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Author
Borrus, Michael

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Michael Borrus

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REVERSING ATTRITION: A STRATEGIC RESPONSE TO THE EROSION OF U.S. LEADERSHIP IN MICROELECTRONICS

Statement of the Argument

For the last six years, merchant U.S. producers of semiconductors have been on the defensive in international markets. Faced with intense competition from large, diversified Japanese producers of components and systems, U.S. firms have seen their market share erode by about 12% since 1978. Although the merchant U.S. industry is still the world's largest producer of microelectronic components, it has been aggressively pursued -- and may be overtaken -- by its Japanese rival. Backed by state policy, comparatively massive resources and a stable base of rapidly growing demand in their essentially closed domestic market, Japanese firms appear intent on spending their way into the semiconductor industry's leadership position. Since U.S. merchants have been primarily responsible for U.S. leadership in the final systems markets that depend upon advances in semiconductors, the consequences could be a loss to Japanese firms of the U.S. position in final markets.

As demand for semiconductors from the user final product markets in Japan begins to resemble demand in the U.S. market, the Japanese industry will become an increasingly competitive producer of the components on which U.S. leadership currently rests. Because U.S. merchants can not match their competitor's resources, Japanese firms would be well placed to capture the largest share of growing demand from the convergence of communications and computing, an information industry that will grow to become the world's largest industrial sector in the next decade, and will drive semiconductor development.

Yet, the simultaneous focus of Japan's producers on gaining market share in both components and final product markets leaves them competitively vulnerable to alliances between U.S. semiconductor merchants and the systems producers at home and abroad who compete against the Japanese industry in final product markets. Europe provides the best example of this, for Europe dramatically lags the U.S. and Japan in the application of microelectronics, and the consequence has been erosion of Europe's position in final markets. European systems producers and U.S. merchants who largely dominate the European component market, have a mutual interest in seeing that microelectronics is applied more rapidly in Europe -- to reinforce the position of European producers against Japanese competition in final markets, and to provide a secure base of rapidly growing demand for U.S. merchant semiconductors that is relatively immune to Japanese encroachment.

For U.S. merchant producers, the logic of such strategic alliances is straightforward: to contain Japanese

gains in final product markets, divert their resources from semiconductors and create secure sources of demand for U.S. chips. That logic applies broadly to alliances between U.S. firms and final market producers in traditional and high technology industries outside of Europe. The creation of such alliances, along with U.S. policy aimed at permitting investment during industry downturns, could leave U.S. firms better positioned than their Japanese challengers to ride the demand boom emerging from growth of the information technology industry. The U.S. industry could regain the initiative on international semiconductor markets.

REVERSING ATTRITION: A STRATEGIC RESPONSE TO THE EROSION OF U.S. LEADERSHIP IN MICROELECTRONICS

I: THE COMPETITIVE CONTEXT AND ITS STRATEGIC CONSEQUENCES

Competitive Context

Since the late 1970s the dominant world market share of merchant U.S. producers of semiconductor components has been steadily eroded by Japanese competition. The merchant world market share of U.S. firms has fallen from about 69% in 1978 to near 50% by the end of 1984. In turn, the share of the merchant world market held by Japanese producers has risen over the same time frame from about 24% to 38%.*.[1] In 1978, U.S. firms dominated every major category of semiconductor production: simple commodity memory (dynamic and static RAMs), more complex non-volatile memory (EPROMS and EEPROMS), commodity logic, microprocessors, microcomputers and peripherals. By 1984, Japanese firms had

* If captive U.S. production (particularly that of IBM, ATT, GM-Delco and Hewlett-Packard) is included in world market share figures the overall U.S. share improves dramatically. In 1984, Department of Commerce figures indicate that the U.S. share was over 60% and the Japanese share under 30%. Nonetheless, the drastic deterioration in the share held by U.S. merchants should be of intense concern to U.S. policy-makers, because U.S. merchants have been primarily responsible for technological advance that increased component performance while simultaneously reducing component costs, thereby spurring diffusion of microelectronics into new uses. As much if not more than any other industry segment, U.S. merchants have been responsible for U.S. leadership in final electronic systems markets like communications and computing that depend upon advances in semiconductor technology.

established an overwhelming leadership position in state of the art commodity memory (both dynamic and static RAMs); U.S. firms were hanging on to a lead in logic, barely hanging on in EPROMS, and the clear U.S. lead in complex commodity components extended only to EEPROMS and microprocessors, microcomputers and peripherals. Even in these latter categories, Japanese firms had begun to demonstrate competitive capabilities.

As these figures suggest, U.S. firms have been on the defensive in international semiconductor competition. Despite an intensified focus on the traditional strengths and strategies that forged their leadership position in the past -- in particular, entrepreneurial strategies aimed at technological innovation and its diffusion into new uses, and innovative design and market development strengths -- U.S. merchant firms have been unable to reverse Japanese gains. By contrast, secure in the relatively closed domestic Japanese market (the world's second largest national market for microelectronics, at about 25% of world consumption, about half the size of the U.S. market), backed by state policy and massive resources -- generated from sales of the final systems products which comprise the bulk of the business of these large, diversified equipment producers -- Japanese firms have siezed the competitive initiative from their U.S. rivals. Table 1 graphically portrays the seemingly unstoppable Japanese drive toward preeminence in semiconductor competition, by examining the

shuffle of position among the world's 10 leading merchant semiconductor producers between 1978 and 1984.

TABLE 1: Rankings of 10 leading firms
($millions)

Firm	1978	Firm	1984
Texas Instr.	990	Texas Instr.	2555
Motorola	720	*NEC	2350
*NEC	520	Motorola	2227
+Phillips#	520	*Hitachi	2140
National	500	*Toshiba	1750
Fairchild	500	Intel	1180
*Hitachi	460	+Phillips#	1150
*Toshiba	400	*Fujitsu	1070
Intel	360	National	1050
+Siemens	270	AMD	920
		*Matsushita	920

Key: * connotes Japanese firm; + connotes European firm.
Phillips includes Signetics.
Source: 1984 figures and 1978 Japanese figures from Hambrecht and Quist; 1984 Phillips figure from ICE; other 1978 figures from EEC.

As Table 1 shows, by 1984 Japanese firms commanded three of the top five and five of the top ten spots, compared to one of five and three of 10 in 1978. Japanese firms had bested their closest U.S. competitors in capturing an expanding share of the semiconductor industry's rapid growth over the six year period.

In two earlier studies of U.S.-Japanese competition in the semiconductor industry, we analyzed how Japanese firms moved from a position of technological and market inferiority in components to establish enduring advantage in semiconductor memory and to challenge overall U.S. leadership.[2] We documented the critical role played by Japanese policy during the 1970s in shaping the development

of the Japanese industry's international competitiveness. State policy closed the domestic Japanese market to foreign firms, thereby ensuring that Japanese firms would capture most of the growth in consumption of semiconductors in their home market. Japanese government policy simultaneously and systematically promoted the domestic Japanese components industry by restructuring it, coordinating cooperative R&D projects, and channeling cheap capital to Japanese producers to fund their growth. While the closed market legacy of past policy endures in Japan's domestic electronics market structure -- there has been no growth in U.S. penetration despite formal liberalization and U.S. leadership in complex chips -- state promotional assistance did not become enduring subsidy for Japan's semiconductor producers. Rather, by leveraging off of the stable, growing demand in their home market, Japanese firms have created characteristic innovations in semiconductor production processes which have led to real competitive advantage on international markets, particularly in commodity memory. Indeed, in 1983 and 1984, Japanese firms captured about 60% of the world 64KdRAM market, 90% of the just emerging 256KdRAM market, and 50% of the 16KsRAM and 75% of the 64ksRAM markets.[3]

Table 2 gives an indication of the significance of these areas of Japanese dominance.

TABLE 2:
World Market for Selected Semiconductor Devices

Device	1984	1990(p)
MOS memory, total	**5790**	**18000-28000**
dRAM	3010	10000-13000
sRAM	1000	3000- 4600
ROM	530	1000- 3200
EPROM	1040	3000- 5000
EEPROM	210	1000- 2200
MPUs, total	**2900**	**8000-13000**
8-bit	1180	1000- 2200
16-bit	440	2000- 3000
32-bit	---	300- 1200
single-chip	880	2500- 3300
others	400	2200- 3300
Logic, total	**4670**	**6300- 9200**
Bipolar	3860	5500- 6000
CMOS	810	1800- 3200

NOTE: 1990 figures are projected on the basis of current growth rates. MPU=microprocessor.
Source: Electronics Week, January 1, 1985.

As Table 2 suggests, Japanese firms have aimed at the most lucrative segments of the commodity semiconductor market. If they merely maintain their current market share advantages in these areas over U.S. firms and encroach no further into the complex chip segments U.S. firms currently dominate, Japanese firms will still control a growing share of future semiconductor revenues.

Indeed, as we argued in our last study, Japanese dominance of commodity memory, in particular RAMs, places severe competitive pressure on U.S. merchant producers for two closely related reasons. First, commodity memory devices like RAMs have historically generated the operating margins necessary to allow U.S. merchant firms to reinvest and

attract additional capital for R&D and growth. Second, and equally important, successive generations of RAMs have been the simplest of increasingly complex integrated circuits; experience gained in their production has heretofore provided U.S. merchant firms with the manufacturing knowhow to move through successive iterations to the competitive production of more complex devices. Japanese leadership in commodity memory therefore poses a double dilemma for U.S. firms. Their margins, and hence their capacity to continue to innovate, are squeezed at the same time that their abilities to acquire critical production knowhow are threatened. In tandem with rapidly rising costs for the R&D and capacity expansion necessary to remain at the industry's leading edge, Japanese dominance of commodity memory bluntly represents a shift in the terms of competition in established semiconductor markets -- a shift that has decisively favored Japanese firms during the 1980s.

Merchant U.S. firms have responded to the Japanese challenge both in the market and politically. In the market, U.S. producers have recognized that enduring Japanese competition has created new dynamic instability in an already competitive environment. The U.S. industry has responded by taking advantage of its traditional strengths in innovating components and introducing them into new uses. Siezing on the advent of the latest generation of technological capability, Very Large Scale Integration (VLSI), existing U.S. firms and a spate of new entrants have

accelerated the pace of innovation, developing new commodity components for new and expanding markets, fragmenting mass commodity markets into high value niches, and pushing the development of new potential markets for custom and semi-custom circuits. Politically, the U.S. industry has managed to place competition in semiconductors on the U.S. government's trade policy agenda. In turn, U.S. policymakers (particularly in Congress) have moved, albeit hesitantly, to introduce legislation (e.g., protection against chip piracy, R&D tax credits) designed to assist the competitive position of U.S. firms.

Nonetheless, as described above, these competitive and political moves have not been sufficient to reverse -- or even to slow -- the Japanese competitive challenge in semiconductor markets. Indeed, Japanese firms are intent upon accelerating the pace and extending the reach of their challenge to U.S. merchant producers, as Table 3 suggests.

TABLE 3:
Comparison of US and Japanese Capital Spending for Semiconductor Production Facilities
($ millions)

Industry	1981	1982	1983	1984
U.S. Merchants	1334	1300	1356	2340
Japanese	830	1100	1452	3180

Source: Extrapolated from Hambrecht and Quist, Japan Economic Journal, and SIA data.

In short, the leap in Japanese capital spending relative to their U.S. merchant competitors suggests that Japanese firms intend to spend their way into a leadership position.

Indeed, combined capital and R&D spending figures suggest that Japanese firms are devoting at least 50% of semiconductor revenues to their push for supremacy.[4] Such an extraordinarily high rate of investment probably could not be sustained without cross-subsidizing semiconductor investment from revenues generated by other divisions of the large, diversified Japanese firms -- in particular, consumer electronics and industrial information industry equipment. Needless to say, such cross-subsidy is unavailable to most merchant U.S. producers whose primary business is semiconductors.

Strategic Consequences

Such leaps in Japanese spending, particularly in the face of recessionary downturns in the highly cyclical semiconductor industry, have been a characteristic strategy of the Japanese push toward leadership in the industry. During each major industry recession over the last decade, Japanese firms have strategically gained market share through high capital investment that is beyond the resources of most U.S merchant firms during a downturn. Their investments in 1974-76 permitted them to enter the U.S. market in the late 1970s. Their spending in 1980-83 permitted them to sieze and extend leadership in commodity memory. Current and anticipated spending may permit them to reach market share parity with the U.S. industry.

The timing of this latest burst of Japanese investment is strategically critical for closely related reasons. The first point to emphasize is that final product demand shapes semiconductor development: The relative competitive capacities of U.S. and Japanese producers today, reflect the composition of the respective domestic final product markets each national industry serves. Table 4 compares these domestic final product markets.

TABLE 4:
Comparison of US and Japanese Final Product Markets
(% of domestic semiconductor consumption -1980)

Market	USA	Japan
Consumer	15	55
Computer	39	25
Industrial	18	14
Communications	17	6
Government	11	--

Source: EEC and BRIE estimates based on European Electronics Components Manufacturers Association (EACEM) and Japanese Electronics Industry Association (EIAJ) data.

As Table 4 hints, the early 1980s U.S. lead in design-intensive chips and associated market development is not the result of any inherent superior ability to develop and market complex chips. **The design and market advantage stems rather from the nature of the final systems markets in which the U.S. retains a lead: complex, design-intensive chips are precisely what the final U.S. computing, telecommunications and industrial systems markets have demanded from U.S. chip producers.** By contrast, until recently, Japanese market demand has been driven primarily

by consumer electronics applications requiring far less sophisticated chips. Similarly, the recent development in Japan of electronics systems products capable of processing kanji has required memory chips with much greater storage capacity than processing English requires, given the complexity of kanji. That situation has pushed Japanese chip producers to emphasize commodity memory development and has been a critical factor behind their recent leadership in memory.

This relative assymetry in the types of components required by the U.S. and Japanese final systems markets is changing however. As Table 5 shows, the relative importance to Japanese chip producers of final consumer electronics system applications has begun to decline dramatically.

TABLE 5:
Shifts in End Uses of Integrated Circuits
(% of domestic Japanese IC shipments)

Product Market	1982	1984
Consumer Products	**50.6**	**41.4**
VTRs	(15.9)	(16.4)
Audio	(12.9)	(10.1)
TVs	(6.4)	(5.3)
Games	(6.2)	(2.8)
Watches/clocks	(2.9)	(2.1)
Other	(6.3)	(4.7)
Industrial Products	**49.4**	**58.6**
Computers/periphs.	(12.7)	(12.9)
Office computers	(2.9)	(3.8)
PCs/WPs	(5.2)	(14.4)
Communications	(7.1)	(8.0)
Desk calculators	(4.8)	(2.7)
Office equipment	(4.0)	(5.5)
Measuring instrumnts	(3.3)	(3.1)
Automobiles	(2.2)	(2.3)
Facsimiles	(1.9)	(2.2)
Other	(5.3)	(3.7)

Note: PC = personal computers; WP = word processors
Source: Electronics Industry Association of Japan

The very shift described in Table 5 has been responsible for pushing Japanese producers into the production of complex non-volatile memory like EPROMs, and underlies their emerging capabilities in microprocessor, microcomputer and peripheral chips. Thus, as demand from final product markets in Japan begins to resemble demand in the U.S. market, Japanese firms will become increasingly competitive producers of the more complex chips in which U.S. merchants currently hold a leadership position. The current surge in Japanese capital investment for semiconductors is intended to bring on-line advanced manufacturing capacity which can be devoted to these increasingly complex chips.

Tables 4 and 5, however, understate the character and significance of compositional changes occuring in final product markets. As our first study of U.S.-Japanese competition in semiconductors showed, each major stage of industry development has been associated with the growth of a leading edge final product market that acted as a 'creative first-user' of semiconductor innovations and a high-volume purchaser driving component industry growth. Thus, for example, the initial U.S. lead in silicon integrated circuits occurred because of creative first-use and high-volume procurement from military and space demand (in particular, the Minuteman Missle and Apollo programs). The subsequent U.S. lead in MOS and the industry's rapid growth was fueled by use and demand from the initial development of the computer industry here rather than abroad. Similarly, the Japanese semiconductor industry did not experience rapid growth until Japanese firms had successfully taken over world leadership in consumer electronics in the early-mid 1970s, thereby providing a large base of domestic demand necessary to sustain the development of a competitive components industry. What tables 4 and 5 understate, therefore, is the emergence of the leading-edge final product market which is likely to drive semiconductor industry development and growth for the remainder of this century.

The largest and fastest growing final product market for VLSI applications lies in **information networking** -- the

convergence of communications and computing into a single information technology industry providing terminal, transmission, switching, database and control equipment, and voice, data, video and facsimile services.[5] As the public and private network infrastructures in the advanced industrial countries -- the electronic equivalent for the movement of information of a nation's roads and rails -- is digitalized over the next 20 years, information networking will grow toward a one-half trillion dollar industry, becoming perhaps the largest industrial sector. Synergistic demand for the VLSI chips necessary to accomplish digital transformation of information network infrastructures will fuel innovation and growth in microelectronics well into the next century. Indeed, this sector is already emerging as the creative first user of leading edge components: For example, Texas Instruments has reemerged as a stong player in microprocessors by virtue of its family of digital signal processors for dedicated communications uses; Intel has increased its strenth in this area by developing commodity controller chips for first use in local area networking; AMD's spectacular growth since the late 1970's has rested largely on communications applications of its chips; and ATT will first incorporate its recently announced 1 megabit dRAM in its PBX and Central Office Switching systems.[6] In this information networking area, U.S. chip producers currently hold an advantage by virtue both of their superior VLSI design skills for complex chips and of their dominant

position in the U.S. domestic market, the fastest growing market for information networking (as a result of divestiture and deregulation in telecommunications). By contrast, Japanese firms are currently less well placed to ride the emerging information-networking boom both because of their relatively inferior position in design-intensive chips and because their domestic market in information-networking is developing more slowly than in the U.S.

Competitive success in semiconductor markets for the remainder of this century, then, is likely to depend upon the relative ability of U.S. and Japanese firms to position themselves NOW to ride the emerging component demand boom associated with information networking. Whichever industry -- Japan or the U.S. -- better succeeds at that positioning will likely emerge as the leading semiconductor industry in the 1990s. It is in this context that the strategic significance of the current spurt in Japanese semiconductor investment is fully revealed. Specifically, increased investment by Japanese firms in R&D and capacity, and their domination of the critical commodity memory markets (eliminating U.S. merchant revenues and production knowhow), has this effect: U.S. merchants will be unable to match Japanese investment during the next industry downturns, and this will permit the Japanese industry to overcome current U.S. advantages (e.g. in the design of complex chips) and ride the next demand boom into the leadership position in

the industry. The consequence of increased Japanese spending on capacity is to cut back or eliminate U.S. margins in the next downturn; the consequence of their spending on R&D is to push their memory lead and catch up in design. If U.S. merchants are thus forced to cut back on their own capacity and R&D spending in the next downturns, then Japanese competitors could emerge during the following boom period very well positioned rapidly to capture market share at U.S. expense. Japanese firms would be strategically well positioned to displace U.S. leadership in microelectronics in ALL of the major, rapid growth applications markets.

Moreover, these Japanese ambitions in microelectronics should not obscure the point that Japanese firms are simultaneously aiming to become the leading producers in the final systems markets driving semiconductor industry growth. Thus, Japanese producers are funding their semiconductor investment with revenues drawn from their final systems divisions precisely as a long-term investment in position for those final product markets. If U.S. merchant leadership in components is eliminated, then U.S. position in the corresponding final electronics systems markets will also erode. This will occur because that position increasingly depends on the merchants for the systems knowhow embedded in silicon VLSI chips that give U.S. systems products performance advantages in international competition. If Japanese producers supplant U.S. leadership in

microelectronics, the real plum for Japanese firms will be dominance of final systems markets.

Yet, Japanese producers will encounter many more difficulties in trying to extend their reach into the new final product markets, then they have encountered in other markets. As observed above, their domestic market (off of which Japanese firms leverage growth) is developing more slowly in the new final products. Moreover, their systems competitors in North America and Europe (e.g. IBM, ATT, Northern Telecom, Ericsson, Hewlett-Packard) have stronger world market positions, are more aware of Japanese strengths and strategies, and will not succumb as easily as have other sectors like steel. Given these difficulties, Japanese firms must retain their leadership position in their strongest final product market, consumer electronics, in order to leverage revenues for their push into the new markets.

Yet, in consumer electronics Japanese producers face a formidable new challenge from the fast growing Korean consumer electronics producers which can not be taken for granted. And determined efforts by large European producers like Phillips and Thomson to remain internationally competitive in consumer electronics will also create difficulties for Japanese firms. In short, Japanese producers must spread their resources across the range of final product markets to meet strong competition there, even as they simultaneously commit resources to overcoming the U.S. lead in semiconductors.

This focus of Japan's producers in spreading resources simultaneously to gain market share in both components and final markets, leaves them competitively vulnerable to alliances between U.S. merchants and the final systems producers who compete with the Japanese firms. **Specifically, if the growth of Japanese competitive position in final product markets is constrained by the presence of strong competitors who are supplied by U.S. component firms, then the U.S. merchants should capture an expanding share of component sales going to final systems markets.** Because their response to the Japanese challenge along the single front of purely semiconductor-oriented strategies has not managed to contain the slow attrition of their market share, U.S. merchants are compelled by the logic of their situation to open a second front: They are only likely to slow Japanese gains by creating strategic alliances with systems producers in final product markets. This is particularly the case, and can be most easily seen, in the European market, which has been a mainstay of the U.S. merchant market position, but in which Japanese firms have begun to take market share in both components and final systems. Therefore, before elaborating the consequences of creating strategic alliances in final product markets, we first examine Europe's situation in microelectronics.

II: THE EUROPEAN DILEMMA AND COMPETITIVE CONSUEQUENCES

The European Microelectronics Dilemma

The European position in semiconductors is extremely weak and has been declining rapidly as Table 6 shows, even in the domestic European market, except in certain MOS IC devices where European firms have recently concentrated both resources and technology exchange agreements with U.S. and Japanese firms. Even in these latter market segments, the European world market position is miniscule.

TABLE 6:
European Firm Semiconductor Market Shares
(% of value)

Market	Type	1978	1984	% Change
Worldwide	**All Semis**	**13.9**	**8.6**	**- 38.1**
	ICs	8.1	6.4	- 20.9
	MOS IC	5.2	5.6	+ 7.6
	MOS Memory	0.8	3.8	+375.0
	Mos MPU	1.5	2.8	+ 86.6
Europe	**All Semis**	**44.6**	**39.4**	**- 11.6**

Note: 1984 figures are estimates.
Source: Dataquest.

As Table 7 suggests, the European market is dominated by U.S. producers. Of the top 25 European manufacturers, 13 are U.S. firms, 8 European and only 4 Japanese.[7] However, from 1977 to 1983, European firms lost share in their home market to Japanese firms, while the U.S. share remained relatively constant, first increasing (at the European's expense) then falling back to the 1978 level (through losses to Japanese firms) over the five year period.

TABLE 7:
Shares of European Semiconductor Market

Companies	1977	1983
European	48%	40%
U.S.	50%	50%
Japanese	2%	10%

Source: Dataquest.

Japanese market share gains in Europe -- the world's third largest market for components accounting for about 16% of consumption -- have strategic consequences for both U.S. merchants and the largely integrated European electronics producers who participate in merchant semiconductor markets. For the latter, the increasing reliance for components on Japanese producers who are competitors to European systems companies in final product markets, augurs increasing vulnerability in those final markets. For U.S. producers, their strong European market position has been an integral part of their overall world leadership; Japanese gains in Europe herald intensified competition in a market that has been a bastion of U.S. strength.

As in the U.S. and Japanese cases, a combination of domestic market structure, government policy and firm strategies has determined the position of European firms in international semiconductor competition -- although in Europe's case, those factors have combined to deliver relative weakness on world markets.[8] Government policy, both at the Europe-wide and national levels has been a critical variable underlying Europe's weak position.

although this consequence was thoroughly unintended. The high European external tariff (currently still 17% ad valorem), encouraged foreign direct investment in Europe behind the tariff wall, particularly by U.S. firms during the 1960s and 1970s when U.S. leadership in semiconductor technology was unchallenged and consequently desired in Europe. Indeed, the setting-up of local European manufacturing subsidiaries of U.S. merchant firms was further encouraged by many European states as a condition of doing business in those countries.

This set of policies contrasts strongly with the Japanese strategy which completely closed the domestic Japanese market to investment by U.S. companies, thereby simultaneously reserving demand in the Japanese market for Japanese firms and forcing U.S. firms to transfer technology to Japanese companies if they wanted any return at all from the growth of the Japanese market. Given the relative competitive position of the European and Japanese semiconductor industries, the consequences of the respective approaches to trade and investment policy have been dramatic: U.S. firms dominate in Europe, Japanese firms in Japan; if U.S. supremacy in Europe is dislodged, it will be as likely by Japanese as by European producers.

A second critical component underlying the relatively inferior position of European producers has been the fragmentation of the large Europe-wide market into much smaller national markets (or regional ones in the case of

the Scandanavian and Benelux countries). While Europe as a whole might have offered European producers the large, high-volume market necessary to leverage world-scale economies, the fragmentation of that market eliminated the potential for Europe-wide product specialization. The fragmentation itself was primarily the result of national policies concerned to develop indigenous national component industries covering the broad range of semiconductor product. Those policies simultaneously discouraged cooperation among European firms from different countries and encouraged cooperation with U.S. producers (necessary because U.S. firms had the required technology). **Paradoxically, then, as a result of national European policies, it has been multinational U.S. producers -- operating in most of the major European countries -- who have captured the scale benefits of the very same Europe-wide market that has been denied to European producers by the very same national policies.** This is, of course, an outcome with which Europe is quite familiar in other sectors like computers.

National European policies aimed at fostering a few large, vertically integrated, national champion producers in the principal end-use final systems markets (particularly computers, telecommunications and even now consumer electronics) also exacerbated Europe's problems in microelectronics. National promotional programs of the 1960s and early 1970s were aimed largely at establishing position

in final markets, and relatively neglected the channeling of resources to semiconductor development. The contrast to Japan is again instructive: Initial Japanese promotional programs were aimed primarily at developing position in computers and, like the European programs, failed to deliver an internationally competitive components industry; Japan succeeded only after it explicitly concentrated resources on establishing position in semiconductors through the VLSI project.

Moreover, the large integrated national champions promoted through those European national programs, like Thomson and Siemens, were primarily interested in developing semiconductor capacities which served their internal needs -- necessitating a strong focus on custom chip production for their final systems products -- and only secondarily interested in serving as merchant commodity component producers for the rest of European industry. As a consequence of that strategic focus, U.S. firms took up the European merchant role. With little European inter-country competition in semiconductor development among the large integrated national champions, and with a high proportion of national demand for both components and systems reserved through state policy for those firms, there was comparatively little stimulus to technological innovation. Indeed, Europe's firms have largely been technology followers of U.S. merchant innovations.

As technological followers of U.S. innovation, Europe has been particularly vulnerable to the strategies of U.S. merchants. In particular, U.S. firms characteristically developed semiconductor innovations and moved to volume production in the U.S. market. Only after the technology was proven, its production refined and costs sharply reduced through learning and scale economies, did U.S. firms transfer the technology to Europe as exports or for production in their European subsidiaries. Thus, by the time component innovations appeared on the European scene, U.S. merchants had substantial competitive advantages which European companies could not hope to overcome. Perhaps even more critical, however, these characteristic strategies of U.S. producers meant that semiconductor innovations appearing in Europe **were developed primarily to meet the needs of U.S. final product markets, and were only secondarily adapted to the needs of European final markets.**

Indeed, as Table 8 shows, European consumption of semiconductors by end-use is significantly different than the comparable U.S. consumption.

TABLE 8:
European and US Semiconductor Consumption By End Use
(1983 - % of each market)

End Use	European	U.S.
Telecommunications	23	20
Consumer	22	10
Industrial	22	17
Computer	20	37
Government/military	9	11
Automotive	4	5

Source: EACEM and BRIE estimates.

This mismatch between European component needs and U.S. component supply -- and Europe's overall inferior position in semiconductors of which it is a piece -- has had important consequences for Europe's position in final markets. In particular, table 9 shows that European per capita consumption of semiconductors is disastrously far behind that of Japan and the U.S., and has been growing far more slowly.

TABLE 9:
Semiconductor Consumption Per Capita
(Dollars)

Country	1978	1984
Europe Total	7	14
France		(15)
Germany		(22)
U.K.		(20)
Italy		(8)
U.S.	16	52
Japan	22	61

Source: Dataquest.

This low per-capita consumption means that Europe is applying microelectronics to product and production processes far more slowly and far less completely than have Japan and the U.S. Relative to their growth, Europe has been much less able to provide a strong source of demand off of which to leverage the growth of domestic European -- and for that matter, entrenched U.S. merchant -- semiconductor suppliers. There are some signs that this situation could change as European plans to digitalize the information network infrastructure unfold. Dynamic growth of that and

related information technology markets could strengthen the position of European and U.S. chipmakers to the extent they participate in the growth of those markets. The recent dramatic growth in use of personal computers in England and the resulting upsurge in demand for related chips from U.S. firms is one example.

Competitive Consequences and Strategic Alliances

For Europe, the consequences of the microelectronics dilemma described above have been serious. In particular, European weakness in components has meant decisive competitive vulnerabilities on final systems markets. The European position in computers is weak and sustained largely through the aid of government policies and procurement. Europe retains a position in consumer electronics mostly by virtue of policies that have limited foreign penetration of domestic European markets. Japanese firms have leapt ahead of the traditionally strong European capital goods sector by applying microelectronics to production equipment at a far more rapid pace. European sources indicate that the European test, monitoring and control equipment industry similarly lags the pace at which microelectronics is being applied outside of Europe. And even the historically strong European telecommunications sector has been losing its share of export markets to Japanese producers at the rate of 1% per year over the last 15 years.[9]

For U.S. merchants, the consequences of Europe's dilemma are equally serious. Europe's comparatively slow application of microelectronics means that U.S. merchants can not rely on their entrenched position in Europe to compensate for Japanese semiconductor gains in Japan and the U.S. Even if U.S. firms maintain their entrenched position in the face of Japanese encroachment in Europe, the growth that they will receive from the European market will not match Japanese gains in the other major industrialized markets. Only if Europe begins to apply microelectronics more rapidly, will the European market provide a renewed and expanding base for U.S. merchants to respond to the widet Japanese challenge.

Yet, Europe's own compelling need is precisely the same: To apply microelectronics in traditional and high technology industries at a more rapid pace in order to prevent the erosion of their position in final product markets. Critically, European producers can not rely on Japanese semiconductor suppliers to achieve this because those Japanese producers -- unlike the U.S. merchants -- are competitors to those European firms in the very same systems markets where Europe needs to apply microelectronics more rapidly. Relying on Japanese components risks letting Japanese systems competitors dictate the pace and extent of microelectronics applications in Europe. That will be a losing strategy for European final market producers: Japanese producers will never give them access in an

appropriate time frame to the same leading edge components that give the final products of those Japanese producers performance advantages in international competition.*

It is, therefore, around this point that the interests and needs of U.S. merchants and European final market producers converge to mutual advantage. It is strategically necessary for both that microelectronics be applied more rapidly in Europe. European firms need to incorporate leading edge components to remain competitive in final systems markets; U.S. merchants need them as customers to fuel the U.S. semiconductor industry's growth relative to Japanese growth. European firms need to win in competition on final systems markets against Japanese producers in order to maintain strong economic growth in Europe: U.S. merchants need them to win in order to contain Japanese gains in final product markets and thereby divert Japanese attention and resources from the challenge in semiconductors. It appears

* It is crucial to note here that current U.S. Defense Department policy restricting the export of dual-use technologies may push European firms directly into the very alliances with Japanese producers that they cannot really afford. Given U.S. defense restrictions, European firms cannot be certain that dual-use technologies which they need for their final systems products will be available when needed from U.S. producers. They may therefore turn to Japanese sources of dual-use technologies. In the process, U.S. firms are likely to lose critical sales opportunities in Europe. Thus, Defense Department restrictions have the disastrous unintended (and largely unexamined) consequence of simultaneously severly injuring the competitive position of U.S. firms in commercial markets and promoting Japanese gains at the expense of U.S. firms. **The outcome is likely to be that Defense policy undermines the industrial sectors on which Defense capabilities rest.**

that only strategic alliances between U.S. merchants and European final market producers can accomplish this set of shared interests and aims. **Specifically, from Europe's perspective, U.S. merchants would have to make a commitment to supply leading edge microelectronic components appropriate to the needs of European end-use markets; from the U.S. industry's perspective, European users would have to commit to long-term supply relations with U.S. merchants in return for leading-edge technology suitable to their needs.**

The former committment would require a change in the historical practice of U.S. merchants in Europe. They could no longer view Europe as a secondary market for the later stages of the product cycle of components developed in the U.S. for U.S. uses. They would have to commit time and resources to working with European final market producers to develop components -- both custom and commodity -- in Europe suitable to European uses. More than likely, they would have to be willing to share their R&D capacities and transfer the technology that is developed to European second sources. Without these quid pro quos, it would be difficult to receive the support of European governments. Similarly, the latter committment of European producers to long-term supply relations with U.S. merchants would also require changes in traditional practice. Without the assurance of long-term supply (defined as guarenteed high-volume purchases over time, so long as cost and quality remain competitive), it is

difficult to imagine U.S. firms committing the kind of resources to Europe that are necessary to assist Europe's long-term development. The logical European final product markets from which to leverage such strategic alliances include consumer electronics, telecommunications, computers, production equipment/capital goods, and test, monitoring and control equipment. These are all sectors in which Japanese producers are aiming to increase their world market share at the expense of European producers, and in which U.S. merchant strengths in complex chips could be fruitfully brought to bear.

It is appropriate, before drawing conclusions, to mention the wide range of new promotional programs in Europe aimed at developing internationally competitive European semiconductor capacities. Appendix A lists these efforts at both the national and Europe-wide levels, and contrasts them to programs of other countries. It appears that European governments have learned from their past policy failures; they are explicitly aiming at developing component knowhow and fostering its application, much as did Japan with the VLSI project. From the perspective of U.S. merchants, these promotional efforts should be viewed as **complementary** to the creation of strategic alliances with European final market producers. To the extent the promotional programs succeed, the climate for rapid application of microelectronics in Europe will improve dramatically. To the extent U.S. merchants can position themselves through strategic

alliances to produce results in Europe comparable to the aims of the promotional programs -- rapid application, and development of knowhow through second source arrangements with European chip-makers -- U.S. firms will be viewed as allies. And that impression of U.S. firms as allies in Europe will be the sine qua non of continued success for merchant U.S. producers in the European market.

Conclusion: STRATEGIC ALLIANCES AND RECAPTURED INITIATIVE

Over the past seven years, Japanese producers of semiconductors have made a remarkably successful push to challenge the international market dominance merchant U.S. chipmakers have held since the industry's inception. By concentrating resources on microelectronics development and application, Japanese producers have simultaneously emerged as formidable challengers to U.S. and European firms in the final product markets that depend upon the incorporation of semiconductors. Given their secure home market, characteristic focus on process innovation and refinement, and vast resources drawn from final product market revenues, Japanese firms are well-placed to outspend their merchant U.S. rivals and attain leadership in microelectronics. From the perspective of Japanese producers, the next years provide critical opportunities: If, through their R&D and capital spending, they can catch up in design of complex chips and put a greater amount (than U.S. firms) of capacity in place, they should be able -- as their domestic market

demand converges with demand in the U.S. -- to capture a growing share of demand from the emerging global boom in information technology.

Even as Japanese firms have risen to challenge U.S. leadership in semiconductors, Europe's producers have seen their international and domestic European market positions deteriorate. Europe is applying microelectronics in final product markets at a far slower pace than are the U.S. and Japan, and the consequence has been an erosion of Europe's position in final product markets as well as in microelectronics. While Europe is making a concerted effort to reverse its declining situation, European producers in final product markets will need substantial assistance in semiconducor development from outside Europe if they are to remain competitive on international markets. Since Europe can not rely on Japanese competitors of Europe's final market producers for the semiconductor assistance needed, Europe is forced toward strategic alliances with merchant U.S. chipmakers. From Europe's perspective, the aim of such alliances is to develop semiconductors appropriate for European uses and to apply them rapidly to sustain the final market position of European producers.

In contrast to Japan and in parallel with Europe, U.S. merchant semiconductor producers have been on the defensive in international markets. The inexorably eroding leadership in microelectronics of U.S. firms places them in a difficult competitive situation; but their traditional stengths

provide them with opportunities to reverse the attrition of their market share. From their perspective, the logic of strategic alliances that emerges from the European situation in microelectronics -- to contain Japanese gains in final product markets, divert their attention from semiconductors, and create secure sources of demand for U.S. merchant firms -- applies broadly outside of Europe. The same kinds of alliances might be struck to the same strategic advantage between merchant U.S. producers and final systems producers in the U.S. and elsewhere. In the U.S., there is an equally compelling need to apply microelectronics in areas that have so far resisted its application, but in which Japan is moving ahead; those areas could become a strong source of secure demand for U.S. merchant producers. For example, the wide range of U.S. manufacturers that have seen their competitive position erode over the last decade, including textile and apparel makers, footwear producers, producers of consumer durables and heavy capital equipment, steelmakers, auto component suppliers, among many others, need to apply microelectronics to their products or processes to remain competitive.

Similarly, selective strategic alliances with producers in Canada or newly industrializing countries which are pressed by Japanese competition, would provide fertile ground for U.S. merchants. For example, Korean consumer electronics producers represent a potent threat to the long-standing dominance of Japanese firms. Alliances

between U.S. merchants and Korean consumer electronics producers are possible. They would be aimed at bringing U.S. design-intensive component strengths to bear in making Korean products competitive on a world-scale with those of Japanese producers. For the U.S. merchants, this would have the benefit of creating a renewed source of vigorous demand for consumer chips from U.S. producers, permitting them to reenter a market segment from which they have been largely eliminated by Japanese competition. Moreover, since the Korean producers of consumer electronics are large, diversified conglomerates with production in a wide range of areas, strategic alliances could extend into other product areas. This would have the effect of locking-in increasing demand from the growth of the Korean economy for the benefit of U.S. producers.

From the perspective of U.S. merchants, strategic alliances of the kind described above will be necessary, but they may not be sufficient to contain the Japanese challenge, in part because they will take some time to develop. Given the Japanese efforts to spend their way into leadership in components, and the inability of U.S. firms to match those expenditures during downturns in the market, there is an additional role for U.S. policy to play in leveling the international playing field. Specifically, this would involve counter-cyclical policies designed to assist U.S. firms through the next downturns. These policies should be experimental, that is, of limited duration so that they

do not turn into enduring subsidy, and aimed at generating sufficient internal funds to sustain both R&D and capital spending during downturns. One example would be a tax credit for use during upturns aimed at generating an investment reserve for spending in the U.S. during downturns (measured, for example, by industry capacity utilization or book-to-bill ratios). Such an investment reserve would permit U.S. merchants to match Japanese spending, and position themselves to ride the next boom period.

Overall, then, international competition in microelectronics is at a critical juncture. Japanese producers have grabbed the initiative from the U.S. industry, and are aiming to overtake U.S. leadership in the industry. Consequently, U.S. merchants face a choice between an enduring loss of world market position or, in alliance with European and other final market producers, a chance to grab back the initiative and forge an enduring lead on world markets for the forseeable future. The dilemma for both the U.S. and Japanese industries is the same -- to position themselves to ride the next critical demand boom, information networking. For Japan this requires outspending U.S. rivals in both R&D and capacity, thereby permitting them to reach technological parity in complex chips and forcing U.S. firms to cede share of growing markets. For U.S. merchants, it requires that they maintain their R&D/design lead intact, bring their manufacturing back to par with the Japanese, and place sufficient capacity in

place to ride the next boom -- while forcing Japanese firms into a defensive posture sufficient to limit their participation in the information networking boom. At a minimum, that requires that U.S. firms survive the next industry downturns at least as well as do the Japanese, without cutting back on their R&D/design lead and capacity.

Indeed, if U.S. merchants are to sieze back the initiative in semiconductor markets from their Japanese competitors, they are forced toward a strategy involving a combination of efforts. These include, short-term, experimental countercyclical policies aimed at sustaining U.S. position during the next downturns; alliances with U.S. information networking system producers to push along the complex semiconductor content of their final products; a continued push for market access in Japan so that U.S. firms can bring to bear in Japan the knowhow associated with supplying the information networking market in the U.S., and can thus push existing advantages in the Japanese home market. Perhaps most critical, U.S. firms would have to foster strategic alliances with producers in Europe, the U.S., Korea and elsewhere, aimed at making them world class competitors to the Japanese in selected final systems markets. In the absense of such a comprehensive strategy, U.S. firms will continue to see their position erode, and Japanese producers are likely to supplant U.S. leadership in semiconductors for the first time in history.

FOOTNOTES

1. Figures extrapolated from data provided by the SIA, Dataquest and ICE.

2. Michael Borrus, James Millstein and John Zysman, U.S.-Japanese Competition in the Semiconductor Industry, (UC Berkeley: IIS, 1982); and Borrus, Responses to the Japanese Challenge in High Technology, (UC Berkeley: BRIE, 1983).

3. Figures are from John J. Lazlo, Jr., The Japanese Semiconductor Industry...1985, (Hambrecht and Quist, January 31, 1985) at p.13-14.

4. This estimate and the speculation that follows come from data prepared by William Finan for the SIA.

5. For a discussion of this emerging industrial sector, see Michael Borrus, Francois Bar and Ibrahim Warde, The Impacts of Divestiture and Deregulation: Infrastructure Change, Manufacturing Transition and U.S. Competitiveness in Telecommunications, (UC Berkeley: BRIE, 1985). See also, A.D. Little, Final Report to the EEC on European Telecommunications, (EEC, November, 1983), at Annex A, B and C.

6. On these points, see e.g., "Chips Forging Telecom Links," and "DSP Chips Spark Lackluster Market," ElectronicsWeek, 2/11/85, p.26 and 20; and "Bell Labs sets production of 1-Mb DRAMs," ElectronicsWeek, 1/1/85, p.24.

7. Electronics Weekly, 18 January 1984.

8. The information on European semiconductor development which follows, but NOT our own interpretation of that information given in the text, is drawn from a number of recent studies of European microelectronics. These include: Rainald von Gizycki and Ingrid Schubert, Microelectronics: A Challenge for Europe's Industrial Survival, (Munich and Vienna: R. Oldenbourg Verlag, 1984); OECD, Trade in High-Technology Products: The Semiconductor Industry, (Paris: OECD, July, 1984); Giovanni Dosi, "Semiconductors: Europe's precarious survival in high technology," in Geoffrey Shepard et al., Europe's Industries: Public and Private Strategies for Change, (Ithaca, NY: Cornell University Press,1983); Rob van Tulder and Eric van Empel, European Multinationals in the Semiconductor Industry, (Amsterdam: IRM, University of Amsterdam, October, 1984); and Maurice English, The European Semiconductor Industry, (Brussels: EEC Intelligence Unit, June, 1984).

9. Telecom figure is from A.D. Little, supra, n.5.