value of the patents. It is a logical evolution of licensing practices reflecting the difficulties and changes in the market for know-how.

"Proud List" Royalty Valuation Process

Balancing payments are negotiated as part of the agreement, to account for the relative value of the IP contributed by two firms. Each firm's contribution is evaluated by estimating the value of a firm's patent portfolio to its licensing partner, with the net royalty payment to the one with the greater contribution. Where both firms contribute similar portfolio values, the net payment will be small or zero. Where one firm has developed little technology and the other a great deal, the payments may be significant. Occasionally, cross-licenses are

royalty-free because contributions are either very close or difficult to assess. However, even in royalty-free agreements it should not be assumed that a detailed patent balancing process has not taken place. Also, the cross-license may be included as part of a larger joint venture.

Royalty balancing is performed according to a “proud list” procedure. In this procedure, each firm identifies a sample list of its most valuable patents and this is used as a representative proxy group for estimating the value of the entire portfolio. There is a great deal of preparation before the negotiations. Having identified a potential cross-licensing candidate, TI first performs extensive reverse engineering of the other’s products to assess the extent of any infringement—called “reading” the patents on the infringer’s products—and identifies product market sizes involved. This may take a year of effort.⁴² As part of this effort, it generates the proud list of about 50 of its major patents which it believes are being infringed, and which apply over a large product base of the other firm. The other firm also prepares a proud list of its own strongest patents.

In the negotiations, each of the sample patents is evaluated by both sides according to its quality and coverage. Quality measures include: the legal validity and enforceability of the patent; the technological significance of this feature to the product compared with other (non-infringing) ways of achieving the same end; and the similarity between the infringing features and the patent. These determine quality weighting factors for each patent so that a legally strong patent, which is hard to invent-around and is close to the infringing feature, has a high relative weight. The coverage is the size of the infringer’s product market using the patent. Each patent is assigned a nominal royalty rate, which is then multiplied by its quality weighting factor and the annual sales of the affected product base to arrive at a dollar amount. Certain patents of particular strategic significance to the technology are assigned a flat rate as a group and do not go through the weighting process.

The dollar amounts are summed for all the listed patents and expressed as a royalty rate percentage of the licensee’s total sales. Typically, the values of each side’s estimated royalty payments are netted out to give a single royalty rate paid by the firm with the less valuable portfolio.⁴³ This royalty rate applies to the licensee’s sales for the term of the license. When the license expires the same procedure will be used to reevaluate the relative portfolio values for the next five years.⁴⁴

Strategic Considerations

TI’s procedures provide a formal mechanism for determining royalty rates based on best estimates of the economic and technological contribution of the patent portfolios of the two firms. These procedures have been applied to a wide variety of relative IP contributions, both where these are roughly in balance and where not. Even so, there are often other considerations to include in final negotiations of a licensing agreement. Much depends on the individual needs of the parties, their negotiating strength, and the broader strategic considerations

of each firm. Individual rates and the overall rates also tend to recognize overall competitive effects of the royalty payments, as well as “what the market will bear.”⁴⁵

There is obviously an upper limit on royalties, since royalties that are too high will cripple the competitive capacities of the licensee, causing royalty payments to decline. If a potential problem in this respect exists, it is usually not with an individual agreement, which is likely to be set at reasonable royalty rates. Rather, problems may arise when a licensee is subject to claims from several licensors and the cumulative royalty payments become onerous. This can create serious problems in negotiating agreements with would-be licensees. There does not seem to be an easy solution to this problem, given that agreements are negotiated individually.⁴⁶

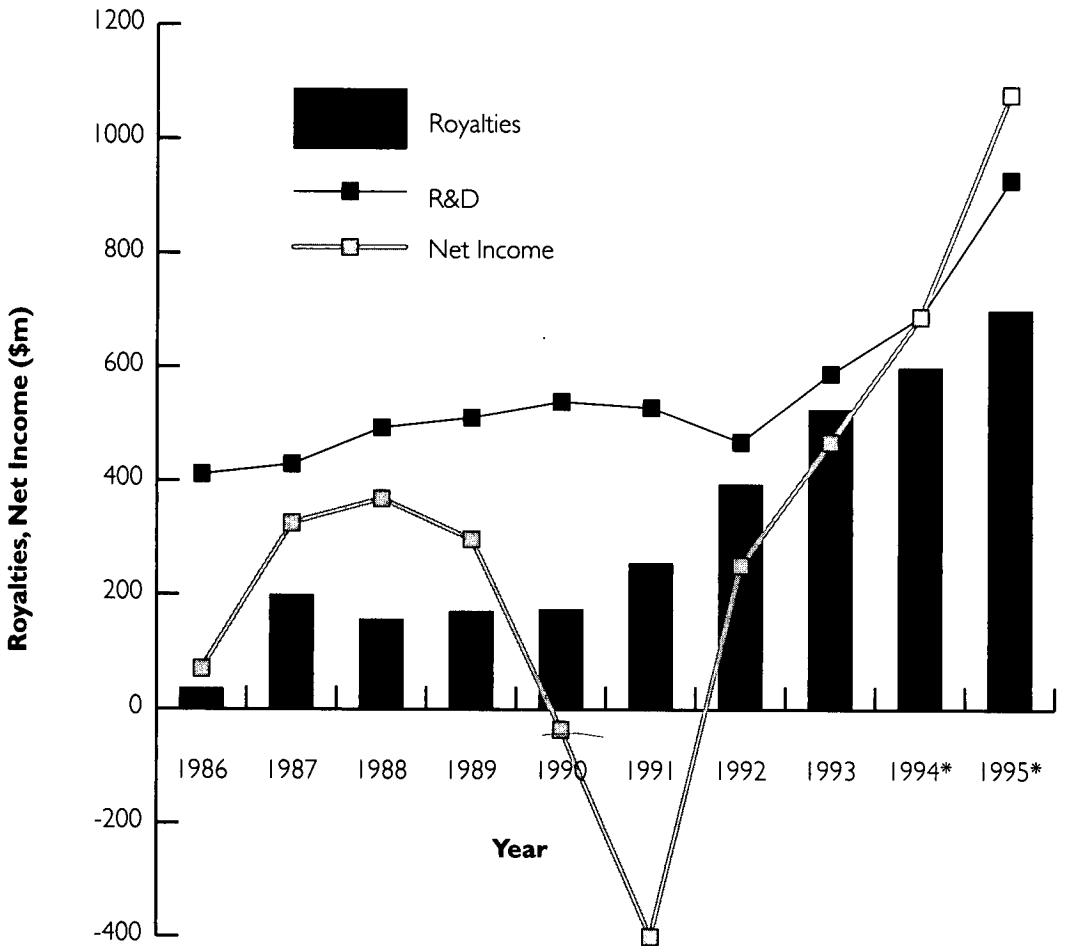
Royalty rates may also be affected by longer-term strategic considerations. For one thing, both parties are likely to need to renew the agreement in future, and an aggressive royalty rate now may make negotiations more difficult later, when the balance of IP may have shifted in a different direction. The firms may have, or expect to have, overlapping interests in other market areas, which will also condition negotiations. Licenses often may also be part of a cooperative venture of some kind. Patents can often be traded for know-how, or used as an entry ticket to a joint development arrangement. For example, rather than seek royalties, TI has had technology development agreements with Hitachi. It also has several manufacturing joint ventures around the world.

Strategic considerations may also affect the usual licensing process where the technology is intended to become part of an industry standard. Industry standards bodies sometimes require that patent holders agree to license their patents with low or zero royalty fees, often on a non-discriminatory basis. Similarly, when trying to establish a *de facto* market standard, a firm may charge low royalty rates.⁴⁷ The aim is to ensure the wide adoption of the technology as an industry-wide standard. Value from the technology may then be earned through product sales in an expanded market. The “reasonable rate” royalty involved is likely to be low, though need not be zero.⁴⁸

Impact of TI's Licensing Strategy

TI has led industry moves to take a more active stance on licensing and cross-licensing. The impact of its licensing strategy on its capability to compete and innovate is of particular interest. TI instituted its current licensing strategy in 1985. Cumulative royalty earnings of over \$1.8 billion had been achieved during the period from 1986 to 1993. Among other effects, this enabled TI to maintain a high level of R&D spending during 1989-91, when the semiconductor market was in a downturn, as shown in Figure 1. However, moving to a more active licensing strategy and the aggressive assertion of its IP rights was a major step for the company—and the industry—and involved considerable risk.⁴⁹ TI's strategy was enhanced by the stronger U.S. treatment of IP after 1982.

FIGURE I. Texas Instruments: Royalty Earnings, Net Income and R&D



*Royalties for 1994 and 1995 estimated
Source: Annual Reports

TI's IP portfolio has been valuable in negotiating R&D cooperation. For example, TI has had a series of ventures with Hitachi for the joint technological development of DRAM memory chips. TI's ability to supply technology, supported by its IP rights, was a crucial component in making these agreements.⁵⁰ TI's changed IP strategy has allowed it to implement new product market strategies to expand its manufacturing capacity by means of joint ventures, based partly on the negotiating value of its IP portfolio, and expanding its development of high value added components. It has been a partner in a number of international manufacturing joint ventures to set up production facilities for memory

TABLE 3. Top 10 Merchant Semiconductor Firms: 1980-1995

	1980			1990			1995		
	Company	\$m	%	Company	\$m	%	Company	\$m	%
1	Texas Inst.	1,580	12.2	NEC	4,952	8.6	Intel	13,830	8.9
2	Motorola	1,110	8.5	Toshiba	4,905	8.5	NEC	11,360	7.3
3	Philips	935	7.2	Hitachi	3,927	6.8	Toshiba	10,190	6.6
4	NEC	787	6.1	Intel	3,135	5.5	Hitachi	9,420	6.1
5	National	747	5.7	Fujitsu	3,019	5.3	Motorola	9,170	5.9
6	Toshiba	629	4.8	Motorola	3,692	6.4	Samsung	8,340	5.4
7	Hitachi	622	4.8	Texas Inst.	2,574	4.5	Texas Inst.	8,000	5.2
8	Intel	575	4.4	Mitsubishi	2,476	4.3	Fujitsu	5,510	3.6
9	Fairchild	566	4.4	Matsushita	1,945	3.4	Mitsubishi	5,150	3.3
10	Siemens	413	3.2	Philips	1,932	3.4	Philips	4,040	2.6
	Others	5036	38.7	Others	24,943	43.4	Others	69,990	45.2
	Total	13,000	100.0	Total	57,500	100.0	Total	155,000	100.0

Source: Dataquest

chip production.⁵¹ TI and Hitachi also entered a joint venture in 1996 to manufacture DRAMs in Texas.

These changes have had a major impact on TI's performance, helping the company to grow and to increase its world market share since the mid 1980s. This helped reverse a relative decline in its position beginning in the mid-1970s due to inroads made in world markets by foreign producers, as seen in Table 3.

IP Management and Cross-Licensing in an Electronics Company—Hewlett-Packard⁵²

Innovation Strategy

Many aspects of licensing elsewhere in electronics are similar to those described for semiconductors. The electronics industry shares many of the basic features of the semiconductor industry: rapid technological innovation, short product life cycles, and significant patenting. The computer, telecommunications, electronics, and semiconductor industries also use many of the same technologies and have been influenced by the practices of AT&T and other major corporations. Field-of-use cross-licensing is used widely.

However, a difference between many electronics firms outside of semiconductors is the breadth of technologies that are practiced. In addition to semiconductor technology, product development may involve integrating many aspects of computing, telecommunications, software, systems design, mechanical engineering, ergonomics and so forth. There are also likely to be

complex manufacturing and marketing requirements. Thus, IP strategies in such firms are likely to involve broader considerations.

Hewlett-Packard (HP) produces many different types of products, from laser printers and computers to hand-held calculators and electronic instruments. HP is currently organized into Computer Products, Systems, Measurement Systems, and Test and Measurement organizations.

To maintain its high rate of innovation, a high priority for HP in its IP strategy is maintaining "design freedom." It has two principal objectives: ensuring that its own technology is not blocked by competitors' patents; and ensuring that it has access to outside technology. HP's products include complex systems that typically involve several different technologies, some of which may be developed by other firms and other industries. HP alone can not develop the complete range of technologies used in its products. To obtain access to needed technologies, Hewlett-Packard needs patents to trade in cross-licensing agreements. The company has a huge portfolio of patents and know-how in leading-edge technologies, developed as part of its extensive R&D programs. This IP portfolio is the basis for protecting HP's own products; it is also invaluable as leverage to ensure access to outside technology.

Licensing Objectives

One type of HP cross-licensing takes place as "program licensing," which is aimed at acquiring access to specific technologies. The company identifies firms with technologies of interest. There may be several different technologies at a given firm so the strategic overlaps must be considered in assessing each licensing opportunity.

HP's licensing activities are not focused primarily on cash income. With a wide range of products, the company's interests in one area are likely to overlap with those in other areas. It may encounter licensing partners in several different markets in a variety of circumstances—a competitor in one field may be a supplier or customer in another. HP does not want negotiations in one product group to interfere with those in another. This leads to a long-term bias towards meaningful cross-licensing agreements and a soft approach to royalties. HP recognizes that it is likely to deal with the same partners repeatedly and therefore normally does not require high royalty rates that could be used as a precedent against it in the future.

There are some exceptions in that some strategic patents are only licensed at high royalty rates, or more likely are not licensed at all. In products where HP has a strong leadership position (e.g. printers), it is unlikely to license out its core IP rights. HP's IP policy in this area is aimed, as it must be, at the aggressive protection of a key source of competitive advantage. The company would normally consider licensing such IP rights only as part of a specific strategic alliance and would normally exclude such technology from cross-licensing agreements.

The form of the cross-license agreements is quite standard, with a limited capture period, usually with survivorship rights. The objective is to estimate the relative value of the infringements that are likely to take place over a five-year period. Other inputs to the licensing decision include the expected R&D spending in the field by each firm, the number of patents held by each party in the particular field, and determination of the value to the infringer of a limited number of pertinent patents. Each side to the agreement may select a limited number of patents which it has determined are being infringed by the other party's products. This may be as few as six to twelve patents each. The imputed royalty fee for these patents over the next five years becomes one of the inputs to the negotiation. In general, this balancing process is not unlike that which exists in the semiconductor industry.

Royalties are often paid as a lump sum. Agreements almost never include sublicensing rights, since the company could lose control of its own technology if sublicensing were permitted. Exclusive licensing is also rare, partly because of potential antitrust concerns, but also because the historical practice of non-exclusive cross-licensing leaves fewer innovations that could be treated as exclusive.

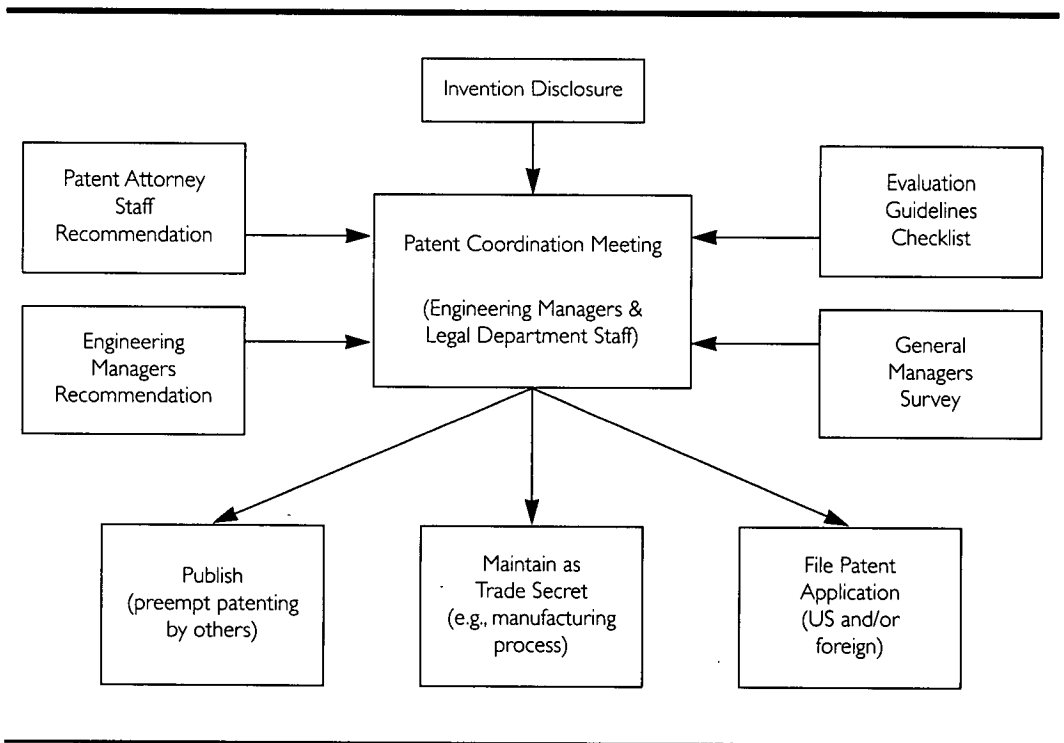
Even after a patent cross-license agreement is concluded, HP policy is not to over-use the technology of the other party to the agreement. This is again related to a long-term view of licensing. The agreement will probably need to be renewed in the future and the more of the other party's technology HP uses, the greater the leverage the other party would have the next time around. Also, patents are lagging indicators of research, so that to be at the forefront of technology each party will need to have developed its own application of the technology well before the patents are issued. One purpose of the agreement is to be able to use the technology in the development of new products without worrying about "accidental infringement."

Licensing is only secondarily seen as a source of royalty earnings. Royalty earnings are significant but not material, given the overall size of HP's operations. However, there are some cases where licensing for revenue is pursued. One is where the company has world-class technology and is approached by others seeking a license. If the technology is not of strategic importance to HP, the company may license it out for profit. Another is the "rifle shot" license, where a single patent may be licensed, if it has specific value to a licensee. Licensing terms in either case are usually very simple, amounting to an agreement to allow use of the innovation for a royalty payment or lump sum without being subject to an infringement claim.

IP Management

Given the importance of IP to Hewlett-Packard, a formal IP strategy has been developed for managing its large and diverse IP portfolio. Since products combine many technologies, IP may need to be even more closely integrated with business strategy than at a single product corporation. HP has a series of

FIGURE 2. Intellectual Property and Patenting Decision Process at HP



procedures for identifying technological areas to stress for patent protection and for making individual decisions about the best method of protecting innovations. Obtaining and maintaining patent protection is costly, and hence only selected innovations are patented. This process starts with “templates” to guide what IP should be protected. The templates are updated each year to protect technologies that will be strategically important to the company in the future. These templates are developed by a process that rates and prioritizes products and technologies and reviews patent needs throughout the world. This does not go as far as targeting R&D programs at innovations that will be useful in negotiating cross-licenses; rather it aims to make maximum use of innovations by creating patent portfolios that will be strategically valuable. This supports rather than directs corporate strategy.

The IP protection decision process for individual innovations is shown in Figure 2. When a product or process innovation is developed, a determination is made whether to patent it, to keep it as a trade secret, or, if it not believed worthwhile to patent, to publish it. The inputs to this decision take place in an internal committee process, with inputs from engineering management and the legal (IP) department. Innovations that are likely to be of strategic value are either patented immediately or, if they are not yet completed or proven, are reviewed again at a later time. If the innovation is valuable but its use by an imitator would be undetectable (such as for some process innovations), then the

innovation may be kept as a trade secret. Marginal ideas are published immediately to preempt patenting by a competitor who might later block their use by HP. “Vanity publishers” for publicly disclosing the results of research exist for this purpose.⁵³

Managing Intellectual Capital in the Electronics Industry

Contrasting IP Management Objectives

The case studies indicate several similarities in the way firms in the electronics industry use licensing and cross-licensing to ensure design freedom as well as some level of licensing earnings. They also illustrate how differences in management objectives are reflected in cross-licensing strategies.

RCA represents a rather complex organizational response to the problem of design freedom, in which a single company acquired exclusive cross-licensed rights to all the patents needed for radio manufacture. It then licensed out these rights to other manufacturers. Partly as a result, RCA was able to dominate the radio market for many years.

AT&T, as a regulated monopoly before 1984, was primarily interested in the dissemination of technology to as many producers as possible, to develop technologies that would be useful in its telecommunications services—as purchased components or in its own systems development. It was barred from competing in product markets, so it cross-licensed on liberal terms with the aim of stimulating development and obtaining access to new technology.

A primary concern of IBM in cross-licensing has been design freedom. As one of the world’s leading innovators it has been very active in using its IP for competitive advantage, both in products and to obtain the widest possible access to other technology. IBM’s interests have spanned a wide range of computer related markets and it has needed broad access to many different technologies. It also obtains significant income from its licenses.

TI’s interests have generally been more specific to the semiconductor industry, although it also has interests in other areas of electronics. Its concerns have been to obtain freedom-to-operate given the dense patent concentration in semiconductors, and to obtain cash from cross-licensing its IP, to help fund R&D and to equalize any advantage it would otherwise be allowing competitors using its IP.

Finally, HP is in a somewhat similar position to IBM in having a broad range of interests in different markets and being especially interested in design freedom for products spanning many technologies. HP’s breadth of interests—in which a competitor in one field may be a customer, supplier, or venture partner in another—moderates its approach to seeking high royalties. IP is central to its business, needed to support its rapid product innovation and to trade for technology access. It has well developed procedures for developing and protecting IP across its diverse fields.

Changing IP Modes in the Semiconductor Industry

The strengthening of IP rights and increased licensing and cross-licensing have extended the ability of the innovator to earn a reward from R&D. In addition to providing better IP protection for new products, there are greater opportunities for earning value via access to technology, joint ventures, technology exchanges, and R&D collaboration. Royalty earnings have become more significant. Much of this is a recent development and there are many questions as to how much strategic emphasis firms should place on licensing and cross-licensing compared with manufacturing, and on the importance of licensing revenue earning compared with freedom-to-operate.

It may help put these questions in context by reviewing the changing modes of competition in semiconductors, where firms have gradually needed to place increased stress on innovation, IP protection, and licensing and cross-licensing as a basis for product competition. There have been major changes in the way firms have obtained value from innovation as the industry has developed. The weak IP regime in effect during the first two or three decades of the industry was not a barrier to R&D and investment, and the liberal licensing practices used by AT&T and others accelerated the initial diffusion of the technology. This nurtured the early growth of a new industry. However, firms could not operate successfully in today's technological and competitive environment with the strategies and policies in place in the 1950s and 1960s. Competition to stay at the forefront of innovation is sharper and R&D and investment take place on a much bigger scale. AT&T no longer has a franchise monopoly, the market power of other industry participants is at best a phantom, and the industry is global.

Initial Growth Phase

From 1950 until the late 1970s, semiconductor and electronics firms used technology to open up new markets. Semiconductor technology was new and developing rapidly, and was too big and too important to be developed and commercialized adequately within one organization. There were benefits from having multiple sources of innovation. This was epitomized by AT&T's policy. As a major consumer of semiconductors, it wished to spread the use of the technology as widely as possible. Elements of this reasoning applied to other firms, who benefited from the rapid expansion of technology and markets. And, given the weak protection of IP afforded by the courts at this time, patents were not seen as a major factor in building competitive advantage.⁵⁴

At that time, firms relied primarily on time-to-market advantages to keep ahead. The basic semiconductor patents were already widely licensed, so any individual patent had limited power.⁵⁵ Product life cycles were short and often firms would simply not bother to patent inventions, believing that there was no point in patenting products and processes that would soon be obsolete. The fragmented structure of the new "merchant" semiconductor industry (which had grown up around spin-offs from Bell Labs and others), the rapidity of

innovation, and the high level of competition reflected the fact that not much attention was paid to protecting IP.⁵⁶ The predominant strategy for capturing value from technology involved “riding the experience curve”—reducing prices rapidly as unit costs fell with the hope of earning enough to fund the next round of development.⁵⁷

Second sourcing, licensed or not, was often required by many of the large customers to ensure continuous and competitive supplies. There was significant cross-licensing (often associated with second sourcing), but it rarely involved significant royalty payments.⁵⁸ Customers like the Department of Defense (DOD) had sufficient clout to force small suppliers like Intel to second source. During this period, licenses were mainly used to get some residual value from an innovation when it could not be recovered via the product market because of investment restrictions or trade restrictions. An example is the difficulty U.S. firms had selling products in Japan. Faced with effective trade protection, most U.S. firms’ only recourse was to license technology to Japanese firms.⁵⁹

At this time, TI was one of the first firms to make strategic use of its IP. It established a production plant in Japan in 1968, one of the very few foreign firms to do so. It achieved these rights from MITI by using the power of its patent portfolio.⁶⁰ This heralded a new role for IP in global commerce and firm competitiveness.

Increased Global Competition

The competitive environment began to change during the 1970s. The complexity of the technology and the scale of investment in R&D and capacity were rising, increasing the business risk of each new development. Moreover, as requirements for specialized investment increased, the business risk associated with a patent holder’s ability to obtain an injunction (in the case of inadvertent or intentional infringement) increased.

Managers were at first distracted by the increasing size of the total market when new mass markets opened up in the 1970s for consumer electronics (including calculators, watches, and later personal computers) and computer memories. By the early 1980s, new competitors from Japan (and later Korea) had entered the world markets and were challenging the U.S. firms, using technology largely developed in the United States. Changes were most dramatic in the manufacture of “commodity” DRAM memory chips, in which U.S. manufacturers’ share of the world market fell from 75% in 1980 to 17% in 1986, while over the same period Japanese memory share rose from 25% to 79%.⁶¹ U.S. firms could no longer rely on success in the product market alone to obtain returns from innovation.

The new entrants to the industry depended on access to existing technology and often sought to cross-license it. Yet nominal or royalty-free cross-licenses, which had been common in the industry prior to the 1980s, came to be seen as unfair when the entrants from outside the industry offered to pay

the nominal cross-license fees, but with no balancing portfolios of patents to offer. Royalty fees also reflect payment for access to technology accumulated in prior years, often at great expense. TI and others realized that more detailed evaluation of relative contributions to cross-licenses were required.

Innovation Leadership

The situation today is that, with numerous qualified competitors, competitive advantage requires more emphasis on strong IP rights. Stronger IP protection calls for dual strategies for capturing value from technology—the simultaneous use of product manufacturing using the IP in question together with IP licensing. Market developments have put more emphasis on chip design, developed close to the customer, and on being able to protect this and leading-edge process technology from imitation by fully able competitors. The increase in cooperative R&D and manufacturing joint ventures, often underpinned by IP rights, represent a market response to increased costs and the risks of development.

A regime shift occurred when many of the once small semiconductor firms such as Intel could no longer be forced into second sourcing their products. The demise of contractually required second sourcing suddenly made the value of IP more significant. The successful blunting of buyers' demand for second sourcing made IP more important—so much so that many companies, such as Intel, now have designated IP managers.

Many in the semiconductor industry have been opposed to stronger assertion of IP rights, having grown accustomed to a relatively open exchange of ideas and personnel. Not surprisingly, advocates of this view include start-ups, who claim that if they pay the full price of technology, it would limit their ability to compete. This may be true, but it is also trite. We observe that supporters of open ideas often become more protective once they have invested heavily in R&D. Most significantly, there has been a change in the global competitive reality. What may have been a useful model in the early days of the industry (in which it may be argued that all firms in a local market benefit from mutual exchange of ideas), becomes a different equation when firms are global.⁶²

Lessons for Innovation Management

To an extent, management today has little choice but to adopt a more active IP and licensing stance. IP rights have been strengthened and, not surprisingly, firms have become more strategic about commercializing IP. Cross-licensing enables firms to protect their IP while at the same time obtaining freedom to manufacture. The new IP and licensing circumstances have increased incentives to build IP portfolios and to innovate. In these new circumstances, there are some key lessons for innovation management.

Using IP to Support Core Business

Despite, or because of, the growing importance of licensing and cross-licensing, IP strategy should still be designed primarily to support technological developments and strategies surrounding the firm's core business. The global marketplace still rewards firms primarily for developing and commercializing products and processes as such, not for developing IP. Accordingly, few firms target technologies primarily for their value in earning royalties or for trading IP rights in future cross-licensing agreements.

Furthermore, for long-term success, firms typically need to be closely involved with the markets in which they operate and to develop core capabilities (in manufacture and design) closely linked to the products and processes. Maintaining a stream of valuable innovations requires extensive, up-to-date information about market demand and technological possibilities, especially in industries where technology is changing rapidly. Although this depends on the nature of the product, it usually also calls for close functional links between design, production, and marketing. These needs are typically best served by active participation in the product market.⁶³

The alternative—becoming a pure “licensing company” not directly involved in the product market and increasingly remote from the manufacture and design of the product itself—can be a risky strategy. Such a strategy, on its own, not only risks the erosion of the dynamic capabilities of the firm to continue innovating, it also is likely to be less financially rewarding than developing and commercializing products.⁶⁴

Importance of Developing a Valuable Patent Portfolio

Developing a valuable patent portfolio is an increasingly important part of strategy. In the electronics industry, patents are valuable because they provide protection from imitation for new proprietary products and services; they provide bargaining chips in negotiating access to other firms' technology (to avoid patent blocking and ensure freedom-to-operate); and patents may be an additional source of earnings or of reduced royalty fees the firm might otherwise have to pay.

The value of a portfolio is greatest when it has a high proportion of high-quality patents that cover significant product markets. These patents affect each of the reasons for holding a portfolio, but are seen most directly in the effect on cross-licensing. Patents have greatest cross-licensing value when they give the firm maximum leverage to obtain a favorable cross-license. This means that the patents should be legally and technically strong and should cover key aspects of the licensee's product base.

Concentrate R&D Where the Firm Is Strongest

In developing its patent portfolio, the firm can concentrate its R&D in those areas where it has the greatest competitive advantage in developing

valuable innovations, provided these are also areas needed by other firms. It need not focus on those technological areas where its cross-licensee is strongest in an attempt to duplicate or avoid the licensee's patents—a hopeless task with complex cumulative technology, such as electronics, where infringement is almost inevitable.⁶⁵ This might be in the same fields that it wishes to cross-license from its partners, or it might be in a more specialized area. For cross-licensing with a multidivisional corporation with interests in several markets, it might be in a different business area or field-of-use than the one from which it wishes to access technology. As argued above, a firm is most likely to create valuable IP where it is actively involved in the market, i.e., its core business. Provided this is also a commercially important field to cross-licensing partners, the firm can concentrate on developing and protecting IP in this field, rather than seeking another.

Licensing and cross-licensing enable firms to capture value from technology so long as they contribute to the common pool of industry knowledge. Innovators who are contributors have every incentive to avoid duplicative R&D investments, since a contribution to an industry's useful stock of proprietary knowledge is recognized no matter what the precise domain of applicability. Firms are advised to focus on innovating where they can best make a contribution to the development of quality patents they and other firms are likely to need. Cross-licensing thus enables firms to play to their technological strengths.

Although the number of patents a firm holds is important, of even greater importance is their quality. A single key patent is often worth more than a portfolio of questionable ones when it comes to assessing the ability of a patent owner to stop an infringer. The most effective way to acquire a portfolio of valuable patents is likely to be through in-house R&D. Occasionally, firms can purchase a portfolio of patents with which to establish cross-licensing relationships; but quality patents often are not available in this fashion.

In summary, the reality of the global marketplace today indicates that firms should proactively develop IP portfolios with an eye towards value in the market for know-how. A corollary is that to create a valuable patent portfolio for cross-licensing, it matters little where R&D is aimed, so long as it creates quality patents in a field that one's competitors need to license.

Policy Issues

Intellectual property is more critical than ever to competitive advantage and, as a result, is being given increasing attention by strategists and policy makers. IP protection has been strengthened and firms are more actively defending and exploiting their IP. Coincident with the increased importance of patents is the increased importance of licensing and cross-licensing. Cross-licensing has become a significant dimension of competition. Absent the ability to offer an equivalent IP portfolio, licensees must incur considerable costs. This in and of itself is a spur to innovation.

Cross-licensing outcomes do not, however, tilt towards the large firm at the expense of the small. Rather, they favor firms with significant IP regardless of size. In a particular market niche where patents from two firms overlap, a small firm may have as many patents as a large firm, and as much bargaining power as the large firm. It may have sufficient IP leverage to block a larger competitor by pursuing a claim in court (or credibly threatening to do so). Indeed, in the evaluation process, a small innovator with a strong patent may be the net gainer, if the patent applies to a high-volume product of a large corporation.⁶⁶ Some competitors may possess “equal patents but unequal products.” Nor need the licensing process disadvantage a new entrant firm. If a new entrant has significant relevant technology, it can in principle be a beneficiary of the cross-licensing regime.

Those investing in R&D need to ensure that they earn an adequate return, and royalties from licensing are an increasingly significant part. A company that develops technology will be at a competitive disadvantage in the market if its competitors are free to use its technology without incurring any expenses. Licensing fees on patented technology help ensure that the innovator earns an adequate return, which helps support future R&D. Cross-licensing helps balance the costs for developers and imitators. Thus, products manufactured by imitators who have not performed R&D do not have a competitive advantage merely by virtue of engaging in “copycat” imitation. If both parties to a licensing agreement have contributed similarly to a product field-of-use—in terms of the number, quality, product base coverage, and commercial significance of the patents included in the agreement—then the net royalty payments will be small, or possibly zero. In short, royalty payments help level the playing field, thereby ensuring competition on the merits.

The result is that IP now often has great value, both as a lever to obtain design freedom and as a vehicle to assist innovators in capturing value from innovation. This is of considerable consequence to firms without much IP—they must expect to pay—and also for firms with significant IP portfolios. IP and other knowledge assets are the core assets of many high-technology companies.

However, and perhaps because IP rights have become more valuable, infringers do not always step forward and offer to pay royalties. Accordingly, patent owners must often be proactive in obtaining royalty payments. Litigation or the threat of it may sometimes be necessary to enforce one’s rights. Unfortunately, at least in the U.S., litigation is often slow and costly, and antitrust and patent misuse defenses are often raised, sometimes frivolously. The archaic state of the law on patent misuse may further handicap the chances of efficient and socially desirable outcomes.⁶⁷ Moreover, antitrust attorneys are often ready to argue that a package license is a tying arrangement with anticompetitive effects, and/or that cross-licensing is a front for collusion. However, the truth of the matter is that such arguments are out of step with the new competitive order.

Such arrangements are pro-innovation and pro-competitive. There would appear to be a significant knowledge gap in some circles with respect to the

nature, purposes, and effects of cross-licensing. For instance, the field-of-use cross-licensing of patents in widespread use today is quite different from the traditional practice of licensing and cross-licensing involving individual patents. In the electronics industries, it is simply too cumbersome and transactionally costly to license specific patents for specific products, and so licensing commonly proceeds on a portfolio basis. Yet patent misuse and patent antitrust arguments often assume a world where infringement is easy to detect and costless to enforce. This is rarely the case in the electronics industry today.

At the most elementary level, licensing and cross-licensing involve merely the sale or exchange of property rights. Indeed, it often involves precisely that and no more. However, such arrangements ensure that firms have freedom-to-operate in developing and using innovations, without risking infringement claims from holders of patents in the same field of technology. In industries experiencing rapid technological innovation, patents, even when developed independently, will inevitably overlap technological domains worked by other firms. Cross-licensing agreements provide firms active in R&D with protection against inadvertent infringement and the rights to use the licensee's patents. Cross-licensing arrangements provide a mechanism for recognizing contributions through the establishment of balancing royalty payments. Royalty flows thus recognize the relative contributions to the product technology of the parties, thereby providing a mechanism for net takers to compensate net contributors. The arrangements thereby provide some limited protection against "free riders" who wish to use an industry's stock of proprietary knowledge without contributing. Balancing royalty payments are part of most cross-licenses, even when the main purpose is freedom-to-operate. "Pure" royalty free cross-licenses are rare for some companies and nowadays tend only to apply where the patent portfolios of both firms are large and the overall technological balance is both hard to assess and roughly equal.

Conclusion

Licensing is no longer a marginal activity in semiconductors and electronics. Whereas the management of patents and other forms of IP have always been of great importance in some industries like chemicals and pharmaceuticals, the ascendancy of IP in electronics is relatively recent. This is not just because the industry is new, but because regulatory and judicial distortions which impaired the value of IP have now been substantially rectified. The U.S. Department of Justice (DOJ) and the Courts forced AT&T, and to a lesser extent IBM, to license their technologies way below market value.⁶⁸ Not surprisingly, the electronics industry worldwide grew up with a distorted view of the value of intellectual property. This was reinforced by second sourcing requirements imposed by the DOD and other large buyers of integrated circuits that could, and did, insist on licensing for second sourcing purposes at low or zero royalties. Moreover, AT&T itself, being a significant purchaser of telecommunications and electronic

equipment, and with protected service markets, had private incentives to diffuse technology rather than use it to build competitive advantage.

This confluence of very special factors has ended. The AT&T consent decree is gone, and AT&T must now be far more proprietary with its technology. The IBM patent provisions ended in 1961. Intel, TI, and other integrated circuit producers are no longer forced to second source. Moreover, the courts are more inclined to enforce IP rights than ever before. In these respects, hopefully the DOJ/FTC 1995 Antitrust Guidelines for the Licensing of IP, which include statements regarding the potential efficiency benefits of licensing and cross-licensing, are an important step in the right direction and reflect more modern thinking about IP.⁶⁹ However, these guidelines are non-binding in litigation, though one would of course hope that the courts would take them into account.

The old regime—whereby the antitrust authorities pressed major IP owners to give up whatever rights they held, where the courts were reluctant to enforce IP rights and were eager to see IP as a barrier to competition rather than as an instrument of it—has faded away. Meanwhile, the ability of the buyers of electronic componentry to bargain for and achieve second source arrangements (which indirectly lowered the value of IP by causing owners to create their own competition) has declined. As a result of these developments, a new order has emerged in which IP rights are valuable. Firms must either invest in R&D and develop patentable technology, or pay to license the patent portfolios of others. The free ride appears to be coming to an end, and IP management is now critical to the success of new entrants and incumbents alike.

Notes

1. By "IT," we refer of course to information technology.
2. In cross-licensing, two or more firms license their IP to each other.
3. Cross-licensing is not the same as a patent pool, in which member firms contribute patents to a common pool and each member accesses them on the same conditions. In cross-licensing, firms agree one-on-one to license their IP to each other and retain control over their proprietary technology, which is used for competitive advantage via product manufacturing and further licensing.
4. Other examples of "cumulative systems" include aircraft and automobiles. In aircraft, problems of blocking patents, stemming from different approaches by pioneers such as the Wright Brothers and Curtiss, were only resolved during World War II when automatic cross-licensing was introduced. In automobiles, the Association of Licensed Automobile Manufacturers (although formed to exploit the Selden patent) developed means for automatic cross-licensing of patents early this century. In both cases, the lack of cross-licensing probably held up industry development. R. Merges and R. Nelson, "On the Complex Economics of Patent Scope," *Columbia Law Review*, 90 (1990): 839-916.
5. In chemicals and pharmaceuticals, although patenting is extensive, individual technology development paths are less likely to overlap, and cross-licensing may be used to ensure broad product lines. For licensing strategy in the chemicals industry, see P. Grindley and J. Nickerson, "Licensing and Business Strategy in the

- Chemicals Industry," in R. Parr and P. Sullivan, eds., *Technology Licensing Strategies* (New York, NY, NY: Wiley, 1996), pp. 97-120.
6. The early history of radio is described in: G. Archer, *History of Radio to 1926* (New York, NY: American Historical Society, 1938); W. Maclaurin, *Invention and Innovation in the Radio Industry* (New York, NY: Macmillan, 1949); J. Jewkes, D. Sawers, and R. Stillerman, *The Sources of Innovation* (New York, NY: Norton, 1969), pp. 286-288; G. Douglas, *The Early Days of Radio Broadcasting* (Jefferson, NC: McFarland, 1987); Merges and Nelson, op. cit., pp. 891-896.
 7. These included the high-frequency alternator, high-frequency transmission arc, magnetic amplifier, selective tuning, crystal detector, heterodyne signal detection, diode valve, triode valve, high vacuum tube, and directional aerials.
 8. Not all early inventors were independent. Alexanderson—who improved the Fessenden alternator, invented a magnetic amplifier, electronic amplifier, and multiple tuned antenna, and co-invented the "Alexanderson-Beverage static eliminator"—was a General Electric employee.
 9. AT&T acquired the de Forest triode and feedback patents in 1913-1914 for \$90,000, and his remaining feedback patents in 1917 for \$250,000; Westinghouse cross-licensed the Fessenden heterodyne interests in 1920, and acquired the Armstrong super heterodyne patents in 1920 for \$335,000. Archer, op. cit., p. 135; Maclaurin, op. cit., p. 106.
 10. The fact that GE and AT&T alone were each devoting major research attention to the vacuum tube led to no less than twenty important patent interferences in this area. Maclaurin, op. cit., p. 97.
 11. Federal Trade Commission, *The Radio Industry* (Washington DC: FTC, 1923); Maclaurin, op. cit., p. 99.
 12. To cite one important example, Marconi and de Forest both had critical valve patents. Marconi's diode patent was held to dominate de Forest's triode patent. Both technologies were vital to radio, yet the interests refused to cross-license. [Archer, op. cit., pp. 113-114; Douglas, op. cit., p. 12.] The application of the triode (audion) to feedback amplification was also the subject of a long-running patent priority dispute between de Forest and Armstrong (finally resolved in de Forest's favor by the Supreme Court in 1934). Its use in transmission oscillation was the subject of four-way patent interference between Langmuir, Meissner, Armstrong, and de Forest. [Maclaurin, op. cit., p. 77.] These problems held up the use of the triode—a crucial component of signal transmission, detection, and amplification, which has been called "the heart and soul of radio" [Douglas, op. cit., p. 8], and "so outstanding in its consequences it almost ranks with the greatest inventions of all time" [Nobel Prize physicist Rabi, quoted in Maclaurin, op. cit., p. 70].
 13. A main concern of the U.S. Navy was that international wireless communications were dominated by the British firm Marconi, and the patent impasse helped perpetuate this. It favored the establishment of an "All American" company in international communications. RCA was formed by GE in 1919, and simultaneously acquired the American Marconi Corp. Major shareholders included GE, AT&T (1920) and Westinghouse (1921). Archer, op. cit., pp. 176-189; Maclaurin, op. cit., p. 105.
 14. As part of its role in the formation of RCA, the U.S. Navy also initiated cross-licensing to resolve the patent situation in radio manufacture. It wished to have clear rights to use the radio equipment it purchased, without risking litigation due to the complex patent ownership—noting in 1919 that "there was not a single company among those making radio sets for the Navy which possessed basic patents sufficient to enable them to supply, without infringement, . . . a complete transmitter or receiver." A formal letter suggesting "some agreement between the

- several holders of permanent patents whereby the market can be freely supplied with [vacuum] tubes," sent from the Navy to GE and AT&T in January 1920, may be seen as an initiating point for cross-licensing in the industry. Archer, *op. cit.*, pp. 180-186; Maclaurin, *op. cit.*, pp. 99-110.
15. RCA concluded cross-license agreements with firms including GE, Westinghouse, AT&T, United Fruit Company, Wireless Specialty Apparatus Company, Marconi (Britain), CCTF (France), and Telefunken (Germany). Archer, *op. cit.*, p. 195; Maclaurin, *op. cit.*, p. 107.
 16. A distinction was that the RCA cross-licenses typically granted (reciprocal) exclusive rights to use the patents in given territories or markets, compared with the non-exclusive cross-licenses that became the norm later. The cross-license with GE (and later Westinghouse) included provisions for the supply of components to RCA. The RCA cross-licenses were for very long terms—many for 25 years, from 1919 to 1945. They covered current and future patents. Other radio manufacturers took licenses with RCA, starting in the late 1920s. Some of RCA's cross-licensing policies were later questioned on antitrust grounds, and modified following a consent decree in 1932. Archer, *op. cit.*, pp. 381-387; Maclaurin, *op. cit.*, pp. 107-109, 132-152.
 17. Historical perspective on competition in the telecommunications industry is given in: M. Irwin, "The Telephone Industry," in W. Adams, ed., *The Structure of American Industry*, 5th ed. (New York, NY: Macmillan, 1977), pp. 312-333; G. Brock, *The Telecommunications Industry: The Dynamics of Market Structure* (Cambridge, MA: Harvard University Press, 1981); Office of Technology Assessment, *Information Technology Research and Development: Critical Trends and Issues* (New York, NY: Pergamon Press, 1985); R. Noll and B. Owen, "The Anticompetitive Uses of Regulation: *United States v. AT&T*," in J. Kwoka and L. White, eds., *The Antitrust Revolution* (New York, NY: Macmillan, 1989); G. Rosston and D. Teece, "Competition and "Local" Communications: Innovation, Entry, and Integration," *Industrial and Corporate Change*, 4/4 (1995).
 18. OTA, *op. cit.*; M. Noll, "Bell System R&D Activities: The Impact of Divestiture," *Telecommunications Policy*, 11 (1987): 161-178; R. Harris, "Divestiture and Regulatory Policies," *Telecommunications Policy*, 14 (1990): 105-124.
 19. The two substantive provisions of the 1956 consent decree were that (a) it confined AT&T to providing regulated telecommunications services, and its manufacturing subsidiary Western Electric to making equipment for those services (effectively prohibiting it from selling semiconductors in the commercial market), and (b) all patents controlled by the Bell System should be licensed to others on request. Licenses for the 8,600 patents included in existing cross-licensing agreements were royalty free to new applicants, and licenses to all other existing or future patents were to be issued at a non-discriminatory "reasonable royalty" (determined by the court if necessary). AT&T was also to provide technical information along with the patent licenses for reasonable fees. Licenses were unrestricted, other than being non-transferable. [*USA v. Western Electric Co. Inc. and AT&T*, Civil Action, 17-49, Final Judgment, January 24, 1956; Brock, *op. cit.*, pp. 166, 191-194; R. Levin, "The Semiconductor Industry," in R. Nelson, ed., *Government and Technical Progress* (New York, NY: Pergamon, 1982), pp. 9-101.] In fact, AT&T went beyond the Consent Decree in its efforts to diffuse transistor technology, including symposia and direct efforts to spread know-how. [Levin, *op. cit.*, pp. 76-77.]
 20. See section later in this article on "Lessons for Innovation Management."
 21. "We realized that if [the transistor] was as big as we thought, we couldn't keep it to ourselves and we couldn't make all the technical contributions. It was to our interest to spread it around." AT&T executive, quoted in Levin, *op. cit.*, p. 77, after

- J. Tilton, *International Diffusion of Technology: The Case of Semiconductors* (Washington, D.C.: The Brookings Institution, 1971).
22. By 1983, Bell Labs had received 20,000 patents. This may be compared to about 10,000 currently at IBM and 6,000 at Texas Instruments.
 23. W. Kefauver, "Intellectual Property Rights and Competitive Strategy: An International Telecommunications Firm," in M. Wallerstein, M. E. Moguee, and R. Schoen, eds., *Global Dimensions of Intellectual Property Rights in Science and Technology* (Washington, D.C.: National Academy Press, 1993), pp. 236-240.
 24. For the capture model, see section below on "Policy Issues." The survivorship period could be as much as 17 years from the grant date (possibly several years after filing), under U.S. patent rules prior to 1995, or 20 years from the filing date, after 1995.
 25. In the U.S., during 1953-1968, 5,128 semiconductor patents were awarded. Bell Laboratories was granted 16% of these; the next five firms were RCA, General Electric, Westinghouse, IBM, and Texas Instruments. Tilton, op. cit.
 26. E. von Hippel, "Cooperation Between Rivals: Informal Know-How Trading," *Research Policy*, 16 (1987): 416-424; A. Saxenian, "Regional Networks and the Resurgence of Silicon Valley," *California Management Review*, 33/1 (Fall 1990): 89-112.
 27. There are also transactions costs reasons for using bundled licensing, as noted previously.
 28. If the parties could not agree on a reasonable royalty rate, the court could impose one. Patent rights could be very long lived, since, at that time, patent life was 17 years from the grant date, which might be some years after the filing date. The patent licensing provisions ended in 1961. The decree also included other provisions related to the sale of IBM products and services. *USA v. International Business Machines Corporation*, CCH 1956 Trade Cases para. 68, 245, SDNY 1956.
 29. This increased from \$345 million in 1993 [IBM Annual Report, 1994]. IBM initiated a more active approach to licensing in 1988, when it increased the royalty rates sought on its patents from 1% of sales revenue on products using IBM patents to a range of 1% to 5%. *Computerworld*, April 11, 1988, p. 105.
 30. R. Smith, "Management of a Corporate Intellectual Property Law Department," *AIPLA Bulletin* (April/June 1989), pp. 817-823; C. Boyer, "The Power of the Patent Portfolio," *Think*, 5 (1990): 10-11.
 31. Gary Markovits, IBM patent process manager, in Boyer, op. cit., p. 10.
 32. Jim McGrody, IBM VP and director of research, in Boyer, op. cit.
 33. Roger Smith, IBM assistant general counsel, in Boyer op. cit. In all, IBM has about 11,000 active inventions, with about 35,000 active patents around the world. Smith, op. cit.
 34. Many firms in the U.S. semiconductor industry were reported to be "dismayed" and "outraged" over the higher royalties and more active IP strategies of TI and others. [S. Weber, "The Chip Industry is Up in Arms Over TI's Pursuit of Intellectual Property Rights at the ITC," *Electronics* (February 1991), p. 51.] For example, T. J. Rodgers, CEO of Cypress Semiconductor described the practice of increased litigation over patent rights as a "venture capital investment." [*Upside* (December 1990).] Others have questioned whether the strengthening of patent rights might be hindering innovation, by enabling IP holders to demand "crippling royalties from young companies." Several small Silicon Valley semiconductor firms, including Cypress Semiconductor, LSI Logic, and VLSI Technology, formed a consortium to defend themselves against patent suits. [B. Glass, "Patently Unfair: The System Created to Protect the Individual Inventor May be Hindering Innovation," *InfoWorld*, October 29, 1990, p. 56.] Although some Japanese manufacturers reportedly described royalty demands as "possibly exorbitant," the Japanese

response has generally been to increase their own patenting effort. [*Computergram*, September 14, 1990; Weber, op. cit.] Similar objections to increased patent strength and licensing activity have also been evident in resistance to the growing use of patents for computer software, which it has been claimed may restrict innovation by small enterprises. [B. Kahin, "The Software Patent Crisis," *Technology Review* (April 1990), pp. 53-58.] However, here too, many software firms who at first resisted the trend have now accepted the need to build their own patent portfolios. [M. Walsh, "Bowing to Reality, Software Maker Begins Building a Patent Portfolio," *The Recorder*, August 17, 1995, p. 1.]

35. This section is based in part on discussions with Texas Instruments executives. However, the views expressed here are those of the authors and should not be seen as necessarily reflecting those of Texas Instruments.
36. The costs of manufacturing facilities have risen dramatically. A new wafer fabrication plant cost \$10-20 million in 1975 (4-kilobit DRAM), \$300-400 million in 1990 (16-megabit DRAM) and over \$1 billion in 1991 (256-megabit DRAM). SEMATECH, *Annual Report, 1991*; "Foreign Alliances Which Make Sense," *Electronic Business*, September 3, 1990, p. 68.
37. Without field-of-use cross-licenses, a typical semiconductor firm might need to reverse engineer an average of two or three competitors' products a day, as each is introduced over the course of a five-year license, to ascertain whether these are infringing its patents. It must do the same for its own products. This would be prohibitively expensive. Tracking sales by each of hundreds of affected products, on a patent by patent basis, to ascertain royalties, would be virtually impossible.
38. In some cases, where there are only a few very specific overlaps between two firms' technology needs, firms may choose to license single patents. Although an option, it is rarely convenient compared with field-of-use cross-licensing when there are substantial technology overlaps.
39. R. Levin, A. Klevorick, R. Nelson, and S. Winter, "Appropriating the Returns to Industrial R&D," *Brookings Papers on Economic Activity*, 3 (1987): 783-820. Of course, even reading the patent is a helpful guide to someone knowledgeable in the field.
40. The most powerful threat to enforce a patent is an injunction to close down the infringer's production line. This could be ruinous for a manufacturing corporation, especially in fast developing markets such as electronics and semiconductors. The threat of damages may also be important, but as these are often based on projected royalties (and hence may be little worse than freely negotiated licensing terms) they are less potent, unless multiplied by the court.
41. For the economics of technology transfer see D. Teece, "The Market for Know-How and the Efficient International Transfer of Technology," *Annals of the American Academy of Political and Social Science*, 458 (1981): 81-96.
42. Reverse engineering a semiconductor product is not a simple matter, involving as it does decapping and microscopic examination at the submicron level. Although the process is by now largely automated, it can take 400-500 man-hours per device.
43. For cross-licenses with firms outside the semiconductor industry, such as the personal computer industry, the process used is simpler. In this case, there may be few patents to balance against the proffered patents. Licensing follows precedents long established in the computer industry, primarily under the leadership of IBM, as the holder of many of the patents used in the industry. The negotiations are similar, but the weighting process is not involved. Royalty rates are influenced by industry norms.
44. In some cases licensees may only wish to license a few selected patents, rather than all patents in a field-of-use. For this reason licenses are generally also offered

- for individual or specific patents, as well as for all patents in a given field. However, there are significant transactions savings to both sides from a field-of-use license, and the cost per patent is likely to be higher when only a few patents are licensed.
45. For general considerations affecting royalty rates, see M. Lee, "Determining Reasonable Royalty," *Les Nouvelles*, 27 (1992): 124-128; R. Parr, *Intellectual Property Infringement Damages: A Litigation Support Handbook* (New York, NY: Wiley, 1993).
 46. To an extent this may be a transitional problem. As licensing becomes more widespread, individual licenses are more likely to be negotiated in the knowledge that other licenses, potential or actual, must be taken into account.
 47. For strategies to establish standards see R. Hartman and D. Teece, "Product Emulation Strategies in the Presence of Reputation Effects and Network Externalities," *Economics of Innovation and New Technology*, 1 (1990): 157-182; L. Gabel, *Competitive Strategies and Product Standards* (London: McGraw-Hill, 1991); P. Grindley, *Standards, Strategy, and Policy: Cases and Stories* (Oxford: Oxford University Press, 1995).
 48. However liberal the licensing terms, the patent holder should not inadvertently assign away IP rights beyond those specifically needed to operate the standard, and may need to condition rights over its IP to uses related to the standard. The innovator might otherwise be deterred from participating in standards setting. There is a balance to be drawn between committing to an open standard and limiting that commitment to what is needed for the standard and to keep access open in future.
 49. Risks include the likelihood that the validity of the patents would be challenged in court, that firms—and nations—would retaliate, and that the corporate image with customers would suffer. Patent assertion against customers and partners is an especially sensitive area.
 50. R&D agreements with Hitachi have ranged from a 4-megabit DRAM know-how exchange in 1988 to a 256-megabit DRAM co-development agreement in 1994. According to Yasutsugu Takeda of Hitachi, "You can't create [a successful cooperative venture] just because you sign up a lot of companies that are barely committed and don't have anything to bring." The Hitachi-TI collaboration on 256-megabit memory chips has been successful because it is a "meeting of equals" [*Business Week*, June 27, 1994, p. 79]. Complementary capabilities are generally considered important factors in selecting international collaborative venture partners. D. Mowery, "International Collaborative Ventures and the Commercialization of New Technologies," in N. Rosenberg, R. Landau, and D. Mowery, *Technology and the Wealth of Nations* (Stanford, CA: Stanford University Press, 1992), pp. 345-380.
 51. TI entered joint ventures during 1989-1990 to build manufacturing plants with total investments over \$1 billion: with the Italian government; Acer (Taiwan); Kobe Steel (Japan); and the Singapore government, HP, and Canon (Singapore).
 52. This section is based in part on discussions with Hewlett-Packard executives. However, the views expressed here are those of the authors, and should not be seen as necessarily reflecting those of Hewlett-Packard.
 53. Examples include *Research Disclosure* and other publications. Such journals charge fees to authors, yet often have large circulations for reference libraries and research laboratories.
 54. Surveys of executives in a range of industries taken in the early 1980s typically rated methods such as lead time and superior sales and service effort as the most effective means of protecting innovations, rather than patent protection, which was considered relatively ineffective. Levin et al., *op. cit.*
 55. The original transistor process patents were held by AT&T, so that all transistor manufacturers needed to cross-license their own patents at least with AT&T.

Similarly, the key patents for the integrated circuit (IC) technology were held by two firms, TI and Fairchild, ensuring that these too were widely licensed. With the critical patents widely available, the cumulative nature of innovation guaranteed broad cross-licensing. Levin, *op. cit.*, pp. 79-82.

56. The first commercial producers of transistors in the 1950s, using AT&T licenses, included Shockley Labs, Fairchild, Motorola and TI. These gave rise to a wave of spin-off companies in the 1960s, such as National Semiconductor, Intel, AMD, Signetics and AMI, which in turn gave rise to subsequent waves of new companies, such as, Cypress Semiconductor, Cyrix, LSI Logic, Chips and Technologies, Brooktree Semiconductor, and others.
57. At TI this approach was formalized in the Objectives, Strategies, and Tactics (OST) product development management process, including "design to cost" methods formalizing experience curve pricing procedures. *Business Week*, September 18, 1978; B. Uttal, "TI Regroups," *Fortune*, August 9, 1982, p. 40; M. Martin, *Managing Technological Innovation and Entrepreneurship* (Reston, VA: Reston, 1984).; R. Burgelman and M. Maidique, *Strategic Management of Technology and Innovation* (Homewood, IL: Irwin, 1988).
58. Tilton, *op. cit.*; M. Borrus, J. Millstein, and J. Zysman, *International Competition in Advanced Industrial Sectors: Trade and Development in the Semiconductor Industry* (Washington, D.C.: U.S. Department of Commerce, 1982).
59. Borrus et al., *op. cit.*
60. The same is broadly true of IBM's entry into Japan.
61. Dataquest figures, quoted in United Nations Organization (UNO), *The Competitive Status of the U.S. Electronics Sector* (New York, NY: United Nations Organization, 1990). For comments on the U.S. recovery since the late 1980s, see W. Spencer and P. Grindley, "SEMATECH After Five Years: High-Technology Consortia and U.S. Competitiveness," *California Management Review*, 35/4 (Summer 1993): 9-32; P. Grindley, D. Mowery, and B. Silverman, "SEMATECH and Collaborative Research: Lessons in the Design of High-Technology Consortia," *Journal of Policy Analysis and Management*, 13 (1994): 723-758.
62. For contrasting views on the responses of Silicon Valley to international competition, see R. Florida and M. Kenney, "Why Silicon Valley and Route 128 Can't Save Us," *California Management Review*, 33/1 (Fall 1990): 66-88; Saxenian, *op. cit.*
63. Hazards for innovation when a firm is remote from business transactions, and hence from the technological frontier, are outlined in J. de Figueiredo and D. Teece, "Strategic Hazards and Safeguards in Competitor Supply," *Industrial and Corporate Change*, vol. 5.2 (1996). The similar vulnerability of the "virtual corporation," which contracts out development and manufacturing, is discussed in H. Chesbrough and D. Teece, "When Is Virtual Virtuous: Organizing for Innovation," *Harvard Business Review* (January/February 1996), pp. 65-73.
64. For the nature of dynamic capabilities of firms and their relationship to innovation, see D. Teece and G. Pisano, "The Dynamic Capabilities of Firms: An Introduction," *Industrial and Corporate Change*, 3.3 (1994): 537-556; D. Teece, G. Pisano, and A. Shuen, "Dynamic Capabilities and Strategic Management," *Strategic Management Journal* (forthcoming in 1997). For the role of complementary assets in commercializing innovation, see D. Teece, "Profiting from Technological Innovation," *Research Policy*, 15 (1986): 285-305.
65. Indeed, in some cases the firm might conceivably do better if it has strengths in an area where the licensee is relatively weak, since it will have greatest difficulty avoiding their patents in those areas, whereas where it is strongest it may have more ability to invent around the patents.

66. An example is Brooktree Corporation, a small semiconductor design company in San Diego, which concluded a favorable cross-licensing agreement with TI in 1993.
67. See E. Sherry and D. Teece, "The Patent Misuse Doctrine: An Economic Reassessment," in *Antitrust Fundamentals*, ABA Section of Antitrust Law, Chicago (forthcoming).
68. IP rights to the transistor were given away to U.S. and foreign firms for very small amounts. Levin, *op. cit.*
69. DOJ/FTC, *Antitrust Guidelines for the Licensing of IP*, April 6, 1995 (Washington, DC: U.S. Department of Justice and the Federal Trade Commission, 1995).

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