# 2 WORLDWIDE IC MANUFACTURERS

## OVERVIEW

Analysis of worldwide integrated circuit (IC) sales by region from 1975 through 1996 provides a perspective to the increasingly global importance of semiconductor manufacturing (Figure 2-1). Historically, sales by North American companies were dominant in the mid-1970s. By the mid-1980s IC sales were evenly split between North American and Japanese companies. By 1990, the Japanese had increased their share of worldwide IC sales to a leading 48 percent, mainly at the expense of North American companies. Then, in 1992 Japan's economy weakened causing their share to drop; a persistent economic slump in the following years coupled with Korean IC manufacturers' success in the memory market caused the Japanese share to continue dropping. The Japanese share fell further in 1996 primarily because of the yen to dollar exchange rate and the decline in the dynamic random access memory (DRAM) market.

While market shares for North American and Japanese IC manufacturers have fluctuated over the past 22 years, European IC companies have continued to capture a relatively steady seven to ten percent of worldwide IC sales. The share belonging to ROW companies, which is dominated by Korean and Taiwanese manufacturers, surpassed that of European companies in 1992, reaching 15 percent in 1995, and 14 percent in 1996.

A ranking of the world's top ten merchant semiconductor sales leaders in 1996, and ICE's estimate for 1997, is given in Figure 2-2. The estimated sales for these companies as a group increased 10 percent during 1997. The 1996 top fifteen worldwide IC sales leaders are listed in Figure 2-3.

## NORTH AMERICAN MERCHANT IC MANUFACTURERS

Figure 2-4 lists the North American merchant IC manufacturers with sales of at least $50 million, based on final 1995 and 1996 data. The figure includes sales for both IC manufacturers and fabless IC suppliers. For the manufacturers, IC sales include all revenue from ICs produced by their own fabrication facilities and by external foundries. Sales by major application specific IC (ASIC) companies, for example Xilinx, Altera, and LSI Logic, include revenue from sales of software design tools. On average, sales for IC companies headquartered in North America grew four percent in 1996 compared to 33 percent in 1995.

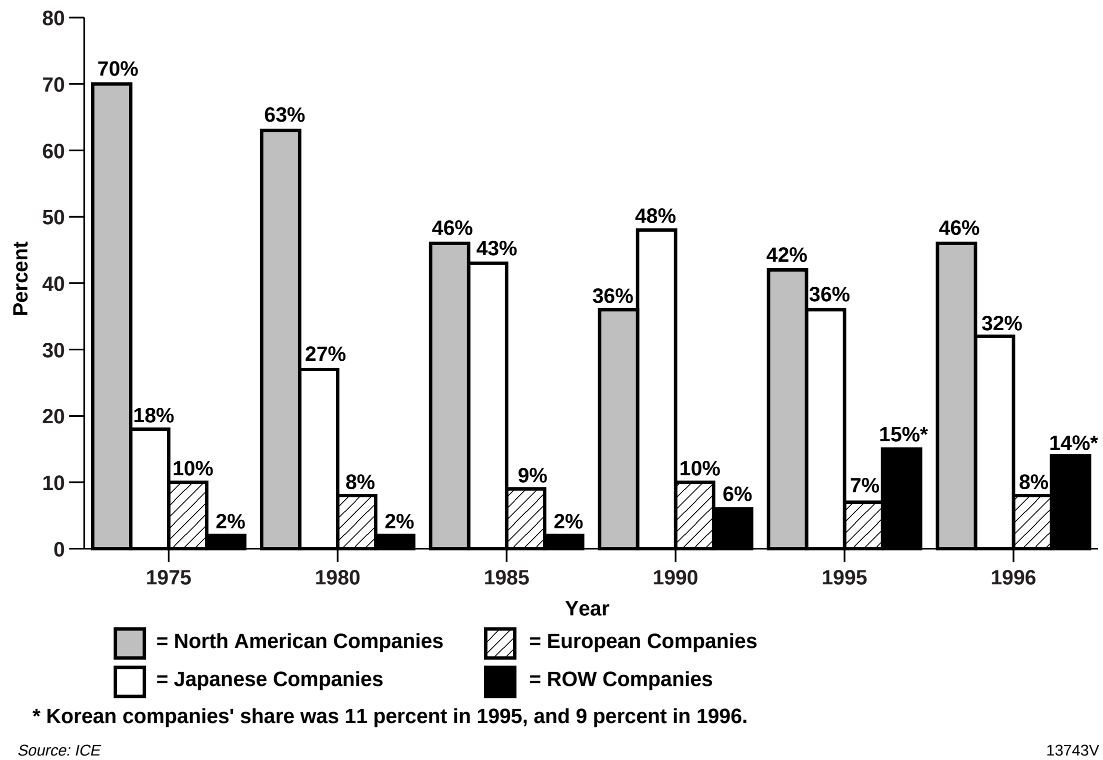



**Figure 2-1. Worldwide IC Sales by Region ($)**

| Rank | | | Company | 1996 Total Semi Sales ($B) | 1997 Total Semi Sales (Est, $B) | 1997/1996 Percent Change |
|---|---|---|---|---|---|---|
| 1997 | 1996 | 1992 | | | | |
| 1 | 1 | 3 | Intel | 17.9 | 22.8 | 27.5 |
| 2 | 2 | 1 | NEC | 11.0 | 11.5 | 4.5 |
| 3 | 3 | 2 | Toshiba | 8.7 | 9.0 | 3 |
| 4 | 4 | 5 | Hitachi | 8.3 | 8.5 | 2 |
| 5 | 5 | 4 | Motorola | 8.2 | 8.2 | — |
| 6 | 6 | 6 | TI | 6.8 | 7.8 | 15 |
| 7 | 7 | 11 | Samsung | 6.7 | 6.8 | 1 |
| 8 | 8 | N/A | IBM Microelectronics | 5.1 | 6.0 | 17 |
| 9 | 9 | 8 | Mitsubishi | 4.2 | 4.5 | 8 |
| 10 | 10 | 14 | SGS-Thomson | 4.1 | 3.8 | –7 |
| — | — | — | Total | 80.9 | 88.9 | |

*Source: ICE* 18072P

**Figure 2-2. Worldwide Top Ten Merchant Semiconductor Sales Leaders**

| Rank | | | Company | 1996 Total IC Sales ($M) | 1996/1995 Percent Change |
|---|---|---|---|---|---|
| 1996 | 1995 | 1992 | | | |
| 1 | 1 | 2 | Intel | 17,870 | 31 |
| 2 | 2 | 1 | NEC | 9,950 | –10 |
| 3 | 3 | 5 | Hitachi | 7,254 | –16 |
| 4 | 4 | 3 | Toshiba | 6,970 | –19 |
| 5 | 7 | 4 | Motorola | 6,745 | –7 |
| 6 | 6 | 6 | TI | 6,700 | –14 |
| 7 | 5 | 9 | Samsung | 6,385 | –22 |
| 8 | 8 | N/A | IBM | 5,100 | –11 |
| 9 | 9 | 8 | Mitsubishi | 3,545 | –20 |
| 10 | 13 | 15 | SGS-Thomson | 3,522 | 19 |
| 11 | 14 | 13 | Philips | 3,253 | 11 |
| 12 | 10 | 27 | Hyundai | 3,150 | –28 |
| 13 | 11 | 7 | Fujitsu | 2,880 | –28 |
| 14 | 12 | 21 | LG Semicon | 2,500 | –31 |
| 15 | 16 | 13 | Matsushita | 2,325 | –11 |
| — | — | — | Total | 88,149 | –8 |

*Source: ICE* 20458C

**Figure 2-3. Worldwide Top Fifteen Merchant IC Sales Leaders**

Those companies with the strongest percent sales gains for 1996 are shown in Figure 2-5. Note that this list includes only those companies with sales of more than $100 million, thereby making growth rates more comparable. A close look at this figure reveals two interesting points: First, most of the companies listed are involved with manufacturing graphics or multimedia and communications-related ICs. Second, over half of them are fabless.

Figure 2-6 lists selected North American IC companies and the end-user markets they rely on. Those companies that sell to a balance of computer, communications, and consumer-product manufacturers are generally more resilient to cyclical fluctuations. Those companies that are heavily dependent on the computer industry have benefited from a booming market for personal computers (PCs) over the past couple of years. However, these same companies are very susceptible to a dropping market during a PC-inventory correction period, like that which occurred in the first part of 1996. A recent example is Cirrus Logic, which after several profitable years experienced net losses and is now working to reduce its reliance on one particular market.

## Top Ten North American Fabless IC Suppliers

Figure 2-7 provides a ranking of the top ten North American fabless IC suppliers for 1996. With few exceptions, the leading fabless firms increased their sales. As a group, sales for the ten companies increased 27 percent.

| Company | Fabless[1] | 1995 MOS | 1995 Bipolar | 1995 IC Total | 1996/1995 Percent Change | 1996 MOS | 1996 Bipolar | 1996 IC Total |
|---|---|---|---|---|---|---|---|---|
| Actel | x | 109 | — | 109 | 38 | 150 | — | 150 |
| Allegro MicroSystems[2] | | 45 | 136 | 181 | 11 | 50 | 151 | 201 |
| Alliance Semiconductor | x | 222 | — | 222 | –67 | 73 | — | 73 |
| Altera | x | 402 | — | 402 | 24 | 497 | — | 497 |
| AMCC[2] | | 14 | 37 | 51 | 18 | 16 | 44 | 60 |
| AMD | | 2,315 | 115 | 2,430 | –20 | 1,880 | 75 | 1,955 |
| AMI | | 221 | — | 221 | 16 | 256 | — | 256 |
| Anadigics[3] | | 51 | — | 51 | 35 | 69 | — | 69 |
| Analog Devices[2] | | 485 | 442 | 927 | 33 | 665 | 565 | 1,230 |
| Atmel[2] | | 634 | — | 634 | 69 | 1,070 | — | 1,070 |
| Burr-Brown[2] | | 60 | 168 | 228 | –10 | 60 | 145 | 205 |
| C-Cube Microsystems | x | 124 | — | 124 | 158 | 320 | — | 320 |
| Catalyst | x | 57 | — | 57 | –5 | 54 | — | 54 |
| Cherry Semiconductor[2] | | 3 | 96 | 99 | 1 | 6 | 94 | 100 |
| Chips and Technologies | x | 137 | — | 137 | 23 | 168 | — | 168 |
| Cirrus Logic[2,3] | | 1,187 | — | 1,187 | –18 | 977 | — | 977 |
| Cypress[2] | | 596 | — | 596 | –11 | 528 | — | 528 |
| Cyrix | x | 228 | — | 228 | –19 | 184 | — | 184 |
| Dallas Semiconductor | | 233 | — | 233 | 24 | 288 | — | 288 |
| ESS Technology | x | 106 | — | 106 | 114 | 227 | — | 227 |
| Exar[2] | x | 103 | 35 | 138 | –28 | 74 | 25 | 99 |
| Gennum | | — | 42 | 42 | 31 | — | 55 | 55 |
| Harris[2] | | 435 | 90 | 525 | — | 435 | 90 | 525 |
| Honeywell | | 52 | 6 | 58 | 3 | 52 | 8 | 60 |
| IBM Microelectronics[2] | | 4,815 | 890 | 5,705 | –11 | 4,300 | 800 | 5,100 |
| IC Works[2] | | 43 | — | 43 | 16 | 50 | — | 50 |
| ICS | x | 117 | — | 117 | –23 | 90 | — | 90 |
| IDT[2] | | 645 | — | 645 | –14 | 554 | — | 554 |
| IMP | | 70 | — | 70 | 13 | 79 | — | 79 |
| Intel[2] | | 13,590 | — | 13,590 | 31 | 17,870 | — | 17,870 |
| ISSI | x | 149 | — | 149 | –26 | 111 | — | 111 |
| Lattice | x | 185 | — | 185 | 9 | 201 | — | 201 |
| Level One | x | 78 | — | 78 | 44 | 112 | — | 112 |
| Linear Technology[2] | | 98 | 230 | 328 | 14 | 125 | 250 | 375 |
| LSI Logic | | 1,268 | — | 1,268 | –2 | 1,239 | — | 1,239 |

1 A company is considered fabless if the majority of its wafers are manufactured by independent foundries.
2 BiCMOS ICs included under MOS.
3 GaAs ICs included under MOS.

*Source: ICE* 9998AB

**Figure 2-4. North American Companies' IC Sales (≥$50M, $M)**

| Company | Fabless[1] | 1995 | | | 1996/1995 Percent Change | 1996 | | |
|---|---|---|---|---|---|---|---|---|
| | | MOS | Bipolar | IC Total | | MOS | Bipolar | IC Total |
| Lucent Technologies[2] | | 1,450 | 230 | 1,680 | 22 | 1,805 | 245 | 2,050 |
| Maxim[2] | | 345 | — | 345 | 23 | 425 | — | 425 |
| Micrel[2] | | 47 | 6 | 53 | 26 | 60 | 7 | 67 |
| Micro Linear[2] | x | 18 | 39 | 57 | –5 | 22 | 32 | 54 |
| Microchip Technology | | 273 | — | 273 | 15 | 313 | — | 313 |
| Micron | | 2,705 | — | 2,705 | –36 | 1,740 | — | 1,740 |
| Mitel Semiconductor | | 68 | — | 68 | 3 | 70 | — | 70 |
| Motorola[2] | | 5,797 | 1,455 | 7,252 | –7 | 5,395 | 1,350 | 6,745 |
| National[2] | | 1,164 | 1,140 | 2,304 | –4 | 1,177 | 1,045 | 2,222 |
| Oak Technology | x | 212 | — | 212 | –18 | 174 | — | 174 |
| OPTi | x | 164 | — | 164 | –27 | 119 | — | 119 |
| Orbit Semiconductor | | 62 | — | 62 | 3 | 64 | — | 64 |
| QLogic | x | 50 | — | 50 | 32 | 66 | — | 66 |
| Raytheon Semiconductor[2,3] | | 40 | 70 | 110 | 5 | 55 | 60 | 115 |
| Rockwell Semiconductor[3,4] | | 760 | — | 760 | 91 | 1,450 | — | 1,450 |
| S-MOS Systems | x | 190 | — | 190 | 11 | 210 | — | 210 |
| S3 | x | 316 | — | 316 | 47 | 465 | — | 465 |
| Sierra Semiconductor | x | 189 | — | 189 | –1 | 188 | — | 188 |
| Silicon Storage Technology | x | 40 | — | 40 | 133 | 93 | — | 93 |
| Silicon Systems[2, 5] | | 205 | 170 | 375 | –47 | 125 | 75 | 200 |
| Standard Microsystems | | 133 | — | 133 | 42 | 189 | — | 189 |
| Symbios Logic | | 520 | — | 520 | 15 | 600 | — | 600 |
| Texas Instruments[2,3] | | 5,995 | 1,805 | 7,800 | –14 | 4,900 | 1,800 | 6,700 |
| Trident Microsystems | x | 139 | — | 139 | 35 | 187 | — | 187 |
| TriQuint[3] | | 46 | — | 46 | 30 | 60 | — | 60 |
| Unitrode[2] | | 10 | 106 | 116 | 14 | 17 | 115 | 132 |
| Vitesse[3] | | 47 | — | 47 | 53 | 72 | — | 72 |
| VLSI Technology | | 720 | — | 720 | — | 717 | — | 717 |
| VTC | | — | 166 | 166 | 7 | — | 178 | 178 |
| Xicor | | 114 | — | 114 | 9 | 124 | — | 124 |
| Xilinx | x | 520 | — | 520 | 9 | 566 | — | 566 |
| Zilog | | 265 | — | 265 | 13 | 300 | — | 300 |
| Others | | 1,525 | 125 | 1,650 | –9 | 1,400 | 100 | 1,500 |
| Total | | 53,006 | 7,599 | 60,605 | 4 | 55,978 | 7,309 | 63,287 |

[1] A company is considered fabless if the majority of its wafers are manufactured by independent foundries.
[2] BiCMOS ICs included under MOS.
[3] GaAs ICs included under MOS.
[4] Includes Brooktree's 1996 sales.
[5] Acquired by TI, figure represents only 1H96 sales.

*Source: ICE*

9998AB

**Figure 2-4. North American Companies' IC Sales (≥$50M, $M, continued))**

| Rank | Company | 1996 Percent Growth | Primary Products |
|---|---|---|---|
| 1 | C-Cube Microsystems** | 158 | Digital video and still image compression chips. |
| 2 | ESS Technology** | 114 | Audio ICs, wavetable synthesizers, and multimedia system chipsets. |
| 3 | Rockwell | 91 | Modem chips, multimedia and graphics devices, and communications circuits. |
| 4 | Atmel | 69 | Programmable non-volatile memory and logic chips, as well as gate arrays and cell-based ASICs. |
| 5 | S3** | 47 | Graphics and video accelerator ICs. |
| 6 | Level One** | 44 | ICs for telecommunications and data communications equipment. |
| 7 | SMC | 42 | PC I/O and systems logic circuits, networking controllers, and foundry services. |
| 8 | Actel** | 38 | Antifuse-based FPGAs. |
| 9 | Trident Microsystems** | 35 | Graphics and multimedia-related devices. |
| 10 | Analog Devices | 33 | Standard and high-performance linear ICs, DSPs, and mixed-signal ICs. |
| 11 | Intel | 31 | MPUs and flash memory. |

*** With sales of at least $100M in 1996.**
**** Fabless**

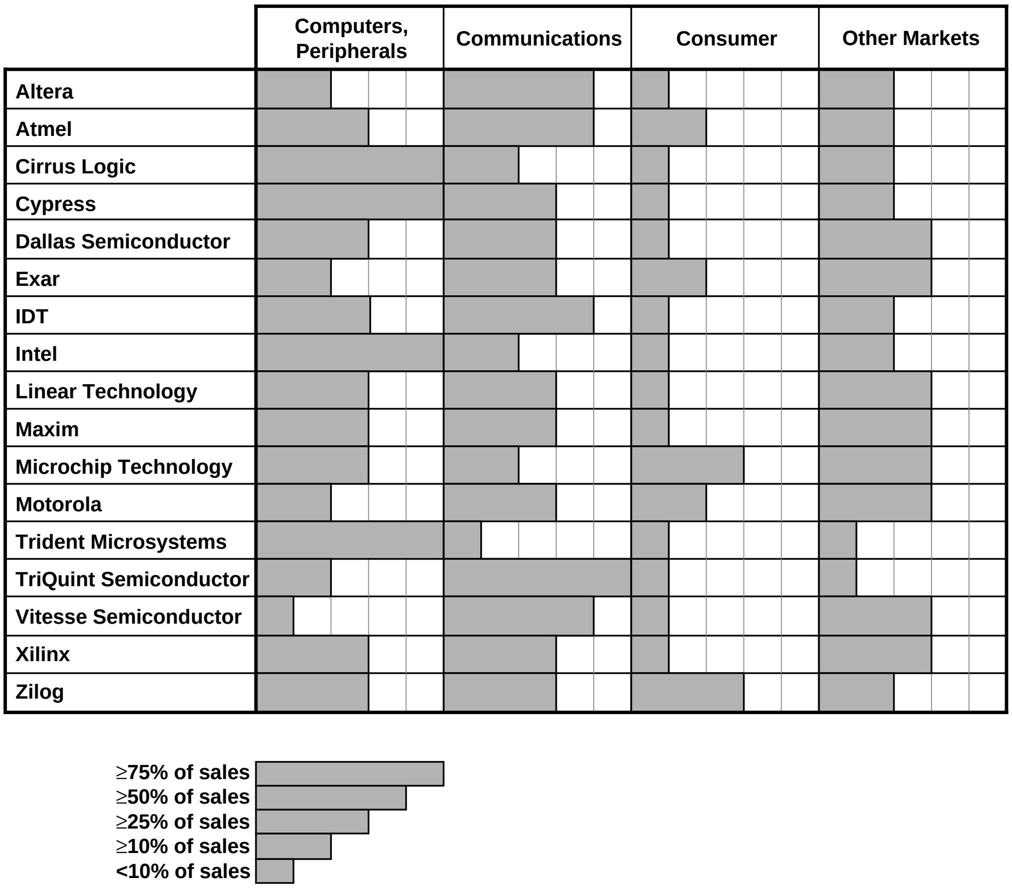
*Source: ICE* 13727V

**Figure 2-5. Top North American IC Sales Growth Companies***

Fabless IC companies are generally focused on one or two IC types. Therefore, their sales are dependent on the condition of the markets for those particular products. As a result, company positions within the top ten fabless rankings can change dramatically from year to year. For example, high demand for C-Cube Microsystems' digital video and still image compression ICs allowed it to enter the rankings at number four in 1996, while Cyrix fell several positions in the top ten ranking because of the difficulty in breaking Intel's grip on the microprocessor market. This may have been part of the motivation behind Cyrix's recent decision to merge with National Semiconductor.

## Top Ten North American Merchant IC Manufacturers

The top ten North American IC manufacturers of 1996 are listed in Figure 2-8. As seen, only a few of the top ten companies showed growth in sales of ICs, and collectively, their sales grew only three percent for 1996, after 33 percent growth in 1995.




Source: ICE 18957D

**Figure 2-6. North American IC Companies' End-Market Reliance**

Since becoming the largest North American IC company in 1990, Intel has continued to widen the gap between it and second place to over $11 billion in 1996. Intel has been very successful in promoting its Pentium and Pentium Pro microprocessors through aggressive pricing and marketing strategies and hopes to have the same success with its recently introduced Pentium II. The company is also the leading flash memory supplier.

Although ranked second in 1996, Motorola experienced a seven percent decline in IC sales following a 24 percent growth in 1995. Its latest corporate restructuring, which Motorola claims is not in response to its decline in sales, moved the company's Semiconductor Products Sector from a product-driven to a market-driven position.

| 1996 Rank | Company | 1995 | 1996 | 1996/1995 Percent Change |
|---|---|---|---|---|
| 1 | Xilinx | 520 | 566 | 9 |
| 2 | Altera | 402 | 497 | 24 |
| 3 | S3 | 316 | 465 | 47 |
| 4 | C-Cube Microsystems | 124 | 320 | 158 |
| 5 | ESS Technology | 106 | 227 | 114 |
| 6 | S-MOS Systems | 190 | 210 | 11 |
| 7 | Lattice | 185 | 201 | 9 |
| 8 | Sierra Semiconductor | 189 | 188 | –1 |
| 9 | Trident Microsystems | 139 | 187 | 35 |
| 10 | Cyrix | 228 | 184 | –19 |
| | | 2,399 | 3,045 | 27 |

* A company is considered fabless if the majority of its wafers are manufactured by independent foundries.

*Source: ICE* 20456C

**Figure 2-7. 1996 Top Ten North American Fabless* IC Suppliers ($M)**

| 1996 Rank | Company | 1995 | 1996 | 1996/1995 Percent Change |
|---|---|---|---|---|
| 1 | Intel | 13,590 | 17,870 | 31 |
| 2 | Motorola | 7,252 | 6,745 | –7 |
| 3 | Texas Instruments | 7,800 | 6,700 | –14 |
| 4 | IBM Microelectronics | 5,705 | 5,100 | –11 |
| 5 | National Semiconductor | 2,304 | 2,222 | –4 |
| 6 | Lucent Technologies | 1,680 | 2,050 | 22 |
| 7 | Advanced Micro Devices | 2,430 | 1,955 | –20 |
| 8 | Micron Technology | 2,705 | 1,740 | –36 |
| 9 | Rockwell | 760 | 1,450 | 91 |
| 10 | LSI Logic | 1,268 | 1,239 | –2 |
| | Total | 45,494 | 47,071 | 3 |

*Source: ICE* 20457C

**Figure 2-8. 1996 Top Ten North American IC Manufacturers ($M)**

After losing momentum in the early 1990s, Texas Instruments (TI) had two record-setting years in a row. Its IC business grew 36 percent in 1994 and 42 percent in 1995. Much of the company's strategic emphasis in semiconductors is on digital signal processors (DSPs), and as a result, its DSP sales have grown substantially faster than the DSP market in the past couple of years. TI has also seen strong demand for its mixed-signal, analog ICs and ASICs. Unfortunately, in 1996, the company's IC sales decreased 14 percent, primarily due to the decline in DRAM prices.

1995 marked the first year that ICE classified IBM Microelectronics as a merchant IC company (i.e., more than about 25 percent of its total IC production is sold on the open market). As a result, the company is now the fourth largest merchant IC manufacturer in North America.

National Semiconductor moved up to fifth place in the 1996 ranking despite a four percent decline over 1995. Much of its time from 1996 through the first half of 1997 was spent reorganizing its operations, including the sale of its Fairchild and digital speech processor businesses, and the acquisition of Cyrix and the PicoPower business unit from Cirrus Logic.

Lucent Technologies moved up in the rankings from 1995 with 22 percent growth in 1996. Its success comes from its focus on communications-related markets. Lucent will continue to focus on its DSP and modem chipset businesses, which have both grown considerably over the past few years, as well as seek out new markets.

Like Cyrix, Advanced Micro Devices (AMD) has had a difficult time competing against Intel in the microprocessor market. The late introduction and less-than-expected performance of its K5 microprocessor contributed to the company's 20 percent decline in sales for 1996. The company is pinning its hopes on its sixth-generation K6 microprocessor, which entered volume production in the first quarter of 1997.

To free itself from the volatile DRAM product cycle, Micron Technology is busy developing other products such as flash memories and radio frequency identification chips. Micron's sales grew 72 percent in 1995, but declined 36 percent in 1996.

Rockwell International continues to see very high demand for its modem ICs. In addition, Rockwell's acquisition of fabless Brooktree helped it become one of the top ten North American IC manufacturers in 1996.

**Top Ten North American IC Manufacturers: 1997 Highlights**

**Intel — Wafer Fab Announcements**

- Began construction in July 1997 on its $1.3 billion wafer fabrication facility in Fort Worth, Texas. However, late in 1997 the company announced a temporary suspension of this project, delaying production until 2000. The facility, to be called Fab 16, is expected to have a 75,000 square foot Class 1 cleanroom. Initial production of microprocessors will begin on 200mm wafers, using a 0.25µm process. Future plans for this facility include a move to a 0.18µm process and 300mm wafers.

- Purchased an equity stake in Samsung's new $1.3 billion fab in Austin, Texas, in early 1997. The fab is expected to begin production of 64M DRAMs in late 1997 or early 1998.

- Intends to begin production on 300mm wafers in 1999.

**Intel — Key Agreements**

- Announced in July 1997, it had agreed to purchase California-based Chips & Technologies for $420 million. The acquisition provides Intel with advancing capabilities for graphics and visual computing for mobile PCs. Chips & Technologies will operate as a wholly-owned subsidiary of Intel and as part of Intel's Graphics Components Division.

- Made a move to back Rambus Technology in the development of very-high bandwidth Direct Rambus DRAMs. Intel has been given the option to purchase $10 million worth of Rambus stock after the technology for Direct RDRAMs, which will link directly to Intel's chipsets, is developed.

- Settled legal litigation with AMD and Cyrix concerning the use of the term MMX (multimedia extension). After several months of discussions since Intel filed a lawsuit against both companies, an agreement was made that AMD and Cyrix must acknowledge MMX as an Intel-owned trademark.

**Intel — Product Briefs**

- Released its fastest chip in early 1997, the Pentium II microprocessor. The single-chip IC contains the company's MMX technology and operates at speeds from 233MHz to 300MHz. The IC is initially being targeted at business desktop PC applications.

- Introduced in April 1997, its newest family of flash memories—the Smart3 Advanced Boot Block family of ICs. The new flash architecture, in conjunction with a new software program called Flash Data Integrator, allows for the storage of both code and data on a single flash IC.

- Added 16M and 32M flash memory ICs to its FlashFile product family. The ICs are being produced in Intel's 0.4µm ETOX process and are also being second-sourced by Sharp, Intel's flash memory partner in Japan.

- Planned to migrate to 0.25µm processing during 1997 for its microprocessor production. During 1996, most of its ICs were processed using 0.35µm and 0.4µm process technologies.

- Released a bare-die form of its mobile Pentium processor with MMX technology, as part of its SmartDie program. Targeting lightweight PC notebooks under three pounds, the bare die comes with a multichip module reference design and is available in 150MHz and 160MHz versions.

- Delayed by one year the introduction of its P7 IC, code named Merced. The IC is based on the IA-64 architecture, which combines Intel's x86 architecture with Hewlett-Packard's PA-RISC architecture. The IC was originally planned to be introduced in 1998, but is now expected in 1999.

- Announced that it will stop taking orders for mil-spec versions of its i960 microprocessors and i860 DSPs. Intel has said it is exiting the market for military ICs because parts for the commercial market are far more lucrative. Other military-grade lines to be discontinued include SRAMs, EPROMs, flash memories, and x86 and Pentium processors.

**Intel — Other Noteworthy News**

- After filing a counter suit to the lawsuit filed by Digital Equipment Corporation (DEC), which claims that Intel infringed upon 10 patents relating to microprocessors, the companies settled late in 1997, pending government approval, with Intel buying Digital's Alpha IC manufacturing and development operations in Massachusetts, Israel, and Texas, for just $700 million, the officially reported amount.

**Motorola — Wafer Fab Announcements**

- Will stop producing 16M DRAMs at Tohoku, its joint venture with Toshiba, by the end of 1997. The capacity will be converted to logic IC production by the end of 1998. Toshiba will continue producing its share of DRAMs until Motorola's conversion is complete, at which time Toshiba will begin converting to logic.

- Announced restructuring plans for its new joint venture with Siemens, White Oak Semiconductor, following its announcement to withdraw from the DRAM market. White Oak Semiconductor, located in Richmond, Virginia, will use DRAMs to ramp to volume production and Siemens will sell all the DRAMs to its customer base. Once volume production is reached in mid-2000, Motorola will convert its share of the production to fast SRAMs.

- Plans to convert its COM 1 facility in Phoenix into a research and development center for embedded microcontroller and DSP technologies.

**Motorola — Key Agreements**

- Announced in early 1997 that it would work with Toshiba and Fairchild Semiconductor to jointly develop next-generation high-speed CMOS logic ICs. The three companies will work to develop 2.5V and 3.3V ICs with a propagation delay of 2ns.

- Acquired the PMeL business from Pilkington, a world leader in glass products, in March 1997. PMeL was absorbed into Motorola's Programmable Logic division and was renamed the Motorola Programmable Technology Center (MPTC).

- Licensed Advanced RISC Machines' embedded processor core technology in early 1997.

**Motorola — Product Briefs**

- Announced in mid-1997 it will withdraw from the DRAM business. Motorola's DRAM resources will be reallocated to other technologies, including fast SRAMs, flash memories, and EEPROMs. Motorola will still continue internal development of embedded DRAM technology.

- Introduced a new 16-bit microcontroller designed for automotive, industrial, and consumer applications that features 48Kbytes of flash EEPROM and 2Kbytes of block-erasable flash EEPROM.

- Introduced its new field programmable analog array (FPAA), one of the first counterparts to the digital field programmable gate array. The 5V MPAA020 FPAA features a switched capacitor CMOS operational amplifier as the core programmable element, operates at 200MHz, and features 20 core cells and 13 I/Os. Designed using a 0.8µm triple-layer-metal CMOS process, the IC is the first of a new generation of programmable ICs to be introduced by Motorola.

- Began shipping samples of its PowerPC-based, 32-bit MPC823 embedded microprocessor early in 1997. The IC combines a PowerPC core with a communication processor module that supports embedded DSP. The IC is designed for use in digital cameras and portable computing products.

- Introduced a 250MHz version of its PowerPC 603e microprocessor, developed with IBM. The two companies expect the 603e microprocessor to reach and possibly exceed 300MHz by the end of 1997. In addition, Motorola and IBM announced the availability of a 350MHz version of the 604e.

**Motorola — Other Noteworthy News**

- Restructured its Semiconductor Products Sector (SPS) into four market-based groups—consumer systems, networking and computing systems, transportation systems, and wireless subscriber systems—and one-product driven group that combines all standard discrete and IC products. The reason for the restructuring was to move Motorola from a product-driven to a market-driven position. Prior to the restructuring, the SPS was made up of seven product-focus divisions and only one market-focus division. In addition the SPS headquarters was moved from Phoenix, Arizona, to Austin, Texas.

**Texas Instruments — Wafer Fab Announcements**

- Pulled out of a $1.4 billion Thailand joint DRAM venture with Charn Uswachoke, founder and CEO of Alphatec, in April 1997. Under the deal two companies were to be formed: Alpha-TI Semiconductor, a $1.2 billion 16M and 64M DRAM fab; and Alpha Memory, a $200 million assembly and test facility. Reasons cited for TI's withdrawal included weakness in the DRAM market and a poor Thai economy. Construction of both facility shells has been completed, but no capital equipment orders were ever placed.

- Announced in early 1997, that it had signed an agreement with the Italian government to build a second fabrication facility and an R&D center in Avezzano, Italy. The $1.2 billion fab will have the capability to process ICs on 300mm wafers, with geometries of 0.28µm and below, when operations start in 1999. Current plans call for the production of flash memories and DRAMs at the facility.

- Decided in early 1997 to halt plans for a new 256M DRAM facility that it planned to build in Japan with Toyota Motor Corporation.

**Texas Instruments — Key Agreements**

- Announced in July 1997, the company licensed Rambus's entire technology portfolio that includes rights to its Concurrent and Direct RDRAM technologies and their respective Rambus Memory Controller and Rambus ASIC cell interfaces. TI plans to integrate the technology into its next-generation DSPs, ASICs, and DRAMs.

- Sold its Defense Systems & Electronics Group (DS&EG) to Raytheon Co. for $2.95 billion. After months of negotiations, the U.S. Justice Department approved the purchase under the condition that Raytheon sell DS&EG's microwave IC division, which produces GaAs ICs for military radar systems.

- Signed a cross-licensing agreement with Taiwanese DRAM manufacturer, Vanguard International Semiconductor. The agreement covers a ten-year period and will include approximately 5000 TI patents. TI signed a similar agreement with NEC that also covers a ten-year period. The TI-NEC agreement, although established in 1997, covers the period from 1996 through 2005. A previous licensing agreement between TI and NEC expired in 1995.

- Announced in early 1997 that the company, along with Hitachi and Mitsubishi, will co-develop the cell architecture for a 1G DRAM as well as the process technology needed to manufacture it. Hitachi has a long-standing relationship with TI to jointly develop and produce DRAMs.

**Texas Instruments — Product Briefs**

- Introduced the Permedia 2 graphics processor that it co-developed with 3Dlabs, Inc. The IC, manufactured on a 0.35µm CMOS process, combines 3D graphics, 2D graphics acceleration, and advanced video processing on a single chip.

- Unveiled the TMS320x2 digital signal processor chipset for use in 56K modems. The chipset began shipping in the first part of 1997.

- Released its new TMS664xxx family of 64M synchronous DRAMs. The ICs are designed for use in workstations, PCs, and servers, feature 3.3V operation, and are manufactured using a 0.3µm implanted CMOS technology. Volume production began in mid-1997.

- Introduced a chipset based on the FLEX messaging technology it licensed from Motorola. The FLEX chipset will be added to its DSP portfolio and is targeted at the one-way data-messaging paging market.

- Introduced a DSP-based controller targeted at the digital motor and motor-control systems market. The IC, TMC320C240, is the first in a planned series of ICs optimized for motor control functionality. The controller features a 16-bit, 20 MIPS DSP core, 16K of ROM or flash memory, and 28-bit I/O capabilities.

**IBM Microelectronics — Key Agreements**

- Announced an agreement with Nortel to commercialize silicon germanium (SiGe) ICs for high-speed telecommunication applications. Nortel will design prototype ICs for fiber transport, high-speed cellular and PCS wireless applications, and IBM will manufacture the ICs. IBM has a similar agreement with Hughes that was announced in mid-1996.

- Signed an agreement with Mitsubishi that allows Mitsubishi to design and market embedded PowerPC microprocessors built by IBM. Under the agreement, Mitsubishi has access to IBM's complete line of PowerPCs, although, the agreement does not cover the high-performance desktop microprocessors in the 600 series. The contract covers a two-year period and will give Mitsubishi access to new microprocessor cores developed during the two-year period.

**IBM Microelectronics — Product Briefs**

- Plans to devote the bulk of new investment to proprietary custom logic rather than microprocessors or memory as part of a goal to increase its percentage of external sales to 70 percent, up from its current 30 percent of total revenues.

- Released its new G4 S/390 microprocessor in mid-1997. This is a single-chip IC that measures 17.35mm x 17.3mm and operates at up to 400MHz. The IC is manufactured using IBM's 0.35µm CMOS 6S process and features about 7.8 million transistors.

- Introduced the 6x86MX microprocessor, which was previously called M2. Under a licensing and foundry agreement signed in April 1994 with Cyrix, IBM will process the associated wafers; wafers will be divided between the companies for dicing, packaging, and testing. IBM has licensed the 6x86MX name from Cyrix.

- Announced the latest and highest performing member of its 400 Series of PowerPC embedded controllers. The 403GCX 32-bit microcontroller, available in 50MHz and 66MHz versions, is designed for use in computing networks, set-top boxes, and communication systems.

- Introduced a line of ultra-fast SRAMs in early 1997. IBM claims its new SRAM ICs are the fastest on the market. Exclusively intended for RISC applications, the 250MHz, 1M and 225MHz, 4M SRAMs are manufactured using 0.45µm and 0.4µm CMOS processes, respectively.

- Introduced a 250MHz version of its PowerPC 603e microprocessor, developed with Motorola. The two companies expect the 603e IC to reach and possibly exceed 300MHz by the end of 1997. In addition, IBM and Motorola announced the availability of a 350MHz version of the 604e.

**National Semiconductor — Wafer Fab Announcements**

- Announced plans to shut down its 125mm and 150mm wafer fabrication facilities in Santa Clara, California, and transfer its analog and CMOS products from that city to its Austin, Texas, facility. The decision to shut down these facilities is part of National's plan to transition to 200mm wafer production at 0.35µm design rules.

- Added a 200mm wafer line at its fabrication facility in South Portland, Maine. Production on the new line is expected to begin in late in 1997.

**National Semiconductor — Key Agreements**

- Announced in July 1997 it agreed to purchase Cyrix Corporation for $550 million. The companies plan to develop system-on-a-chip technology for low-cost PC and information-appliance markets.

- Sold its digital speech processor business to Information Storage Devices (ISD) for $5 million in early 1997, and soon after purchased MPEG video and audio decoder supplier, MediaMatics, for $100 million.

**National Semiconductor — Product Briefs**

- Unveiled a four-IC chipset designed for use in portable PCs. The "Mobile System Solution" is made up of three new ICs: a PCI system controller, a PCI system I/O controller, and a keyboard and power management controller, which are combined with National's PT80C525 bridge interface controller. This is the first IC to be released from the recently acquired PicoPower business unit.

**National Semiconductor — Other Noteworthy News**

- Sold its general-purpose logic and memory subsidiary, Fairchild Semiconductor. National and Fairchild will remain closely linked through a long-term agreement to make the transition as smooth as possible. The two companies also share and swap wafer fabrication facility capacity.

**Lucent Technologies — Wafer Fab Announcements**

- Began production in early 1997 at its joint-venture facility with Cirrus Logic, called Cirent Semiconductor. The venture, located in Orlando, Florida, will provide an equal supply of 200mm wafers for both of the partners. Ownership is divided 60/40 for Lucent and Cirrus, respectively.

**Lucent Technologies — Key Agreements**

- Licensed Advanced RISC Machines' high performance, low-power RISC microprocessor core technology (ARM7TDMI). Lucent plans on offering the core as part of its own ASIC library.

- Established an alliance with Mitsubishi in mid-1997 to jointly develop a set of ICs that together will perform all of the functions needed for next-generation HDTV sets for the U.S. market. The first samples of the chipset are expected to be available in early 1998.

**Lucent Technologies — Product Briefs**

- Introduced its next-generation 0.3µm family of ORCA FPGAs that includes densities ranging from 4K to 40K usable, logic-only gates. The company also announced its plans to sample 0.25µm ORCA FPGAs by the end of 1997.

- Began volume production in mid-1997 of its new USS-720 universal serial bus that features on-chip memory and is designed for integration into a variety of PC peripherals.

**AMD — Wafer Fab Announcements**

- Plans to increase flash memory output at its jointly-owned facility with Fujitsu, called FASL. The new FASL-2 fab extension, located adjacent to FASL-1 will contain an 82,000 square-foot cleanroom and will be used to produce 16M, 32M, and 64M flash memories. Future fab plans for FASL include a migration to 300mm wafers within the next few years.

**AMD — Key Agreements**

- Settled legal litigation with Intel about using the term MMX. After several months of discussions since Intel filed a lawsuit against AMD, an agreement was made that AMD must acknowledge MMX as an Intel-owned trademark.

**AMD — Product Briefs**

- Developed a 16M 3V flash memory IC with partner Fujitsu. The IC was developed using a 0.35µm CMOS process. Volume production of the IC was expected to begin in mid-1997.

- Began volume shipments of its sixth-generation K6 MMX microprocessor in the first quarter of 1997. The IC contains 8.8 million transistors, features operating speeds up to 233MHz, and is manufactured using AMD's 0.35µm 5-layer metal CMOSCS34 process at AMD's Fab 25 in Austin, Texas. The company plans to increase the operating speed up to 300MHz by migrating the K6 to a 0.25µm process by the end of 1997.

- Ceased production of its K5 microprocessor in the third quarter of 1997. AMD had previously planned on producing the K5 until the end of the year.

**AMD — Other Noteworthy News**

- Announced that Jerry Sanders plans to gradually step down as chairman of the company beginning with the relinquishing of his CEO title in 2002. In 2003, Sanders plans to step down as chairman to become vice chairman.

**Micron Technology — Wafer Fab Announcements**

- Plans to install an IC test line at its Lehi, Utah, facility and begin test production in mid-1998. The facility exterior has been completed, however, the company has no immediate plans for equipping it, pending warranting market conditions. It was originally scheduled to begin operations in 1997.

**Micron Technology — Key Agreements**

- Licensed the Rambus interface technology needed to make Direct Rambus DRAMs.

- Teamed up with LSI Logic to develop a stacked-cell process based on LSI Logic's 0.25µm G11 process. Both will manufacture the wafers, beginning with Micron and then moving to LSI Logic's facility for metal layers. Volume production using the new process is expected to begin in mid-1998.

**Micron Technology — Product Briefs**

- After years of development, began beta testing a microwave radio IC called a MicroStamp; it is about the size of a postage stamp. It is a 20-pin CMOS small-outline package IC that integrates a 2.4GHz direct-sequence spread spectrum microwave frequency radio, a micro-controller, and a low-power SRAM. Potential applications for this IC include automatic inventory, electronic toll collection, and various security tracking measures.

**Rockwell Semiconductor Systems — Wafer Fab Announcements**

- Announced a one year delay of construction on its $1.2 billion fab located in Colorado Springs, Colorado. The company expects to complete the shell of the facility by 1998, but will wait until late 1999 to begin volume production.

**Rockwell Semiconductor Systems — Key Agreements**

- Licensed the ARM810 and the ARM7TDMI "Thumb" 32-bit RISC microprocessor core technologies of Advanced RISC Machines, as well as a core to be developed in the future. Rockwell will integrate the cores into a variety of communication products.

**Rockwell Semiconductor Systems — Product Briefs**

- Began shipping what it claims to be the industry's first single-chip, high-bit-rate digital subscriber loop modem chipset.

**Rockwell Semiconductor Systems — Other Noteworthy News**

- Purchased the Hi-Media broadband communications chipset business from ComStream Corporation for approximately $50 million. The Hi-Media business will be part of the newly formed Digital Infotainment Division.

**LSI Logic — Wafer Fab Announcements**

- Will begin production at its Gresham, Oregon, facility at the beginning of 1998.

**LSI Logic — Key Agreements**

- Teamed up with Micron Technology to develop a stacked-cell DRAM process based on LSI Logic's 0.25µm G11 process. The two will both manufacture the wafers, beginning with Micron and then moving to LSI Logic's facility where final metal layers will be added. Volume production using the new process is expected to begin in mid-1998.

**LSI Logic — Product Briefs**

- Entered the cable modem market early in 1997 with the introduction of its Cablestream QAM Receiver core.

- Announced its next-generation G11 process technology featuring a 0.25µm gate length, providing up to 64 million transistors, or up to 8.1 million usable gates, and allowing greater density and increased functionality on a single chip. Devices in the G11 ASIC family will operate on 1.8V, 2.5V, or 3.3V, and consume one-fourth the power of G10 ICs. Initial production of G11 ASICs is due to begin before the end of 1997.

## U.S. MILITARY IC TRENDS

The U.S. military industry continues to shrink as a percentage of U.S. gross domestic production (GDP, Figure 2-9). After 2000, military spending is forecast to represent less than three percent of the total U.S. GDP.

The good news for military IC suppliers, however, is that military spending for electronics is forecast to rise through at least 2006 (Figure 2-10). From 1986 to 1996 the total U.S. military spending for electronics declined at an average rate of four percent per year. On the other hand, the ten year forecast from 1996 to 2006 calls for a cumulative average annual growth rate (CAGR) of 1.4 percent per year.

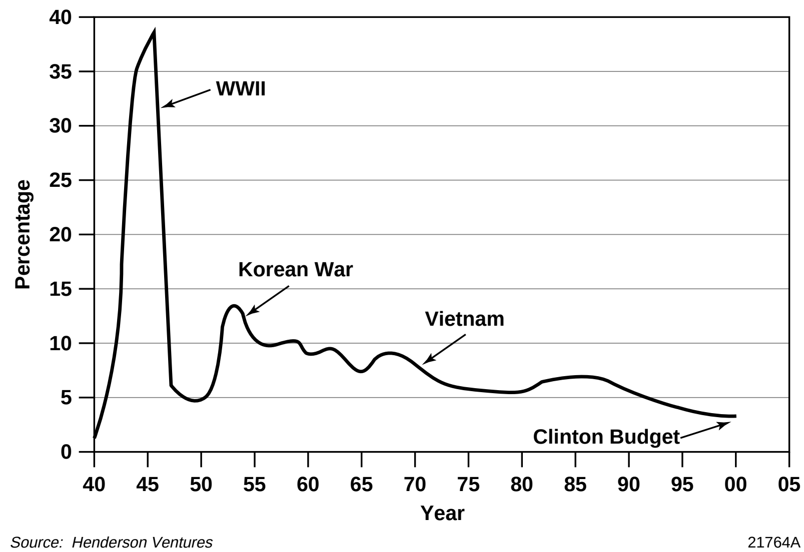



**Figure 2-9. U.S. National Defense Outlays as a Percent of GDP**

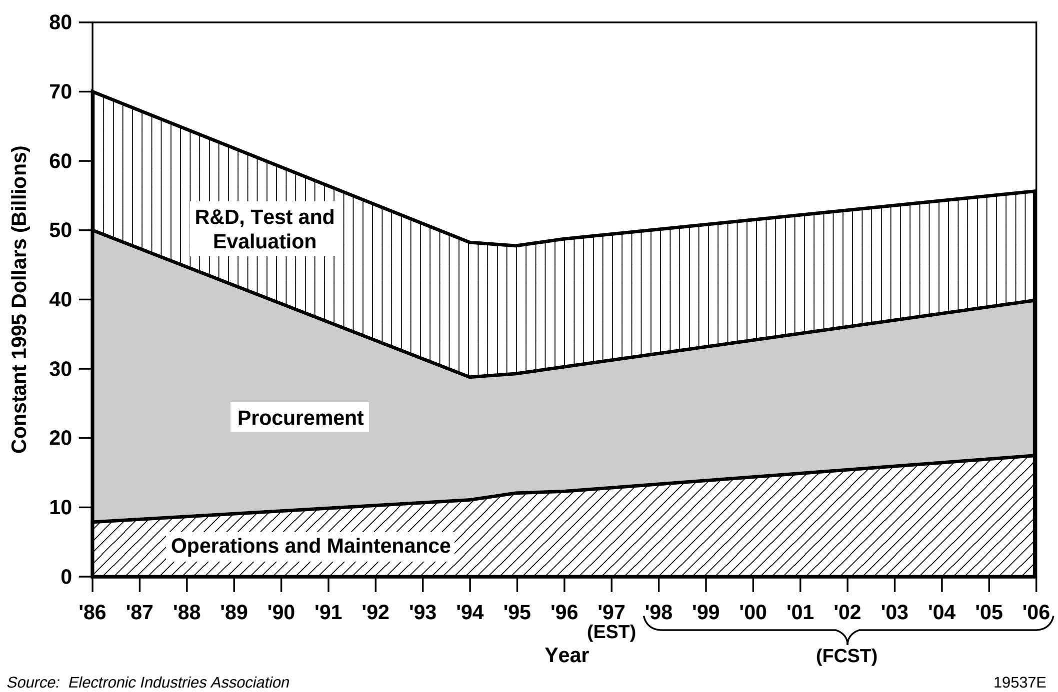



**Figure 2-10. Electronic Conent of DOD Budget**

The three major categories that make up the military electronics budget include research and development (R&D), procurement, and operations and maintenance. The military has initiated a plan to decrease spending on electronics R&D through 2006, specifically by –2 percent CAGR. Offsetting this decline in R&D spending over the next 10 years will be increased spending for procurement and operations and maintenance, 2.4 percent CAGR and 3.5 percent CAGR, respectively. Maintenance includes weapons upgrades.

Unfortunately, the military IC market has not been immune from Pentagon cutbacks over the years. Many military IC suppliers have found themselves squeezed between two factors—a steep drop in defense spending, which hit the semiconductor industry harder than first anticipated, and the growing acceptance of commercial off-the-shelf (COTS) electronic components in military systems. It was these two factors that led AMD and Motorola to announce and implement in mid-1996 the termination of their military semiconductor product lines. As part of Motorola's exit from the market, it sold to Omnirel in May 1995, various manufacturing assets, test equipment, and finished goods from its military operation. Similarly, in November 1995, Altera made its formal announcement to exit the military IC business. However, it continued to ship military-grade ICs through 1996.

The top ten U.S. military and aerospace IC manufacturers and their sales are shown in Figure 2-11. Grabbing the headlines over the last two years were the stories of lessening emphasis or the phasing-out of military semiconductor businesses. In December 1996, Intel announced its departure from the military IC market. The company will stop taking orders for mil-spec (military specification) versions of its i960 microprocessor and i860 DSPs and plans to discontinue other military-grade products including SRAMs, EPROMs, flash memories, and x86 and Pentium microprocessors by the end of 1997.

| Rank | Company | 1996 Sales | 1995 Sales | 1996/1995 Percent Change | Military/Aerospace Emphasis |
|---|---|---|---|---|---|
| 1 | Harris | 150 | 150 | — | Steady* |
| 2 | National | 147 | 140 | 5 | Steady |
| 3 | TI | 145 | 135 | 7 | Steady to Increasing |
| 4 | Analog Devices | 140 | 132 | 6 | Steady |
| 5 | Intel | 120 | 110 | 9 | Steady to Increasing |
| 6 | LSI Logic | 80 | 76 | 5 | Steady |
| 7 | Honeywell | 45 | 42 | 7 | Steady |
| 8 | Raytheon | 35 | 35 | — | Steady |
| 9 | AMI | 33 | 29 | 14 | Steady |
| 10 | Motorola | 30 | 65 | –54 | Decreasing |
| — | Others | 160 | 176 | –9 | Decreasing |
| Total | | 1,085 | 1,090 | — | Steady |

*Decreasing military, increasing aerospace.

*Source: ICE* 12137T

**Figure 2-11. Top Ten U.S. Military and Aerospace IC Suppliers ($M)**

Announced in mid-1997 was the purchase of Texas Instrument's Defense Systems and Electronics Group (DS&EG) by Raytheon. After months of negotiations, the U.S. Justice Department approved the $2.95 billion purchase under the condition that Raytheon sell DS&EG's microwave IC division, which produces gallium arsenide (GaAs) ICs for military radar systems. Meanwhile, Raytheon has been involved in negotiating the purchase of Hughes Electronics, the Hughes Aircraft military unit.

Figure 2-12 shows how the military percent of the total semiconductor market has declined in the past two decades. In 1975, the military market accounted for 17 percent of the total semiconductor market. In 1996, it accounted for about one percent of the total semiconductor market.

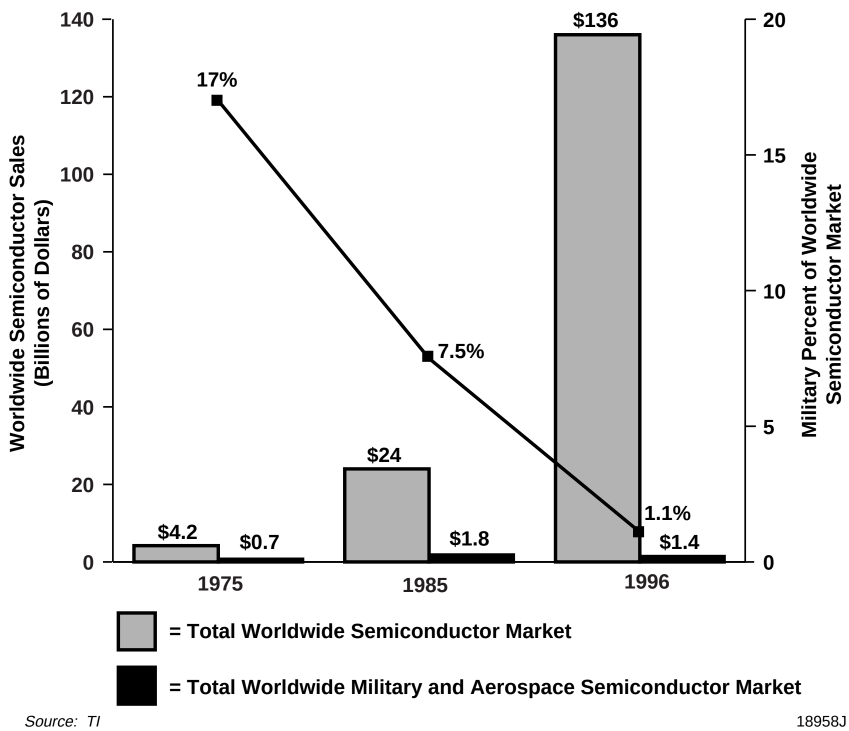



**Figure 2-12. Declining Military and Aerospace Presence**

To lessen the paperwork and testing burden of military IC suppliers, the Department of Defense developed military standard Mil-Prf-38535. This standard allows IC manufacturers to have individual wafer fabrication lines certified. Thus, any IC that was produced by a Mil-Prf-38535 wafer fabrication facility would qualify as an acceptable military part.

These certified fab lines are known as Qualified Manufacturing Line or QML facilities. The companies that hold QML certification, as of mid-1997, are shown in Figure 2-13.

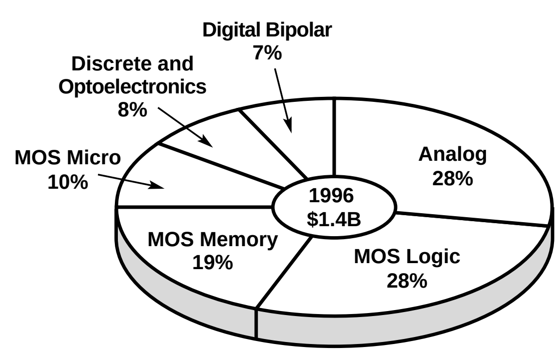
| | |
|---|---|
| Actel | Lockheed Martin Federal Systems |
| AMI | Lucent |
| Analog Devices | Motorola |
| Austin Semiconductor | National |
| Cypress | Philips |
| Harris | Signal Processing Technologies |
| Honeywell SSEC | Siliconix |
| Intel | TI |
| Linear Technology | UTMC |
| Linfinity | Xilinx |

Source: ICE 21763B

**Figure 2-13. QML (Mil-Prf-38535) Certified IC Suppliers: 1997**

As a way to further reduce IC costs to military contractors, a Defense Department report on semiconductor packaging, released in early 1996, urged the Pentagon to explore buying more plastic-encapsulated ICs in place of more costly ceramic-packaged ICs. According to the report, ceramic packages constitute more than 90 percent of all chips used in military systems, but that they are more expensive and, in many cases, are no more reliable than state-of-the-art plastic-packaged ICs available on the commercial market.

Figure 2-14 provides a look at the worldwide market for military and aerospace semiconductors in 1996 by IC type. DSPs, programmable logic ICs (PLDs), and monolithic microwave ICs (MMICs) are a few of the products that are actually displaying growth in the military IC market. In contrast, discrete devices ("discretes") and bipolar ICs will not be as large a share of the market in the future.




Source: ICE 18537G

**Figure 2-14. Worldwide Military and Aerospace Semiconductor Market**

One of the bright spots in the military IC industry over the past few years has been the aerospace market. The satellite communications market has been growing at a phenomenal rate since the mid-1990s and is forecast to continue this growth past 2000. About one-fourth, or $350 million, of the 1996 $1.4 billion military IC market was for radiation-hardened or radiation-tolerant ICs. Figure 2-15 shows the characteristics of these specialty ICs. Most space applications are able to use radiation-tolerant ICs as opposed to the more expensive radiation-hardened ICs.

| Rad-Hard | Rad-Tolerant | Commercial |
|---|---|---|
| Designed for specific hardness level | Hardness offered as a by-product of the design | Hardness limited by inherent process and design; customer risk |
| Total dose: >200 krad to >1 Mrad | Total dose: 20 krad to 50 krad (typical) | Total dose: 2 krad to 10 krad (typical) |
| SEU threshhold LET: 80-150 MeV/mg/cm$^2$ | SEU threshhold LET: 20 MeV/mg/cm$^2$ (typical) | SEU threshhold LET: 5 MeV/mg/cm$^2$ (typical) |
| SEU error rate: 10E-10 to 10E-12 errors/bit-day | SEU error rate: 10E-7 to 10E-8 errors/bit-day | SEU error rate: 10E-5 errors/bit-day (typical) |
| Latchup: silicon on insulator technologies; no latchup problems | Latchup: customer evaluation and risk | Latchup: customer evaluation and risk |

*Source: Harris Semiconductor/Military & Aerospace Electronics* 21762

**Figure 2-15. Rad-Hard IC Characteristics**

In general, the military and aerospace markets are being influenced by numerous factors; Figure 2-16 shows some of the positive and negative influences. Although there are some factors that will positively affect the military semiconductor market in the future, the edict to use commercial ICs whenever possible in military systems will negate these factors.

**Negative**

- – Edict to use more commercial ICs in military systems.
- – Flat military electronics budget.
- – Increasing use of cheaper plastic packaged devices.

**Positive**

- + Increasing IC content in military electronic systems.
- + Increasing rad-hard aerospace market.
- + End-of-life buys temporarily increased military IC market (1995-1996).

*Source: ICE* 19539A

**Figure 2-16. Factors Influencing the Military and Aerospace IC Markets**

## JAPANESE IC MANUFACTURERS

Integrated circuit sales for Japanese companies decreased 17 percent in 1996 in terms of U.S. dollars, or four percent in terms of Japanese yen (Figure 2-17). This compares to a 1995 increase of 35 percent in terms of U.S. dollars, or 25 percent in terms of Japanese yen.

| 1996 Rank | Company | 1995 | | | 1996/1995 Percent Change | 1996 | | |
|---|---|---|---|---|---|---|---|---|
| | | MOS | Bipolar | Total | | MOS | Bipolar | Total |
| 1 | NEC[1,2] | 10,395 | 650 | 11,045 | –10 | 9,350 | 600 | 9,950 |
| 2 | Hitachi[1,2] | 7,805 | 825 | 8,630 | –16 | 6,384 | 870 | 7,254 |
| 3 | Toshiba[1] | 7,535 | 1,080 | 8,615 | –19 | 6,050 | 920 | 6,970 |
| 4 | Mitsubishi[1,2] | 3,995 | 440 | 4,435 | –20 | 3,145 | 400 | 3,545 |
| 5 | Fujitsu[1,2] | 3,580 | 430 | 4,010 | –28 | 2,560 | 320 | 2,880 |
| 6 | Matsushita[1,2] | 1,670 | 930 | 2,600 | –11 | 1,440 | 885 | 2,325 |
| 7 | Sanyo[1] | 1,255 | 990 | 2,245 | –16 | 985 | 900 | 1,885 |
| 8 | Sharp | 1,910 | 110 | 2,020 | –13 | 1,660 | 100 | 1,760 |
| 9 | Sony | 1,460 | 620 | 2,080 | –18 | 1,220 | 490 | 1,710 |
| 10 | Oki[2] | 1,990 | 40 | 2,030 | –32 | 1,350 | 30 | 1,380 |
| 11 | Seiko Epson[1] | 950 | — | 950 | –13 | 825 | — | 825 |
| 12 | Rohm[1] | 315 | 515 | 830 | –14 | 310 | 400 | 710 |
| 13 | Yamaha | 515 | — | 515 | –5 | 490 | — | 490 |
| 14 | Ricoh[1] | 355 | — | 355 | –11 | 315 | — | 315 |
| 15 | KTI Semiconductor | 500 | — | 500 | –45 | 275 | — | 275 |
| 16 | Asahi Kasei Microsystems | 220 | — | 220 | –5 | 210 | — | 210 |
| 17 | Seiko Instruments | 240 | — | 240 | –13 | 210 | — | 210 |
| 18 | Nippon Steel | 580 | — | 580 | –66 | 200 | — | 200 |
| 19 | Fuji Electric[1] | 130 | 45 | 175 | –14 | 110 | 40 | 150 |
| 20 | Kawasaki Steel | 100 | — | 100 | –10 | 90 | — | 90 |
| | Others | 385 | 95 | 480 | –18 | 325 | 70 | 395 |
| | Total | 45,885 | 6,770 | 52,655 | –17 | 37,504 | 6,025 | 43,529 |

1995: 94¥=$1.00
1996: 109¥ = $1.00

[1]BiCMOS ICs included under MOS.
[2]GaAs ICs included under MOS.

*Source: ICE* 20455C

**Figure 2-17. Japanese Companies' IC Sales (Calendar Year, $M)**

As can be seen, all of the Japanese companies in the figure experienced a decline in sales, based on final 1996 data. The collapse of DRAM prices in 1996, coupled with yen-to-dollar exchange rate fluctuations prevented Japanese companies from repeating the strong year they had in 1995.

While Japanese IC manufacturers are heavily dependent on the DRAM market, they are placing a high degree of emphasis on non-memory ICs. For example, Hitachi plans to decrease its percentage of memory product sales and increase its percentage of microprocessors, microcontrollers and ASICs. Oki and Fujitsu announced plans to expand into other market areas, and joined Hitachi, Mitsubishi, and Toshiba in announcing plans to put off construction of new DRAM wafer fabrication facilities or to convert existing DRAM manufacturing lines to manufacture other products.

**Top Ten Japanese Manufacturers: 1997 Highlights**

**NEC — Wafer Fab Announcements**

- Announced plans to build a $700 million DRAM joint venture facility with Shanghai's Huahong Microelectronics. The facility, to be located in China, will process 200mm wafers using 0.35µm to 0.5µm process technologies when production begins in 1998.

- Intends to construct a 1G DRAM pilot production line at its Sagamihara site, capable of a 0.18µm process.

- Plans on resuming construction of a new wafer fabrication line at its ASIC production facility in Yamagata, Japan. NEC halted construction there in 1996.

**NEC — Key Agreements**

- Teamed with Los Altos, California, In-Chip Systems to develop a new gate array architecture with dramatically improved density. The resulting CMOS9HD process, which uses the In-Chip core cell architecture, has shown the ability to cut die cost by 20 to 50 percent compared with NEC's existing CMOS9 0.35µm arrays.

- Signed a cross-licensing agreement with Texas Instruments that covers a ten-year period. The TI-NEC agreement, although established in 1997, covers 1996 through 2005. A previous licensing agreement between NEC and TI expired in 1995.

**NEC — Product Briefs**

- Released the first member of a planned family of DSP cores to be added to its ASIC core library. Called the MASPX family, these cores are designed for use in wireless and hand held applications. The first core features a 60 MIPS performance level operating at 60MHz.

- Announced that in October 1997 it will begin commercial production of ASICs with 0.25µm drawn gate lengths. The new CMOS-10 family of ASICs, with up to 20 million gates and operating speeds of 300MHz, will target high-end workstations and cellular base stations.

- Decided to hold off beginning volume production of 256M DRAMs until late 1999 or early 2000. NEC has been sampling 256M DRAMs since early 1996 and was expected to ramp up production by early 1998.

**Hitachi — Wafer Fab Announcements**

- Joined with Texas Instruments for 16M, 64M, and 256M DRAM development and production. The partners have built a joint 16M and 64M DRAM manufacturing facility in Texas. The $500 million factory, called TwinStar Semiconductor, began producing 16M DRAMs in July 1996 and production of 64M parts is expected to start during 1997. The output is shared equally between Hitachi and TI.

- Announced plans to close its new memory line at its Takasaki plant and move the equipment to its Hitachinaka plant by mid-1997.

- Plans to convert its 16M DRAM line at its Koku fab facility in Yamanaski Prefecture into a flash memory line.

- Built a $400 million 32,000 square-foot cleanroom at its fab in Texas. The facility began manufacturing 32-bit RISC microprocessors in 1997.

**Hitachi — Key Agreements**

- Established a cross-licensing agreement with SanDisk that covers flash memory technology. The agreement gives the two companies worldwide rights to each other's patents.

**Hitachi — Product Briefs**

- Introduced its first ASIC featuring embedded-DRAM in mid-1997 and revealed a roadmap for future ASIC ICs that will embed flash memory as well as a combination of both DRAM and flash memory. Hitachi also revealed plans for its next generation of ASIC ICs that the company claims will support DRAM, flash, logic, and microprocessor capabilities on a single IC.

- Announced in early 1997 that the company, along with Mitsubishi and Texas Instruments, will co-develop the cell architecture for a 1G DRAM as well as the process technology needed to manufacture it. Hitachi has a long-standing relationship with TI to jointly develop and produce DRAMs.

- Introduced its fourth-generation SH RISC microprocessor, which includes a floating point unit optimized for 3D graphics and runs at 300 MIPS. Volume shipments of the SH-4 chip are not expected to begin until mid-1998. Future product plans call for a fifth-generation SH RISC microprocessor, which is expected to offer 500 MIPS performance, to be introduced around 2000.

- Announced plans to offer 0.35µm CMOS cell-based ASICs based on its 32-bit SH-3 RISC core or its 16-bit H8S microcontroller. With the new technology, the company will be able to combine the SH-3 with up to 16M of DRAM.

- Developed a 64M flash memory IC with flash memory partner, Mitsubishi. The IC is based on Hitachi's AND flash cell technology and manufactured using a 0.4µm process. The alliance between Mitsubishi and Hitachi was established in 1994 for the support of Mitsubishi's DINOR and Hitachi's AND-type flash memory architectures.

- Began sampling a 64M synchronous DRAM in early 1997 that features a clock frequency of 100MHz or 83MHz, operates at 3.3 volts, and is designed using a 0.3µm CMOS process.

**Toshiba — Wafer Fab Announcements**

- Announced plans to convert its joint venture DRAM fab facility with Motorola, Tohoku Semiconductor, to logic IC production. The decision follows Motorola's announcement to withdraw from the DRAM market and stop producing its portion of 16M DRAMs at Tohoku by the end of 1997. Motorola's capacity will be converted to logic by the end of 1998. Toshiba will continue producing its share of DRAMs until Motorola's conversion is complete, at which time Toshiba will begin converting to logic.

- Will install a 0.25µm process line at its joint venture facility with IBM, Dominion Semiconductor. Toshiba originally planned to only install 0.35µm equipment, but later decided to install 0.25µm equipment as well. Production is scheduled to begin in early 1998.

- Completely converting building 4 at its site in Oita from DRAM to system-on-a-chip production with 0.25µm geometries. Starting in October 1997, the lines will process ICs integrating 32-bit microprocessors with 64M of DRAM and a 3D image processing engine. Additionally, Toshiba plans to build a 256M DRAM fab facility adjacent to its Oita plant. The facility will be equipped to process 7,500 200mm wafers per week using a 0.25µm process. In addition to 256M DRAMs, the facility will produce ASICs and DSPs. Construction is scheduled to begin in fiscal 1998.

**Toshiba — Key Agreements**

- Established a five-year technology licensing and manufacturing agreement with Chartered Semiconductor. As part of the agreement, Toshiba will license its embedded 0.35µm DRAM technology, later migrating to 0.25µm technology, to Chartered Semiconductor, who will manufacture embedded DRAM products for Toshiba and itself.

- Extended its existing technology agreement with Mips Technologies in April 1997 by licensing the Mips16 instruction set architecture. Toshiba will use the technology to design microprocessors and ASICs, based on the Mips16 core.

- Announced in early 1997 that it would work with Motorola and Fairchild Semiconductor to jointly develop next-generation high-speed CMOS logic ICs. The three companies will work to develop 2.5V and 3.3V ICs with a propagation delay time of 2ns.

**Toshiba — Product Briefs**

- Began sampling a 3.3V 64M synchronous DRAM that features a minimum cycle time of 6.5ns and was designed using a 0.2µm process. Volume shipments are set to begin in late 1997.

- Developed a 0.25µm ASIC family, the TC240 series, that can integrate over 10 million gates, making it possible to integrate 64M DRAM and five million gate logic circuits on a single chip. Toshiba also plans to offer MIPS processor cores with its TC240 ASIC family. Toshiba claims that the technology will eventually allow for the integration of up to 128M of memory.

- Introduced a 64M NAND flash memory IC jointly developed with Samsung. The IC uses a 0.4µm process technology and operates from a 3.3V power supply.

- Began sample shipments of a 16-bit microcontroller with on-board flash memory, targeting engine control and industrial automation applications. The IC features an on-board 10-bit A/D converter, operates between 4.5 and 5.5 volts at 25MHz, and is packaged in a 144-pin quad flat package.

- Began volume shipment of the Mpact media processor. The processor, jointly designed with Chromatic Research and LG Semicon, accelerates 2D and 3D graphics, MPEG-1 and MPEG-2 video, audio, fax/modem, and video conferencing.

**Mitsubishi — Wafer Fab Announcements**

- Plans to build a 300mm wafer fab at its Kochi site by 2000 for 64M and 256M DRAM production. Construction of the $2.5 billion facility is expected to start in 1998.

- Converting its 4M DRAM production line at its North Carolina facility into a 16-bit microcontroller line. Plans for this facility also include building a future-generation DRAM fab.

- Will stop DRAM production at its Saijo fab facility by the end of 1997.

**Mitsubishi — Key Agreements**

- Announced in early 1997 that the company, along with Hitachi and Texas Instruments, will co-develop the cell architecture for a 1G DRAM as well as the process technology needed to manufacture it.

- Licensed the Rambus interface technology needed to make Direct Rambus DRAMs. ICs using the licensed technology are expected to enter volume production in 1999.

**Mitsubishi — Product Briefs**

- Developed a technique to house flash memory and SRAM ICs in a single package and introduced its first multi-chip package in mid-1997 that contains 16M flash memory and 2M SRAM ICs.

- Entered the media coprocessor market with the first generation of the D30V product family. The D30V is a dual issue, very-long-instruction-word RISC microprocessor targeted at DVD players and other consumer electronic applications.

- Introduced several 4M fast SRAM ICs designed specifically for higher density applications. The ICs are designed using 0.4µm CMOS process technology and feature access times of 12ns.

- Expects to begin sampling a new 16M DRAM on a silicon-on-insulator wafer in 1998. The company claims the IC achieves the access speed of a 64M IC.

- Developed a 64M synchronous DRAM, using a 0.3µm process, that features a clock speed of 125MHz.

- Began volume production of its M32R 32-bit RISC microprocessor that includes 8M of embedded DRAM, which the company refers to as eRAM. Besides DRAM integration, the M32R also features on-chip DSP functions and on-chip memory support. The RISC processor core in the M32R measures only 2mm x 2mm, allowing for the integration of the large DRAM.

- Began shipping an 8M flash memory based on its DINOR architecture developed with flash memory partner, Hitachi. Manufactured on a 0.5µm process, the IC features 3.3V operation and random access speeds of 80ns. In addition, the two companies developed a 64M flash IC based on Hitachi's AND flash cell technology. The IC is manufactured using a 0.4µm process. The alliance between Mitsubishi and Hitachi was established in 1994 for the support of Mitsubishi's DINOR and Hitachi's AND-type flash memory architectures.

**Fujitsu — Wafer Fab Announcements**

- Announced in mid-1997 plans to build a 300mm wafer fabrication facility in Aizu-Wakamatsu, Fukushima Prefecture, for 256M and 1G DRAMs using 0.18µm geometries. Construction is set to begin in early 1998 with operations expected to start in late 1999.

- Announced in early 1997 that it had abandoned its plans to construct a second-phase memory production facility at its Durham plant in the UK, citing the plunge in DRAM prices in 1996.

- Decided to make its Gresham, Oregon plant its first facility to produce memory and logic ICs on the same line. The chips will be manufactured in the second facility, which is being constructed at the site.

- Plans to double its overseas IC production to 20 percent of its total IC production.

- Building its second flash memory production facility at Fujitsu AMD Semiconductor in Aizu-Wakamatsu. The new FASL-2 facility will cost approximately $1.2 billion (split 50-50 between the two firms) and will eventually produce at least 6,000 200mm wafers per week when fully ramped. Initial shipments should begin before the end of 1997. Fujitsu also plans to triple flash memory production at this facility.

- Closed an older, 125mm wafer line at its Iwate facility.

**Fujitsu — Key Agreements**

- Purchased a license from Rambus for high-bandwidth Direct RDRAM technology being developed by Rambus and Intel.

**Fujitsu — Product Briefs**

- Announced in late 1996, its plans to discontinue production of SRAMs, EPROMs, and mask ROMs, markets the company was not a major force in. Fujitsu will continue to develop SRAM technology, which will be applied to on-board cache for microprocessors and to core-based ASICs.

- Expanding its SPARC processor product offerings by adding high-end and low-voltage products including a 2.5V 133MHz part, a 1.1V part for portable-battery-operated equipment, and a 200MHz 300 MIPS version using a superscaler architecture. In late 1996, Fujitsu announced a new 170MHz TurboSparc microprocessor as a follow up to the MicroSparc II architecture.

- Plans to enter the NAND-type flash memory market in 1998 with an IC jointly developed with AMD.

- Entered the merchant consumer graphics market in 1997 with the introduction of a 3D geometry processor that can be paired with third-party graphics accelerators. In addition, by the first half of 1998, the company plans to ship a single-chip version of Microsoft's Talisman graphics hardware design.

- Developed a 256M synchronous DRAM IC that will begin sample shipping in 1998. The IC will be produced using a 0.24µm CMOS process.

**Matsushita — Wafer Fab Announcements**

- Announced plans to add a 0.25µm 200mm wafer line at its Tonami plant, to be on-line by October 1997. The company plans to produce 64M DRAMs and 32-bit controllers on the new line.

**Sharp — Key Agreements**

- Acquired the assets of Butterfly DSP in early 1997. Butterfly DSP was created in 1993 to support Sharp's DSP product line.

- Signed a cross-licensing agreement with SanDisk in early 1997 that gives both companies worldwide rights to each other's flash memory patents.

**Sharp — Product Briefs**

- Introduced two mask ROM ICs in early 1997 that feature 3.3V operation, 100ns access time, and 30ns page-mode access. The ICs are manufactured in a 0.4µm CMOS process.

- Began sampling a 16-bit microcontroller with built-in flash memory in early 1997.

**Sony — Wafer Fab Announcements**

- Announced in early 1997 that it would add a $420 million 0.25µm process line at its Kokubu fab in Kagoshima that will partly be used for the manufacture of DRAM-embedded logic ICs for image processing applications. The new line will have a weekly capacity of 2,500 200mm wafers and will begin operations in mid-1998.

- Plans to begin production at its first 300mm wafer fab, to be located at the company's site in Isahaya, Nagasaki, in 1999.

**Sony — Product Briefs**

- Introduced the CXK77B family of 3.3V SRAM ICs designed for high-speed applications. The six IC family features speeds of 8ns and is based on 0.35µm CMOS and BiCMOS process technologies.

- Developed a single-chip DSP that features 2.2 gigabit operations per second at 81MHz on a 3.3V power supply. The IC was designed using a 0.4µm, three-metal-layer CMOS logic process.

**Oki — Wafer Fab Announcements**

- Plans to increase 64M DRAM production at its Miyagi fab facility by converting its 16M line into a 64M production line.

**Oki — Key Agreements**

- Signed an agreement with Silicon Architects of Synopsys in early 1997 to license Silicon Architects' cell based array architecture to add to its 0.35µm ASIC offerings.

**Oki — Product Briefs**

- Introduced its five-member EchoPath family of echo cancellation ICs that are targeted at the digital wireless market. The ICs are manufactured on a 0.5µm process.

- Entered the graphics market with a multimedia accelerator co-developed with partner Silicon Magic. The IC integrates logic functions with a 10M SDRAM frame buffer and uses a 256-bit internal bus.

- Claims to have developed a 1G SDRAM, designed using a 0.16µm process. The chip measures 572 square millimeters and operates at 150MHz on 2.5V.

## Oki — Other Noteworthy News

- Directed 40 percent of its fiscal 1997 semiconductor investment toward research and development, primarily for 256M and 1G DRAM development.

## EUROPEAN IC MANUFACTURERS

Figure 2-18 shows sales for the leading European IC companies in 1995 and 1996, based on final market data. As a group, sales by these companies grew nine percent in 1996, following 35 percent growth the previous year. The growth was driven primarily by fast-growing demand for digital mobile phones and other telecommunications equipment, and automotive electronics.

| 1996 Rank | Company | 1995 | | | 1996/1995 Percent Change | 1996 | | |
|---|---|---|---|---|---|---|---|---|
| | | MOS | Bipolar | Total | | MOS | Bipolar | Total |
| 1 | SGS-Thomson[1] | 1,844 | 1,120 | 2,964 | 19 | 2,888 | 634 | 3,522 |
| 2 | Philips[1] | 2,711 | 225 | 2,936 | 11 | 3,048 | 205 | 3,253 |
| 3 | Siemens | 1,990 | 323 | 2,313 | –2 | 1,960 | 297 | 2,257 |
| 4 | TEMIC | 272 | 128 | 400 | –4 | 267 | 118 | 385 |
| | Telefunken | 28 | 128 | 156 | –7 | 27 | 118 | 145 |
| | Matra MHS[1] | 150 | — | 150 | –3 | 145 | — | 145 |
| | Siliconix | 64 | — | 64 | 2 | 65 | — | 65 |
| | Dialog[2] | 30 | — | 30 | — | 30 | — | 30 |
| 5 | Ericsson | 300 | — | 300 | 30 | 390 | — | 390 |
| 6 | GEC Plessey | 160 | 182 | 342 | –11 | 128 | 177 | 305 |
| 7 | Robert Bosch[1,3] | 30 | 210 | 240 | 6 | 35 | 220 | 255 |
| 8 | Alcatel Mietec | 170 | — | 170 | 21 | 205 | — | 205 |
| 9 | ITT Semiconductors | 138 | 17 | 155 | 16 | 171 | 9 | 180 |
| 10 | Austria Mikro Systeme | 175 | — | 175 | –1 | 173 | — | 173 |
| 11 | Newport Wafer Fab | 80 | — | 80 | 25 | 100 | — | 100 |
| 12 | EM Microelectronic | 84 | — | 84 | 13 | 95 | — | 95 |
| 13 | Thesys Microelectronics | 60 | — | 60 | — | 60 | — | 60 |
| 14 | Micronas[1] | 46 | — | 46 | 9 | 50 | — | 50 |
| 15 | Melexis | 34 | — | 34 | 32 | 45 | — | 45 |
| 15 | SMI | — | 45 | 45 | — | — | 45 | 45 |
| 16 | ZMD | 24 | — | 24 | 71 | 41 | — | 41 |
| | Others | 116 | 21 | 137 | –17 | 98 | 16 | 114 |
| | Total | 8,234 | 2,271 | 10,505 | 9 | 9,754 | 1,721 | 11,475 |

[1]BiCMOS ICs included under MOS.
[2]Fabless IC supplier.
[3]Captive IC manufacturer.

*Source: ICE* 11064AC

**Figure 2-18. European Companies' IC Sales ($M)**

SGS-Thomson continues to hold the top spot in European IC sales, achieving a 19 percent growth in sales over 1995. SGS-Thomson is focusing on high-growth applications and on high-margin products—particularly emphasizing areas such as multimedia, mobile phones, computers, and automotive electronics. New products for 1997 include a multimedia PC on a single chip and the company's first embedded DRAM IC.

Having survived a couple of years of heavy restructuring, Philips Semiconductors is now in a much better position to compete with world leaders in the IC industry. Philips is working hard to be among the world's top ten semiconductor companies in the near future. The company aims to maintain its dominant position in consumer electronics, while becoming an established leader in the digital communications and multimedia markets. The company has, therefore, chosen microcontrollers and standard high-performance logic ICs as two areas of focus. Philips is already among the leaders in 8-bit microcontrollers, and it intends to become an equally serious player with 16-bit ICs.

Siemens' IC group focuses on four strategic product areas: memories, microcontrollers, chip cards, and communications ICs. As the only European DRAM producer, the company plans to be among the top ten DRAM manufacturers in the world within the next few years; it is currently within the top 15. Siemens' efforts in microcontrollers are targeted at applications in the industrial and automotive markets. In communications ICs, the company claims to be the second largest supplier after Lucent Technologies. Siemens is also considering a move into the flash memory market.

**Top Ten European IC Manufacturers: 1997 Highlights**

**SGS-Thomson — Wafer Fab Announcements**

- Continued its plans to open one 200mm wafer production facility each year until 2000. Its Catania facility began volume production in 1997. ST is currently building a new $800 million facility in Rousset, France, with production scheduled for early 1998. Additional fabs will be in Italy and Singapore, the latter running with 0.25µm process technology by 1999.

**SGS-Thomson — Key Agreements**

- Established a licensing agreement with Rambus that gives ST access to Rambus' high-speed memory interface technology.

- Purchased Hyundai's majority stake in Metaflow Technologies, a developer of microprocessors. ST will use Metaflow's design team to develop a new, general-purpose microprocessor.

- Established an agreement with Ramtron in February 1997, covering FRAM production. The agreement calls for SGS-Thomson to provide CMOS wafers to Ramtron, who will return the wafers to ST as finished 64K FRAMs. The two companies may extend this relationship in the future to include joint foundry or technology licensing agreements.

**SGS-Thomson — Product Briefs**

- Announced a substantial increase in its flash memory production, specifically its 2M and 4M ICs. The company began flash memory production at its second facility in Agrate, Italy, late in 1996 and will begin flash memory production at its new Catania facility late in 1997.

- Introduced in early 1997, the first IC from its Omega line of system-on-a-chip ICs that will feature 1M of embedded DRAM at first, moving to 4M later. Using embedded DRAM technology licensed from U.S.-based Artisan Components, the introduction marks the first time ST has fabricated DRAM circuitry on ICs in any quantity.

- Entered the integrated-processor market with an integrated x86 microprocessor, called the PC Consumer, which consists of a 133MHz Pentium x86 CPU with cache; a 64-bit DRAM controller and 2D graphics accelerator; integrated RAMDAC, TV output, and scaler blocks; and an IDE/ISA controller. The IC is manufactured on a 0.35µm process and is scheduled for mass production in 1998.

- Unveiled a 64-bit proprietary, multimedia microprocessor, called the Chameleon, that will be used in an automotive system-on-a-chip IC that will include navigation, a global positioning system, a GSM wireless phone, DVD audio, and radio-link data-system functions. In tandem to Chameleon, the company is developing MPEG-4 technologies and intends to demonstrate a Chameleon MPEG-4 system in a set-top box by the end of 1998.

- Introduced the first in a planned family of MPEG-2 audio-video decoders combined with a 32-bit microprocessor and other functions to produce a complete DVD or set-top box on a single-chip.

**Philips — Key Agreements**

- Licensed the ARM7 32-bit microprocessor core from Advanced RISC Machines in early 1997. Philips will use the core to design ICs tailored for wireless communications applications.

**Philips — Product Briefs**

- Introduced the final member in its CoolRunner line of low-power (3.3V), high-performance CPLDs based on a design technique Philips calls Fast Zero Power (FZP). The IC features 128-macrocells and is the first Philips IC to integrate in-system programming functionality.

- Launched the 80C51RX+ microcontroller family which features ICs with up to 64K of mask ROM / OTP and 1K of RAM, and operates between 2.7V-5.5V at speeds up to 33MHz. Philips also introduced its 80C51 8-bit flash-based microcontrollers that feature in-system reprogrammable memory. The company plans to integrate flash memory into its new RX+ family.

- Began selling its powerful programmable digital signal processor, named TriMedia, in late 1996. The first generation single-chip TriMedia processor, the TM1000, has the power (up to four billion operations per second) to process audio, video, graphics, and communications data concurrently. Philips is also working on a licensing strategy for the TriMedia processor technology.

- Demonstrated MPEG-4 capabilities on its TriMedia TM1000 processor in mid-1997.

**Siemens — Wafer Fab Announcements**

- Announced that by the end of 1998, most of its DRAM facilities will only be using 0.25µm processes.

- Plans to build a 300mm wafer pilot production facility, to be located in Dresden, Germany. Siemens has said it will seek a partner or two for the facility.

- Announced a change of plans for its new joint venture with Motorola, White Oak Semiconductor, following Motorola's announcement to withdraw from the DRAM market. White Oak Semiconductor will use DRAMs to ramp to volume production and Siemens will sell all the DRAMs to its customer base. Once volume production is reached in mid-2000, Motorola will convert its share of the production capacity to fast SRAMs.

**Siemens — Key Agreements**

- Joined the SLDRAM consortium, initially known as SyncLink, in early 1997. Seeking a successor to synchronous DRAM, the SLDRAM consortium is developing an open DRAM architecture capable of enabling data transfer rates of 500MBytes to 3.2GBytes per second. The first SLDRAM is scheduled for completion in early 1998.

**Siemens — Product Briefs**

- Announced it will put off development of an embedded DRAM-based MPEG multimedia single chip, but will continue to develop system-on-a-chip ICs for its core automotive and telecommunications markets.

- Introduced a speech processing IC with 1M of embedded DRAM, based on its third generation of embedded DRAM technology. The IC was designed using a 0.35µm 64M DRAM process. The company plans to introduce a fourth generation of this technology, using a 0.25µm CMOS process, by mid-1998. The fourth generation technology uses a 256M trench-capacitor DRAM process that Siemens jointly developed with IBM and Toshiba.

- Added to its line of smart card controllers a high-end family of Triple E microcontrollers; Triple E refers to enhanced performance, enhanced on-chip security, and enhanced memory capacity. The SLE 66CX160S IC features memory capacity of 32K ROM, 16K EEPROM with about 2K of on-board RAM.

**TEMIC — Key Agreements**

- Licensed Analog Devices' ADSP-21020 DSP architecture in early 1997. TEMIC plans to use the architecture to design a radiation-tolerant version of this IC using a 0.6µm radiation-tolerant CMOS process.

**GEC Plessey — Product Briefs**

- Entered the digital cellular baseband market with a tandem processor targeting GSM communications systems. The processor integrates a 13MHz ARM7 Thumb RISC core and DSP Group's OakDSPCore.

- Began prototyping its first 0.35µm CMOS ICs in 1997. A 1.8V 0.18µm CMOS process is expected to be in use by the end of the decade.

**GEC Plessey — Other Noteworthy News**

- Announced in mid-1997 that the company was for sale. The company stated that because of the level of interest in GEC Plessey from other major companies in the high-technology industry, an alliance should be secured by the end of 1997.

### Alcatel-Mietec — Other Noteworthy News

- Announced a restructuring plan in mid-1997 that will divide chip design and chip manufacturing into separate groups. The IC design activities will be grouped into the Alcatel Design Factory (ADF) and will encompass all semiconductor design activities for Alcatel's ASIC and ASSP ICs and offer design services to external customers. The existing manufacturing activities of Alcatel-Mietec, now called Alcatel Semiconductors, will manufacture ICs for Alcatel and ADF, as well as offer foundry services. ADF will have the option to use Alcatel Semiconductors for its manufacturing needs or seek manufacturing contracts with outside foundries.

### ITT — Key Agreements

- Entered into an agreement with General Instruments (GI) to sell its discrete semiconductor business to GI's Power Semiconductor Division.

## ROW IC MANUFACTURERS

Many so-called rest-of-world (ROW) nations have in recent years undertaken major efforts to establish competitive semiconductor industries. This has especially been the case for the rapidly developing countries in the Asia-Pacific region, excluding Japan. One of the main driving forces behind these efforts is the desire many of these countries have to build self-contained electronics industries.

### Korean IC Manufacturers

Korea has grown into a memory chip manufacturing powerhouse in a very short time. Aided by strong demand for DRAMs through 1995, the three main Korean companies—Samsung, LG Semicon, and Hyundai—experienced 90 percent growth in their sales of ICs in 1995. Unfortunately, that performance could not be repeated in 1996 because of the plunge in DRAM prices. Overall, the three top companies experienced a 25 percent decline in IC sales for the year (Figure 2-19).

DRAMs accounted for about 70 percent of their IC sales for 1996, down from more than 80 percent in 1995. The Koreans have been working to lessen their dependence on DRAMs through alliances with and investments in companies that have strengths in other areas. Additionally, all three Korean manufacturers have announced plans to increase investment in non-memory ICs, while continuing to be key players in the memory market.

| Rank | Company | 1995 | | | 1996/1995 Percent Change | 1996 | | |
|---|---|---|---|---|---|---|---|---|
| | | MOS | Bipolar | Total | | MOS | Bipolar | Total |
| 1 | Samsung[1] | 8,183 | — | 8,183 | –22 | 6,385 | — | 6,385 |
| 2 | Hyundai | 4,350 | — | 4,350 | –28 | 3,150 | — | 3,150 |
| 3 | LG Semicon | 3,500 | 100 | 3,600 | –31 | 2,400 | 100 | 2,500 |
| — | Others | 337 | — | 337 | 4 | 350 | — | 350 |
| | Total | 16,370 | 100 | 16,470 | –25 | 12,285 | 100 | 12,385 |

[1]GaAs ICs included under MOS.

*Source: ICE* 11725AB

**Figure 2-19. Korean Companies' IC Sales ($M)**

## Korean IC Manufacturers: 1997 Highlights

### Samsung — Wafer Fab Announcements

- Indicated its next three fab facilities will be located outside of South Korea—the first in Austin, Texas, the second in the United Kingdom or Germany, and the third in Malaysia or Indonesia.

### Samsung — Key Agreements

- Acquired 3DO Corp. for approximately $20 million. Just prior to the acquisition, the two companies discontinued their joint development of the much-publicized Media Signal Processor. Samsung will leverage the acquisition to form a Silicon Valley company that will concentrate on multimedia systems and semiconductors.

- Licensed ferroelectric RAM (FRAM) technology from Ramtron in early 1997. Samsung became the fifth semiconductor manufacturer to license the technology.

- Will provide Intel with a reliable supply of DRAMs in exchange for an equity investment by Intel in Samsung's memory IC fab currently under construction in Austin, Texas.

### Samsung — Product Briefs

- Plans to increase its portion of non-memory product sales from 15 percent to about 20 percent of total product sales by 2000 as part of its ongoing strategy to broaden its product offerings. As part of its strategy, Samsung intends to achieve a leadership position in the ASIC market.

- Introduced a one-time-programmable (OTP) 8-bit microcontroller with 16K of embedded EPROM. The IC is one in a series of 8-bit microcontrollers planned for release by Samsung.

- Received a ruling from the ITC restricting the export of its flash memory chips to the United States. The ruling comes after SanDisk claimed that Samsung infringed upon two of SanDisk's patents involving flash memory. The ruling orders Samsung to stop shipping all densities of its flash memory ICs into the U.S. The ruling did not, however, specify whether Samsung could embed its existing flash memory into a logic IC or ASIC cell.

- Introduced a single-cell 64M flash memory IC based on its NAND technology. The IC operates from a single 3.3V power supply and is targeted at PDAs and palmtop computers. Samsung also released a newer enhanced version of its 32M NAND-based flash memory.

- Announced the MDL90, its next-generation cell-based ASIC IC that offers up to 24M of DRAM on the logic chip. The IC is manufactured on Samsung's four-layer-metal, 0.35µm stacked three-poly CMOS process. The IC began sampling late in 1997.

**Hyundai — Wafer Fab Announcements**

- Plans to build a second manufacturing facility in the Taejeon Science industrial park. The facility will be used to produce 64M and 256M DRAMs.

- Began construction on Fab 1, the first of two fab facilities it plans to build in Dumfermline, Scotland, in early 1997. The first fab will produce 64M DRAMs, later moving to 256M DRAMs, on 200mm wafers. It is expected to be operational by late 1998.

**LG Semicon — Wafer Fab Announcements**

- Broke ground on its first fab facility outside of Korea. The facility, located in Newport, South Wales, will be used for 64M and 256M DRAMs as well as logic IC production and assembly, starting in late 1998. DRAM production at the new facility is expected to make up about 50 percent of total output, down from original plans that called for 70 percent DRAM output.

**LG Semicon — Product Briefs**

- Rolled out its 0.35µm standard cell ASIC product line in early 1997.

- Began volume shipment of the Mpact media processor. The processor, jointly designed with Chromatic Research and Toshiba, accelerates 2D and 3D graphics, MPEG-1 and MPEG-2 video, audio, fax/modem, and video conferencing.

## LG Semicon — Other Noteworthy News

- Plans to increase its percentage of non-memory product sales to 30 percent of total sales, up from the current ten percent. LG Semicon intends to invest about $845 million in non-memory ICs over the next four years. In a separate announcement, the company announced its "Leap 2005 Vision Statement" that calls for LG to be one of the top five semiconductor companies by 2005.

## Taiwanese IC Manufacturers

In the matter of only a few years, several Taiwanese companies have grown to become significant players in the worldwide IC industry. The Taiwanese companies did well in 1996, with the exception of United Microelectronics (UMC), Winbond Electronics, TI-Acer, and Mosel-Vitelic, who were affected by memory IC pricing pressures. Collectively, the Taiwanese companies experienced a one percent decrease in sales, compared to 62 percent growth in 1995 (Figure 2-20).

| 1996 Rank | Company | 1995 | 1996 | 1996/1995 Percent Change |
|---|---|---|---|---|
| 1 | TSMC | 1,092 | 1,435 | 31 |
| 2 | UMC | 900 | 825 | –8 |
| 3 | Mosel-Vitelic | 540 | 461 | –15 |
| 4 | Winbond | 676 | 435 | –35 |
| 5 | TI-Acer | 556 | 400 | –28 |
| 6 | Macronix | 328 | 373 | 14 |
| 7 | Hualon | 150 | 175 | 17 |
| 8 | Acer Labs* | 95 | 110 | 16 |
| 9 | Holtek | 90 | 105 | 17 |
| | Others | 262 | 300 | 15 |
| | Total | 4,689 | 4,619 | –1 |

*Fabless Supplier

*Source: ICE* 17717N

**Figure 2-20. Taiwanese Companies' IC Sales ($M)**

A good portion of Taiwan's IC industry consists of foundry services. The country's two largest IC firms, Taiwan Semiconductor Manufacturing (TSMC) and UMC, are entirely dedicated to foundry work. UMC spun off its standard IC product groups into separate businesses during 1996 and the first quarter of 1997. Both companies announced aggressive plans for future fab facilities. Meanwhile, Winbond, the third largest firm, has dedicated more space and funding to increase its foundry capabilities.

Aside from foundry work, IC production in Taiwan is largely focused on lower-margin products such as PC chipsets, EPROMs, ROMs, and SRAMs. However, with backing from a pro-technology government and through partnerships with foreign IC companies, the Taiwanese are shifting their product mixes to more advanced ICs like DRAMs, microprocessors, flash memories, multimedia ICs, and communications ICs. Although DRAM is expected to become Taiwan's industry driver, it is not expected to dominate as it does in Korea.

**Taiwanese IC Manufacturers: 1997 Highlights**

**TSMC — Wafer Fab Announcements**

- Announced in early 1997 its long-term plans for future wafer manufacturing facilities, including investment of approximately $14.5 billion over the next five years to build one 200mm and six 300mm wafer manufacturing facilities in the new Tainan Science Industrial Park in southern Taiwan.

**TSMC — Key Agreements**

- Licensed DSP Group's OakDSPCore technology that it plans to integrate into its ASIC cell library.

**TSMC — Product Briefs**

- Unveiled in early 1997 its so-called BlendIC process for combining DRAM and logic on the same chip. The 0.35µm triple-well process combines embedded three-poly, two-metal layer DRAM and a multilayer ASIC process using one poly and four metal layers.

- Began development of a 0.18µm process technology in early 1997.

**TSMC — Other Noteworthy News**

- Announced in May, 1997 that TSMC President, Donald Brooks, resigned from the company. Brooks then announced in July, 1997, that he joined TSMC competitor, UMC.

**UMC — Wafer Fab Announcements**

- Announced in mid-1997 plans to invest about $18 billion over the next ten years to build six manufacturing facilities in the Tainan Science Industrial Park in southern Taiwan. Plans call for the construction of one 200mm wafer facility by 1999 and five 300mm wafer facilities within ten years. Construction of the first facility is set to begin by early 1998 and will feature 0.16µm-0.18µm process geometries.

**UMC — Other Noteworthy News**

- Spun off its standard IC product lines, turning itself into a pure foundry company. Its two new U.S. subsidiaries, Davicom Semiconductor and Integrated Technology Express will develop and market communications ICs and PC chipsets, respectively. The memory IC business, named Amic, is headquartered in Santa Clara, California, and will develop and sell system-on-a-chip and embedded memory products. The consumer products unit, now Novatek, is based in Taiwan and will market UMC's consumer ICs. The multimedia products business, Mediatek, is now a separate, fabless IC design company based in Taiwan that will sell the former multimedia lines of UMC.

**Mosel-Vitelic — Wafer Fab Announcements**

- Announced plans to build a 300mm DRAM fab facility in the new Tainan Science Industrial Park in southern Taiwan. Plans include constructing two modules beginning in 1999 and reaching full production by 2003.

**Mosel-Vitelic — Key Agreements**

- Formed a joint venture company with Siemens that will manufacture advanced high-density DRAMs, beginning with 64M ICs. The new company, called ProMOS Technologies, is headquartered in Hsinchu, Taiwan, and began production in mid-1997. Mosel-Vitelic holds a 62 percent share in the venture with Siemens holding the remaining 38 percent.

**Mosel-Vitelic — Product Briefs**

- Plans to introduce a 120MHz version of a synchronous graphics RAM (SGRAM) by the end of 1997.

- Entered the flash memory market in 1997 with a line of 2M flash memory ICs featuring a combination boot-block and sector-erase technology. Shipments of the new flash ICs began in mid-1997.

**Winbond — Key Agreements**

- Will invest in Worldwide Semiconductor Manufacturing Corporation's (WSMC) 200mm wafer manufacturing facility that is currently under construction in Hsinchu. Winbond will have a 20 percent stake in the facility and will receive wafers from the facility when production begins in July 1998. Winbond also licensed its 0.35µm logic process to WSMC and the two companies will work together to develop a 0.25µm process.

**Winbond — Product Briefs**

- Entered the communications IC market in early 1997 with its ISDN S-Controller IC designed for use in PC-based, board-level products. The company also introduced the first in a family of Fast Ethernet controllers designed for 10-Mbits/s and 100-Mbits/s LANs.

**TI-Acer — Wafer Fab Announcements**

- Plans to spend about $3.6 billion over the next three to four years to expand its joint venture operations. Beginning with Fab 2, TI-Acer plans to equip the facility with a 0.25µm and below line for DRAM production.

**Macronix International — Wafer Fab Announcements**

- Announced in mid-1997 its plans to build three 300mm wafer fabrication facilities. The company has indicated that construction of the first facility, to be located in Hsinchu, Taiwan, will start around 2000. Possible locations for the next two facilities are Tainan, in southern Taiwan, or outside of Taiwan.

**Macronix International — Product Briefs**

- Announced a new type of reprogrammable ROM chip called multiple time reprogrammable ROM (MTPROM). Based on its own small-cell architecture, the company is shipping 512K and 1M MTPROM versions and will soon offer a 64M version.

**Holtek — Wafer Fab Announcements**

- Building its first 200mm wafer fab adjacent to its Fab I facility. Fab II is expected to begin operations in January 1998 and will have a capacity of 8,750 wafers per week by 2001.

**Singaporean IC Manufacturers**

The semiconductor industry is an increasingly important part of Singapore's electronics infrastructure. Assembly, packaging, and testing remain the primary activities of semiconductor manufacturing in Singapore, but investment in front-end IC fabrication is rising substantially. Singapore wants to duplicate the success of Taiwan's semiconductor industry.

Figure 2-21 shows sales for Singapore's few IC companies in 1996. As a group, the three companies experienced a nine percent decline in sales during 1996, which follows a 79 percent growth in 1995. The decline is primarily due to TECH Semiconductor who was adversely affected by plunging DRAM prices. TECH Semiconductor is a joint venture between Texas Instruments, Canon, Hewlett-Packard, and the local government. Like Taiwan's TSMC, Chartered Semiconductor Manufacturing is having success at focusing all its efforts on providing advanced silicon foundry services to other IC companies. TriTech Microelectronics, a designer and supplier of ICs for the communications and consumer markets, was split off from Chartered Semiconductor in 1990.

| Company | 1995 | 1996 | 1996/1995 Percent Change |
|---|---|---|---|
| TECH Semiconductor | 620 | 450 | –27 |
| Chartered Semiconductor | 285 | 360 | 26 |
| TriTech Microelectronics* | 75 | 78 | 4 |
| Total | 980 | 888 | –9 |

*Fabless Supplier

*Source: ICE* 18959F

**Figure 2-21. Singaporean Companies' IC Sales ($M)**

## Singaporean IC Manufacturers: 1997 Highlights

### Chartered Semiconductor — Wafer Fab Announcements

- Announced in April 1997 the development of a new joint venture foundry company with partner, Hewlett-Packard, and the Economic Development Board of Singapore. The new venture, called Chartered Silicon Partners, will be located adjacent to Chartered's existing facilities in the Woodlands Industrial Park in Singapore. Construction of a 200mm wafer manufacturing facility is expected to begin in September 1997 with production beginning in mid-1999. HP will receive a specified amount of wafers, for 0.35µm and 0.25µm ASICs, from the venture in exchange for its investment, while the remaining capacity will be offered as part of Chartered's usual foundry services.

### Chartered Semiconductor — Key Agreements

- Established a five-year technology licensing and manufacturing agreement with Toshiba. As part of the agreement, Toshiba will license its embedded 0.35µm DRAM technology, later migrating to 0.25µm technology, to Chartered Semiconductor, who will manufacture embedded DRAMs for Toshiba and itself.

### TriTech Microelectronics — Product Briefs

- Entered the 3D graphics market in early 1997 with its Pyramid3D processor, which is capable of 50 million-pixel-per-second performance and is manufactured on a 0.6µm process.

## SEMICONDUCTOR CAPITAL SPENDING TRENDS

### Overview

Attempting to keep up with what seems to be unstoppable growth in demand for semiconductors, many IC manufacturers have spent heavily to increase wafer fabrication capacity. As shown in Figure 2-22, total semiconductor capital spending in 1995 increased a staggering 74 percent. That was by far the highest growth rate in the past decade.

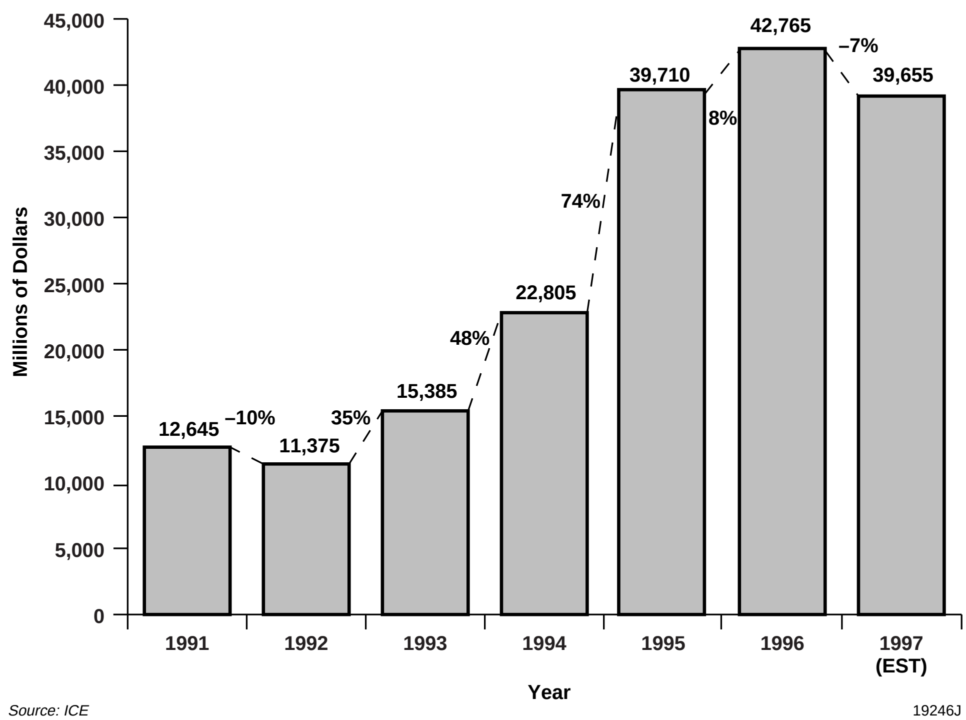



**Figure 2-22. Worldwide Merchant Semiconductor Capital Spending Trends**

Capital spending for 1996, however, was an entirely different picture. The growth rate for capital spending in 1996 slowed to eight percent. The majority of the spending cutbacks in 1996 were for DRAM production facilities. Spending on foundry-dedicated fabs however, continues to be substantial. Figure 2-23 lists several foundry-dedicated operations that have recently began or are soon to begin around the world. Note that the majority of these fab sites are located in the Asia-Pacific region.

When final data are tabulated, ICE estimates that capital spending for 1997 will show a seven percent decrease from the 1996 level. Much of the spending in 1997 was used to re-equip facilities from production of DRAMs to logic and other products and to install 0.25µm manufacturing capabilities. Figure 2-24 shows further evidence that the industry is rapidly moving to 0.25µm technologies.

| Company | Location | Start of Production |
|---|---|---|
| Advanced Semiconductor Manufacturing | Shanghai, China | 1996 |
| Chartered Semiconductor Manufacturing | Singapore | 1997 |
| GMT Microelectronics | Valley Forge, Pennsylvania | 1996 |
| Huajing Electronics | Wuxi, China | 1996 |
| InterConnect Technology | Sarawak, Malaysia | 1997 |
| Lien Hsing Integrated Circuits | Hsinchu, Taiwan | 1996 |
| Mid-West Microelectronics | Lee's Summit, Missouri | 1996 |
| Newport Wafer-Fab | Wales, United Kingdom | 1998 |
| Seaway Semiconductor | Livermore, California | 1997 |
| Submicron Technology | Bangkok, Thailand | 1997 |
| Tower Semiconductor | Migdal Haemek, Israel | 1998 |
| Taiwan Semiconductor Manufacturing | Hsinchu, Taiwan | 1996 |
| Taiwan Semiconductor Manufacturing | Hsinchu, Taiwan | 1998 |
| Taiwan Semiconductor Manufacturing (WaferTech) | Camas, Washington | 1998 |
| United Integrated Circuits | Hsinchu, Taiwan | 1997 |
| United Semiconductor | Hsinchu, Taiwan | 1996 |
| United Silicon | Hsinchu, Taiwan | 1998 |
| Worldwide Semiconductor Manufacturing | Hsinchu, Taiwan | 1998 |

*Source: ICE* 20460C

**Figure 2-23. New Foundry Facilities are Starting Everywhere**

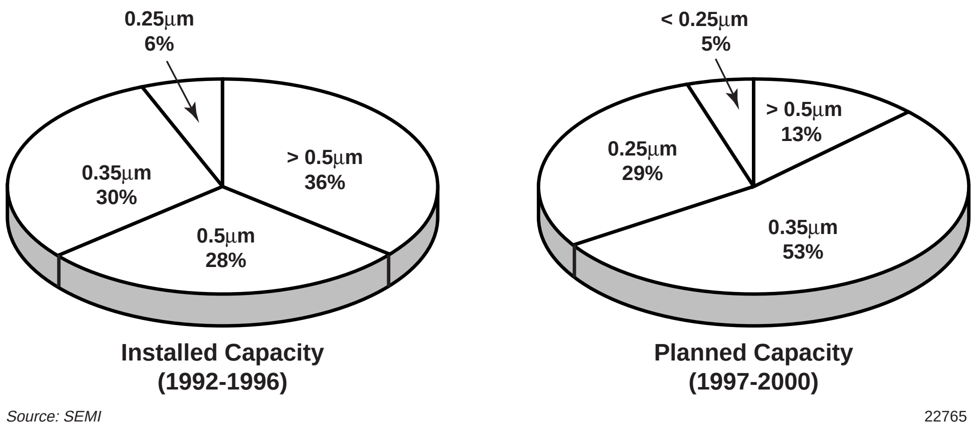



**Figure 2-24. The Speedy Switch to Advanced Fabs**

The estimated 1997 worldwide top ten capital-spenders are listed in Figure 2-25. Collectively, spending by the top ten is estimated to have decreased three percent over 1996 levels. However, this figure is considerably weighted by Intel. Excluding Intel, spending by the other top spenders in 1997 would show an 11 percent decrease.

| Rank | Company | Headquarters Location | 1997 Capital Spending ($M, EST) | 1997/1996 Percent Change |
|---|---|---|---|---|
| 1 | Intel | U.S. | 4,500 | 50 |
| 2 | LG Semicon | Korea | 2,380 | 3 |
| 3 | Hyundai | Korea | 1,920 | –23 |
| 4 | Samsung | Korea | 1,900 | –17 |
| 5 | NEC | Japan | 1,625 | –7 |
| 6 | Toshiba | Japan | 1,285 | –18 |
| 6 | Hitachi | Japan | 1,285 | –7 |
| 7 | Fujitsu | Japan | 1,265 | –12 |
| 8 | IBM | U.S. | 1,200 | –20 |
| 9 | SGS-Thomson | Europe | 1,170 | 4 |
| | Total | | 18,530 | –2 |

**1997: 117¥ = $1.00**

*Source: ICE* 19820E

**Figure 2-25. Worldwide Top Ten 1997 Semiconductor Capital Spenders**

For the seventh year in a row, ICE estimates that Intel will qualify as the largest spender in the semiconductor industry, showing a 50 percent growth over 1996, spending $4.5 billion. The top three Korean companies have established a significant presence among the top ten worldwide spenders. LG Semicon was the next biggest spender and the only other company in the top ten expected to show more spending in 1997 over 1996. When final data are in, Hyundai and Samsung will likely show that they spent less than 1996 levels, but both are still investing heavily in new facilities.

Figure 2-26 shows the annual capital spending levels by world region from 1991 through 1996, as well as an estimate for 1997. North America continues to be the largest spending region. Since 1995, ROW companies, excluding those in Korea, have spent more than European companies. More significantly, combined expenditures for Korean and ROW companies in 1996 exceeded that of Japanese companies and was not too far behind that of North American companies. This trend is expected to hold in 1998 as well.

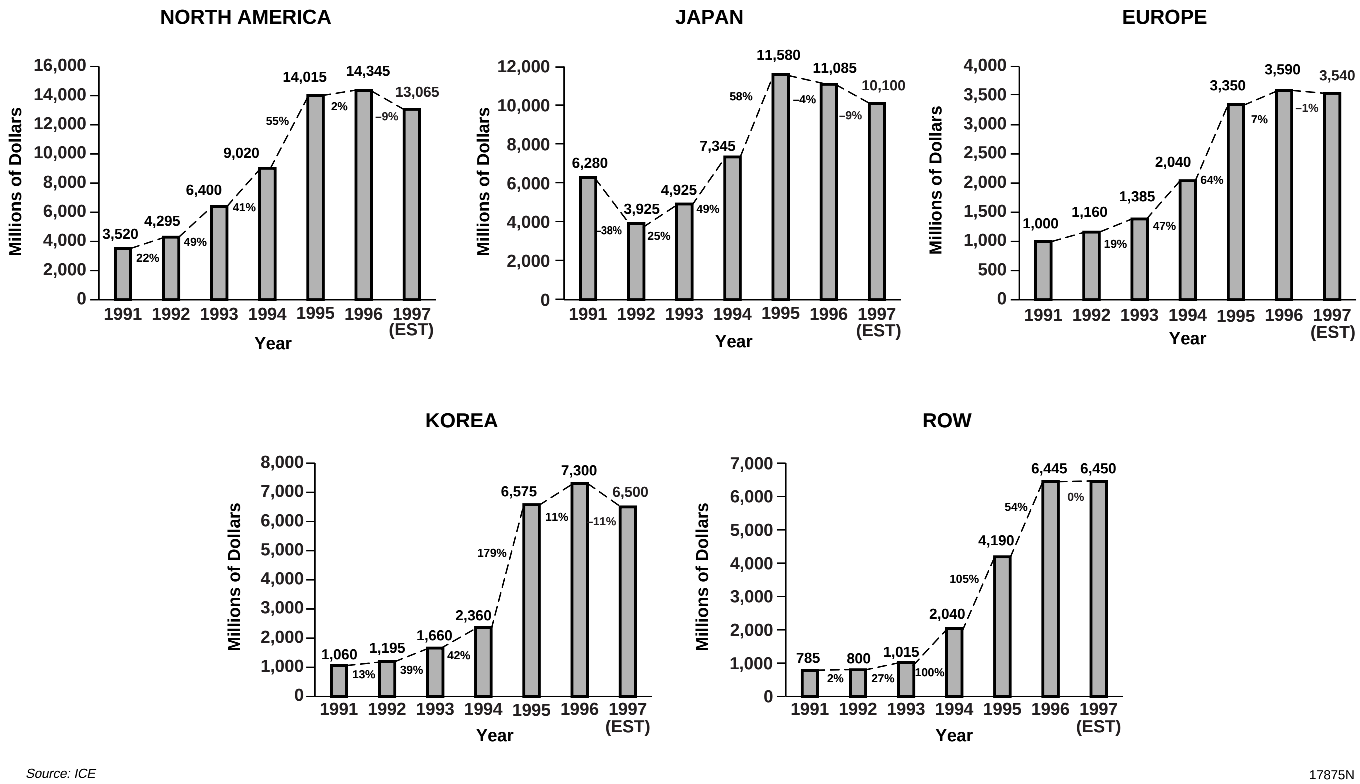



**Figure 2-26. Capital Spending by Region**

Figure 2-27 shows how dramatically the regional share of spending has changed since 1991. As shown, Japanese companies were once responsible for about half of the semiconductor industry's capital expenditures. That was before Japan's economy collapsed in 1992, causing the Japanese producers to slash their budgets substantially. In the years since, Japan has seen its share of the world's capital spending shrink to less than one third, even despite healthy investment increases in 1995. The percent share of spending held by Korean and ROW companies has more than doubled since 1991.

Figure 2-28 shows the total capital spending as a percentage of IC sales for each of the world regions in 1995 and 1996. There are two key trends revealed by this data. One is the fact that companies in Taiwan and Korea spent a very large percentage of their sales on semiconductor capital during 1996. In fact, Taiwanese companies spent over 100 percent of their IC sales on fab facilities and equipment. Second, they did not trim their budgets in response to weak market conditions during the year. In 1996, Taiwanese and Korean companies spent 107 percent and 59 percent of their IC sales on fab facilities and equipment, respectively. In comparison, North American, Japanese, and European companies spent between 23 and 32 percent.

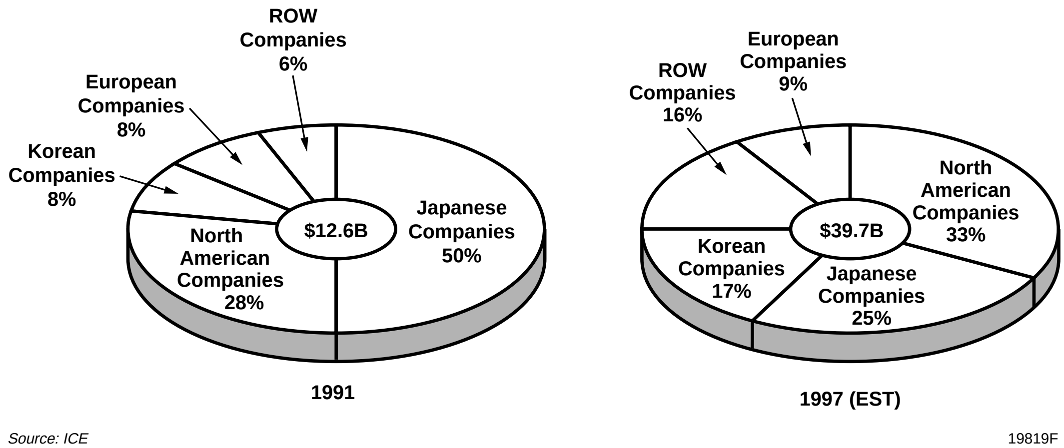



**Figure 2-27. Capital Spending by Regional Companies**

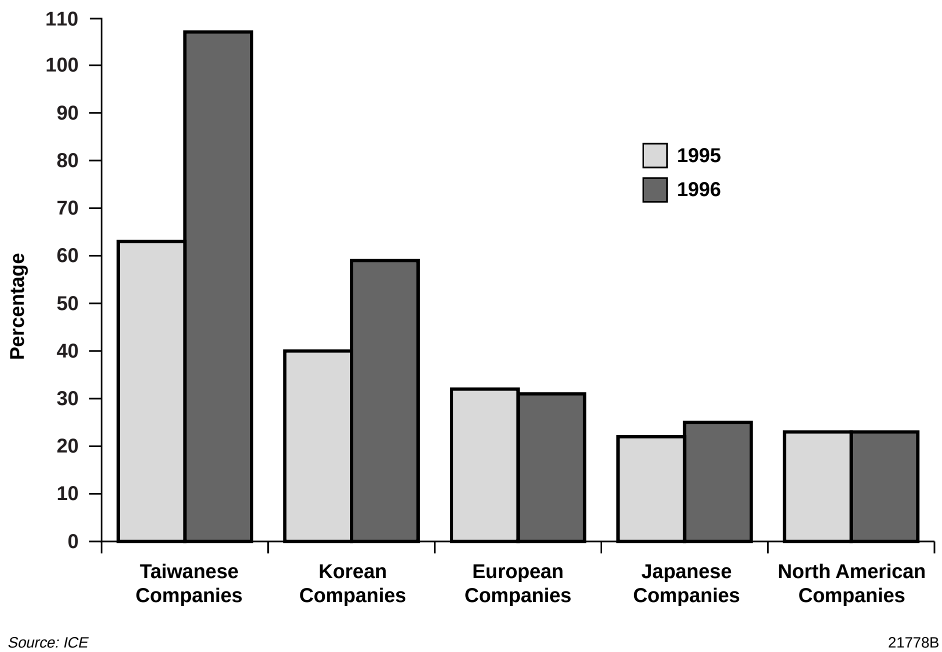



**Figure 2-28. IC Manufacturers' Capital Spending as a Percent of IC Sales (1995-1996)**

## Leading North American Spenders

Figure 2-29 estimates capital spending by the leading North American semiconductor manufacturers for 1997. Spending by these companies is estimated to have decreased nine percent in 1997, following a three percent increase in 1996. Once again, overall capital spending by North American companies is heavily weighted by Intel. Excluding Intel, North American semiconductor-related capital expenditures are estimated to have declined 24 percent over 1996.

| 1997 Rank | Company | 1997 (EST) | 1996 | 1997/1996 Percent Change |
|---|---|---|---|---|
| 1 | Intel | 4,500 | 3,000 | 50 |
| 2 | IBM | 1,200 | 1,500 | –20 |
| 3 | Motorola | 1,100 | 1,400 | –21 |
| 4 | TI | 1,000 | 1,840 | –46 |
| 5 | National | 540 | 525 | 3 |
| 6 | AMD | 500 | 494 | 1 |
| 6 | Lucent Technologies | 500 | 498 | — |
| 7 | LSI Logic | 475 | 362 | 31 |
| 8 | Micron | 400 | 1,100 | –64 |
| 8 | Atmel | 400 | 566 | –29 |
| 9 | Rockwell | 300 | 525 | –43 |
| 10 | Analog Devices | 175 | 250 | –30 |
| 11 | VLSI Technology | 150 | 245 | –39 |
| 11 | Cypress | 150 | 195 | –23 |
| 12 | IDT | 125 | 245 | –49 |
| | Others | 1,550 | 1,600 | –3 |
| | Total | 13,065 | 14,345 | –9 |

Source: ICE 14538S

**Figure 2-29. North American Merchant Semiconductor-Related Capital Expenditures ($M)**

To maintain its lead in the rapidly changing and increasingly competitive microprocessor market, Intel has invested heavily in new plants and equipment during the past few years. As mentioned above, Intel’s 1997 spending will be substantially above that of 1996. The company’s 1997 spending included starting (then delaying) a $1.3 billion fab facility in Ft. Worth, Texas, an assembly and test facility in California, and a flash memory assembly plant in China. The company continues to increase capacity for its Pentium and Pentium Pro microprocessors and prepares for future capacity needs.

IBM ranked second highest in North American capital spending for 1997, despite a 20 percent decrease in spending over 1996. IBM plans to devote the bulk of its new investment to proprietary custom logic, rather than microprocessors or memory, as part of a goal to increase its percentage of external sales to 70 percent up from its current 30 percent of total revenues. Its current fab projects include the expansion and upgrade for 64M DRAM production at the joint venture fab it shares with Siemens in Essones, France, and the construction of a new $1.2 billion 64M DRAM plant in Manassas, Virginia, with Toshiba.

Motorola’s capital spending for 1997 is estimated to have declined 21 percent from 1996. In 1996, the company indefinitely postponed construction plans for its MOS 19 facility, in Richmond, Virginia, and delayed by one year Phase II expansion plans at its MOS 13 fab facility in Austin, Texas. The company also delayed construction of a new fab at its Aizu facility, which was originally expected to be in production in 1998. Motorola is, however, building a new 200mm fab, MOS 17, in Tainjin, China, where production is expected to begin in 1998. It is also beginning a new wafer fabrication facility in Chandler, Arizona.

Texas Instruments' 1997 spending is estimated to have declined 46 percent, following a 57 percent growth in 1996. TI's decrease in 1997 spending is not so much due to the company scaling back spending, but more due to the fact that TI has spent significant amounts over the past couple years on a new DSP fab facility and a new R&D facility. Future fab plans include a second fabrication facility in Avezzano, Italy, for production of flash memories on 300mm wafers.

## Leading Japanese Spenders

Figure 2-30 provides an estimate for 1997 semiconductor capital spending by several of Japan's largest semiconductor manufacturers. Overall, 1997 spending by these Japanese companies is expect to show a decline of nine percent from 1996 in terms of dollars, or two percent in terms of yen. This compares to 1996 capital spending for Japanese companies that declined four percent in term in dollars, or increased eleven percent in terms of yen.

| 1997 Rank | Company | 1997 (EST) | 1996 | 1997/1996 Percent Change |
|---|---|---|---|---|
| 1 | NEC | 1,625 | 1,740 | –7 |
| 2 | Toshiba | 1,285 | 1,560 | –18 |
| 2 | Hitachi | 1,285 | 1,380 | –7 |
| 3 | Fujitsu | 1,265 | 1,435 | –12 |
| 4 | Mitsubishi | 990 | 1,055 | –6 |
| 5 | Matsushita | 900 | 950 | –5 |
| 6 | Sharp | 600 | 675 | –11 |
| 6 | Sony | 600 | 460 | 30 |
| 7 | Sanyo | 500 | 485 | 3 |
| 8 | Oki | 275 | 400 | –31 |
| 9 | Seiko Epson | 250 | 330 | –24 |
| 10 | Nippon Steel | 135 | 180 | –25 |
| 11 | Rohm | 180 | 195 | –8 |
| | Other | 210 | 240 | –13 |
| | Total | 10,100 | 11,085 | –9 |

1996: 109¥ = $1.00
1997: 117¥ = $1.00
*Source: ICE* 19098H

**Figure 2-30. Japanese Semiconductor-Related Capital Expenditures ($M)**

The Japanese have been hit hard by the decline in DRAM prices, but are doing their best to keep up with the high level of spending by Korean and Taiwanese DRAM manufacturers. While maintaining a presence in DRAMs, many Japanese manufacturers have announced plans to increase their focus on non-memory products and are making room for non-memory production in their facilities. For example, Hitachi plans to convert its 16M DRAM line at its Kofu fab facility to flash memory and plans to construct a facility for microprocessors; Toshiba plans to convert its DRAM joint venture at Tohoku Semiconductor to produce logic ICs and is converting lines at its Oita facilities to system-on-a-chip production; Mitsubishi is converting a 4M DRAM line into a microcontroller production line; Sony plans to add a line at its Kokubu fab for DRAM embedded logic ICs; and Matsushita is building in Tonami to expand its capacity not only for DRAMs, but also for microcontrollers and advanced ASICs.

Due in part to dramatic fluctuations in the yen-to-dollar exchange rates, Japanese companies have in recent years placed greater emphasis on spending abroad. NEC added a new $800 million 64M DRAM fab to its Scotland site and announced plans to build a joint venture facility in China with Huahong Microelectronics. Hitachi completed its two fab projects in Texas: the expansion of its existing fab in Irving, and its new joint DRAM manufacturing facility in Richardson with TI.

The most significant offshore announcement came from Toshiba, who, until 1995, stuck by its strategy to focus its IC production in Japan. The announcement of intentions to establish its first overseas wafer fab came in April 1995. A few months later, the company made its official announcement; it had agreed to join IBM in constructing a $1.2 billion 64M DRAM plant in Manassas, Virginia. The facility is currently under construction and will be ready for volume production early in 1998.

**Leading Korean Spenders**

Korean IC manufacturers, mainly Samsung, LG Semicon, and Hyundai, as a group are estimated to have decreased their semiconductor capital spending levels by eleven percent in 1997 (Figure 2-31). Although spending by the top Korean companies is estimated to have decreased, the three companies are estimated to be the top spenders worldwide, following Intel.

As mentioned earlier, the Koreans have been working to lessen their dependence on DRAM manufacturing, which represented 70 percent of total sales for 1996. All three Korean manufacturers have announced their plans to invest in non-memory ICs, while remaining key players in the memory market.

| 1997 Rank | Company | 1997 (EST) | 1996 | 1997/1996 Percent Change |
|---|---|---|---|---|
| 1 | LG Semicon | 2,380 | 2,300 | 3 |
| 2 | Hyundai | 1,920 | 2,500 | –23 |
| 3 | Samsung | 1,900 | 2,300 | –17 |
| | Others | 300 | 200 | 50 |
| | Total | 6,500 | 7,300 | –11 |

Source: ICE 13859S

**Figure 2-31. Korean Semiconductor-Related Capital Expenditures ($M)**

Another significant area of investment for Korean IC manufacturers has been in offshore fab facilities. In early 1997, LG Semicon began construction of its first fab outside of Korea. Located in South Wales, United Kingdom, the facility will produce DRAMs as well as logic ICs. Samsung plans to build its next three fab facilities outside of Korea, the first in Austin, Texas (currently under construction), the second in Europe, and the third in Malaysia or Indonesia. Samsung has set a long-term goal to produce more than half of its products in foreign facilities.

In early 1997, Hyundai began construction of one of two fabs it plans to build in Dunfermline, Scotland. This is Hyundai's second offshore site. Hyundai's first offshore facility, located in Eugene, Oregon, began operations in the second half of 1997.

### Leading ROW Spenders (Excluding the Koreans)

Taiwanese semiconductor companies are the big spenders in the ROW region, outside of Korea (Figure 2-32). Looking closely, the companies who are estimated to have spent less in 1997 are primarily DRAM producers. As a group, spending by Taiwanese companies is estimated to have declined seven percent in 1997. Overall, however, spending by Taiwanese companies is still high considering the fact that 1996 spending grew 67 percent. As seen earlier in this section, Taiwanese companies invested over 100 percent of their semiconductor sales on capital equipment in 1996. Much of the 1997 spending went for building foundry-dedicated facilities and DRAM plants (Figure 2-33).

Foundry suppliers TSMC and UMC are both investing in new facilities and each announced aggressive plans for the future. TSMC completed construction of its second 200mm wafer fab in 1996 and is currently working on its third, both located in Hsinchu. Two of UMC's three 200mm joint venture wafer foundries, located in Hsinchu, are in production and its third will begin in early 1998. In the first part of 1997, TSMC and UMC separately announced aggressive fab plans, each planning to build one 200mm wafer fab and six 300mm wafer facilities in a new industrial park in Southern Taiwan. Other future fab plans were made by Mosel-Vitelic, who announced plans to build a 300mm DRAM facility, and Macronix, who announced plans to build three 300mm wafer production facilities.

| 1997 Rank | Company | 1997 (EST) | 1996 | 1997/1996 Percent Change |
|---|---|---|---|---|
| 1 | TSMC | 1,015 | 780 | 30 |
| 2 | Vanguard | 400 | 300 | 33 |
| 2 | Macronix | 400 | 250 | 60 |
| 2 | Powerchip | 400 | 500 | –20 |
| 3 | UMC | 350 | 700 | –50 |
| 3 | Winbond | 350 | 350 | — |
| 3 | Nan Ya | 350 | 600 | –42 |
| 4 | TI-Acer | 280 | 675 | –59 |
| 5 | Mosel-Vitelic | 200 | 210 | –5 |
| 6 | HMC | 55 | 50 | 10 |
| | Others | 800 | 530 | 51 |
| | Total | 4,600 | 4,945 | –7 |

Source: ICE 19549G

**Figure 2-32. Taiwanese Semiconductor-Related Capital Expenditures ($M)**

With all the new construction taking place over the past few years in Taiwan, it's no surprise that the Science Industrial Park in Hsinchu has reached its capacity. Responding to the need for more space, the Taiwanese government established a new industrial park in Tainan. This new industrial park in Southern Taiwan is said to have the capacity for about 50 wafer manufacturing facilities.

Other firms located in the Asia-Pacific region are also making heavy investments in semiconductor production. For example, Chartered Semiconductor of Singapore, a foundry-dedicated company, began construction of its third major plant. Chartered has plans to build three additional fabs by the end of 2000.

In the coming years, look for semiconductor expenditures in China to grow substantially as the country strives to become a significant semiconductor producer. New fabs are also sprouting up in countries like Malaysia and Thailand.

### Leading European Spenders

European semiconductor capital expenditures are estimated to have declined by only one percent in 1997, compared to a seven percent increase in 1996 (Figure 2-34). Spending by Europe's three largest semiconductor suppliers—SGS-Thomson, Philips, and Siemens—continues to increase as a percentage of total European semiconductor capital spending, representing 83 percent for 1997, up from 82 percent in 1996 and 78 percent in 1995.

| Company | Product Lines | Current Fabs/No. | Future Fabs/Production Date |
|---|---|---|---|
| Holtek | Controllers,<br>Consumer ICs | 5-in. (1) | 8-in./1998 |
| Hualon | SRAMs, Consumer ICs | 5-in. (1) | Delayed 8-in. fab |
| Macronix | Flash ICs, ROMs, EPROMs,<br>Telecom ICs | 6-in. (1) | 8-in./late 1997 |
| Mosel-Vitelic | DRAMs, SRAMs | 6-in. (1) | (See ProMos) |
| Nan Ya Technology | DRAMs | 8-in. (1) | Not Disclosed |
| Powerchip (Umax/Mitsubishi/<br>Kanematsu joint venture) | DRAMs | 8-in. (1) | Not Disclosed |
| ProMos Technologies<br>(Siemens/Mosel-Vitelic<br>joint venture) | DRAMs | None | 8-in./late 1997 |
| TSMC | Foundry | 6-in. (3)<br>8-in. (2) | 1 8-in./early 1998<br>1 8-in./1998 (WaferTech) |
| TI-Acer | DRAMs | 6-in. (1)<br>8-in. (1) | Delayed 8-in. |
| UMC | Foundry | 6-in. (1)<br>8-in. (2) | 2 8-in./1997 and 1998 |
| Vanguard | DRAMs | 8-in. (2) | Not Disclosed |
| Winbond | DRAMs, SRAMs, Telecom ICs,<br>Consumer ICs | 6-in. (2) | 1 8-in./delayed<br>1 8-in./1998 |
| WSMC<br>(Worldwide Semiconductor<br>Manufacturing) | Foundry | None | 8-in./1998 |

*Source: EBN/ICE* 22764A

**Figure 2-33. Taiwan Chip Makers' Fab Plans**

Spending by SGS-Thomson in 1997 is estimated to have increased over its 1996 level, placing it in the top spot. This is consistent with SGS-Thomson's plan to open one fab facility a year through 2000. Current fab activity includes moving its new Catania facility into volume production, constructing its fourth 200mm fab in Rousset, France, at the site of an existing 125mm wafer plant, and constructing a new submicron wafer fab in Singapore.

The majority of Siemens' spending in 1996 was for construction of a new $1.9 billion fab facility in Newcastle, United Kingdom, which came on line in the second half of 1997. Siemens is currently constructing a new fab at its joint venture company with Motorola, White Oak Semiconductor, in Richmond, Virginia. A large part of its 1997 spending will be for completing construction and equipping the facility for production, which is set to begin in early 1998.

| 1997 Rank | Company | 1997 (EST) | 1996 | 1997/1996 Percent Change |
|---|---|---|---|---|
| 1 | SGS-Thomson | 1,170 | 1,125 | 4 |
| 2 | Siemens | 1,160 | 1,300 | –11 |
| 3 | Philips | 620 | 510 | 22 |
| 4 | Newport Wafer-Fab | 150 | 200 | –25 |
| 5 | TEMIC | 110 | 113 | –3 |
| 6 | GEC Plessey | 60 | 60 | — |
| 7 | Ericsson | 50 | 45 | 11 |
| 8 | Alcatel Mietec | 40 | 37 | 8 |
| 9 | ITT Semiconductors | 35 | 40 | –13 |
| 10 | Thesys | 20 | 18 | 11 |
| | Others | 125 | 142 | –12 |
| | Total | 3,540 | 3,590 | –1 |

*Source: ICE* 12143U

**Figure 2-34. European Semiconductor-Related Capital Expenditures ($M)**

For 1997, spending by Philips will be used to increase capacity and upgrade process technologies at its existing facilities. Philips opened its largest fab facility in Nijmegen, The Netherlands, in early 1997. The new facility, named MOS4YOU (Yield Output Utilization), is processing 200mm wafers using 0.5µm process technology, with plans to switch to a 0.35µm process in 1998.

## Future Capacity Trends

About 17 new wafer fabrication facilities or major expansions where begun in 1997 compared to 40 in 1996. Of those, three where in North America, three in Japan, five in Europe, and six in other parts of the world (Figure 2-35).

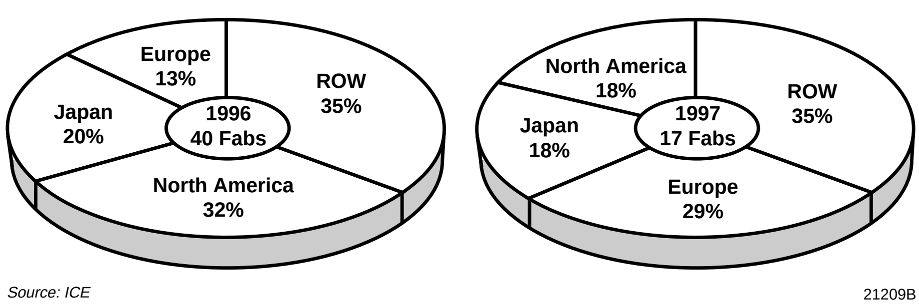



**Figure 2-35. New Fabs or Major Expansions Started in 1996 and 1997**

Figures 2-36 and 2-37 provide a look at the industry's capital expenditures as a percent of semiconductor production from 1979 to 1996, as well as an estimate for 1997. As shown, spending in 1996 as a percentage of production is estimated to have been at its highest level since the mid-1980s. The spending percentage for 1997 is estimated to have dropped as the result of an overcapacity situation beginning to fully impact IC manufacturers. However, it is still higher than 1995's percentage.

| Year | Worldwide Semiconductor Production ($B) | Worldwide Capital Spending ($B) | Capital Spending (Percent Of Production) |
|---|---|---|---|
| 1997 (EST) | 146.2 | 39.7 | 27.2 |
| 1996 | 135.6 | 42.8 | 31.6 |
| 1995 | 147.7 | 39.7 | 26.9 |
| 1994 | 104.6 | 22.8 | 21.8 |
| 1993 | 79.8 | 15.4 | 19.3 |
| 1992 | 62.3 | 11.4 | 18.3 |
| 1991 | 58.5 | 12.6 | 21.5 |
| 1990 | 57.5 | 12.0 | 20.9 |
| 1989 | 55.0 | 11.6 | 21.1 |
| 1988 | 50.5 | 9.4 | 18.6 |
| 1987 | 36.7 | 5.9 | 16.1 |
| 1986 | 29.6 | 4.8 | 16.2 |
| 1985 | 23.7 | 6.3 | 26.5 |
| 1984 | 28.1 | 7.7 | 27.4 |
| 1983 | 18.3 | 4.1 | 22.4 |
| 1982 | 14.4 | 2.8 | 19.4 |
| 1981 | 14.3 | 2.9 | 20.3 |
| 1980 | 13.8 | 2.6 | 18.8 |
| 1979 | 10.9 | 2.0 | 18.3 |

*Source: ICE* 14532S

**Figure 2-36. Trends in Semiconductor Capital Spending as a Percent of Production**

The 26 to 27 percent spending of 1984 through 1985 led to significant overcapacity while the 16 percent spending rate in 1986 and 1987 ultimately led to a capacity shortage in the late 1980s. ICE believes that it currently takes about a 20 to 21 percent spending rate to prevent severe undercapacity or overcapacity situations from occurring in the industry. 1997 marks the third year in which spending as a percent of production is above this estimated ideal spending level.

Overall, it appears that the majority of semiconductor companies' spending plans are reactions to market trends. Thus, when the market is booming, spending surges. However, when demand slows, most companies will put expansion plans on hold until business picks up.

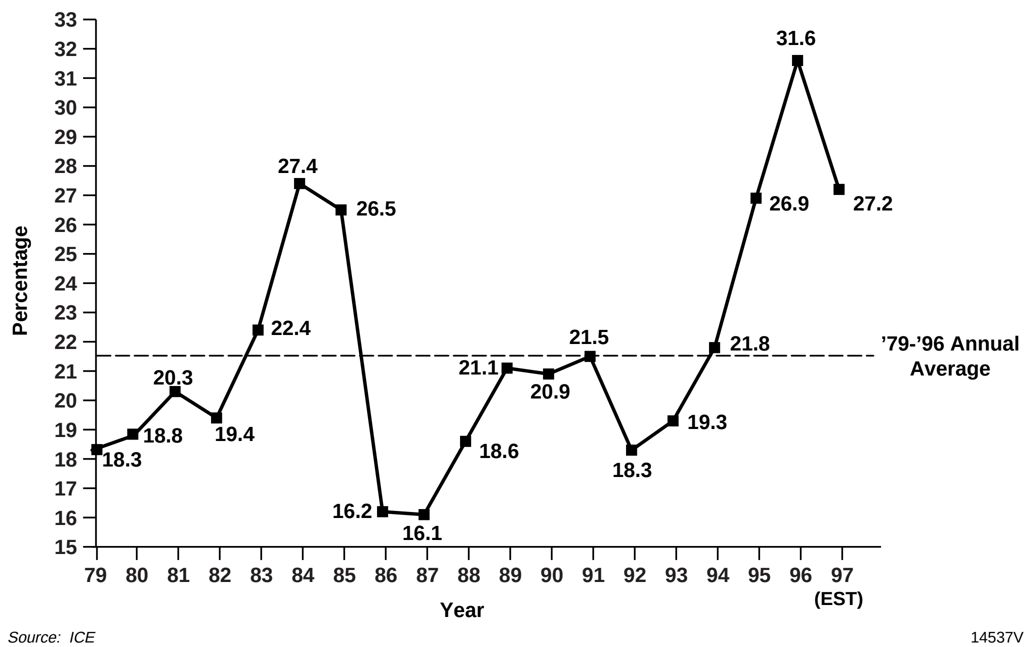



**Figure 2-37. Worldwide Capital Spending as a Percent of Worldwide Semiconductor Production (1979-1997)**

## STARTUPS

Over the past decade, some 150 or more semiconductor startup companies have been established, and despite the increasingly competitive nature of the semiconductor industry, startup companies continue to emerge. Development programs cost more, require more time, and are much more risky. As a result, many technology advances require the financial resources of huge semiconductor companies. Nevertheless, many innovations are still brought forth from small, entrepreneurial ventures.

Today, semiconductor startups in the U.S. rarely begin with a new fab. Looking back on the formative years of the semiconductor industry in the 1960s, most firms included funding for a production facility as part of the capital needed to initiate business. In most cases, a wafer fab was a mandatory part of being in the IC business. With few exceptions, this thought process continued throughout the 1970s and early 1980s. Figure 2-38 lists the few firms that have started operations with a fab in recent years. It should be noted that three of the companies in the figure, namely Cirent Semiconductor, GMT Microelectronics, and Mid-West Microelectronics, own fabs that were already in existence, but were significantly upgraded.

| Company | Location | Products | Processes | Start Up Date | Comments |
|---|---|---|---|---|---|
| Cirent Semiconductor | Orlando, FL | Logic ICs | CMOS | 1997 | The joint venture between Cirrus Logic and Lucent Technologies began manufacturing 200mm wafers in mid-1997. |
| Dominion Semiconductor | Manassas, VA | DRAMs | CMOS | 1997 | Joint venture between IBM and Toshiba. Former IBM fab that was shut down in 1992. |
| Extel Semiconductor | Livermore, CA | Foundry | CMOS, BiCMOS | 1997 | Purchased Intel's vacated Fab 3, which Extel will convert to a foundry by the end of 1997. Extel is upgrading the fab to process 150mm wafers, with an expected capacity of 4,000 wafers per week. |
| GMT Microelectronics | Valley Forge, PA | ASICs, foundry | CMOS, BiCMOS | 1996 | A group of investors led by GMT management purchased the facility formerly owned by Commodore. The operation offers 1-, 2-, and 3-micron double-level metal CMOS, 1-, 2-, and 3-micron BiCMOS, and active-matrix LCD process capabilities. |
| InterConnect Technology | Sunnyvale, CA | Foundry | CMOS | 1997 | Fab formerly owned by MicroUnity Systems. Upgrading to 200mm wafers. |
| Mid-West Microelectronics | Lee's Summit, MO | Foundry | CMOS | 1996 | Former AT&T fab. Mid-West Micro intends to upgrade the facility to make memory and microprocessor-related chips. |
| TwinStar Semiconductor | Richardson, TX | 16M and 64M DRAMs | CMOS | 1996 | A joint venture of Texas Instruments and Hitachi. The company produces DRAMs for the partners at a new $500 million, 200mm wafer plant in Texas. Initial production of 16M DRAMs began in the summer of 1996. |
| WaferTech | Camas, WA | Foundry | CMOS | 1998 | Joint venture between TSMC and Altera, Analog Devices, and ISSI. |
| White Oak Semiconductor | Richmond, VA | DRAMs | CMOS | 1998 | Joint venture between Motorola and Siemens. |

*Source: ICE* 20236E

**Figure 2-38. Recent and Upcoming North American Startups with Fabrication Facilities**

Over the years, production costs increased as process geometries shrank and the financial burden associated with fab ownership became too great for many startup companies. Thus, going the fabless route and using foundry capacity became the most common method for startup companies to get their products to market. The number of fabless companies in North America is estimated to be about 120. Figure 2-39 lists a number of fabless companies that have recently started operations in North America.

ICE is not aware of any new Japanese IC manufacturers that have started operations in the past couple of years. Most startups in Japan in the past were the result of the country’s large automobile, steel, and chemical manufacturers and other conglomerates seeking to diversify their businesses to include semiconductor production.

| Company | Location | Products | Processes | Start Up Date | Comments |
| --- | --- | --- | --- | --- | --- |
| Accelerix | Carp, Ontario, Canada | Graphics Accelerators | CMOS | 1996 | Accelerix is a spin off from Symbionics Ltd. |
| Centaur Technology | Austin, TX | MPUs | CMOS | 1995 | Centaur is a wholly-owned subsidiary of Integrated Device Technology and specializes in microprocessor design and development. |
| Enable Semiconductor | San Jose, CA | SRAMs | CMOS | 1995 | The privately-held company is designing products targeting the portable computer and wireless communications markets. |
| Lanstar Semiconductor | Arlington, TX | DRAMs | CMOS | 1995 | A wholly-owned subsidiary of Lanstar Computer Corp., Lanstar Semiconductor is initially operating as a fabless entity, but is seeking to purchase an existing foundry to expand its products to include SRAMs, VRAMs, and EPROMs. |
| Marvell Semiconductor | Cupertino, CA | PRML read-channel ICs | CMOS | 1995 | A wholly owned subsidiary of Marvell Technology Group. |
| Novalog | Costa Mesa, CA | Wireless infrared ICs, ASICs | — | 1995 | Founded as a wholly-owned subsidiary of Irvine Sensors Corporation, Novalog specializes in the design and development of analog and mixed-signal circuitry. |
| SiGe Microsystems | Nepean, Ontario, Canada | RF ICs | Bipolar, BiCMOS | 1996 | SiGe Microsystems is a supplier of SiGe-based bipolar and BiCMOS ICs for RF and high-speed digital applications. |
| Summit Microelectronics | Saratoga, CA | EEPROMs, Analog ICs | CMOS | 1996 | Summit's products are targeted at the telecommun-ications, consumer, and automotive markets. |
| Suni Imaging Microsystems | Mountain View, CA | CCDs and CMOS Imaging Devices | CCD, CMOS | 1995 | Suni's products are designed for use in consumer electronics applications as well as medical and scientific instrumentation. |

*Source: ICE* 12995AC

**Figure 2-39. Sampling of Recent North American Fabless Startups**

Figure 2-40 shows the only recent European startup that ICE has record of, Wesson France. It operates what was once an IBM-owned bipolar IC fab.

| Company | Location | Products | Process | Fab Start | Comments |
| --- | --- | --- | --- | --- | --- |
| Wesson France | Corbeil-Essones, France | Telecommunications devices | Bipolar | 1995 | The fab was purchased from IBM by Wesson France, a new company representing a group of Hong Kong investors. The plant will process 1.0-micron bipolar chips primarily for Asian telecom markets. |

*Source: ICE* 18545H

**Figure 2-40. Recent European Startups with Fabrication Facilities**

Recent startups in the Asia-Pacific region have been located primarily in Taiwan. Taiwan's semiconductor industry continues to pump large sums of money into its fab facilities. Figure 2-41 provides a sampling of recent IC startup firms in the Asia-Pacific region.

| Company | Location | Products | Processes | Fab Start | Comments |
|---|---|---|---|---|---|
| Advanced Semiconductor Manufacturing of Shanghai (ASMC) | Shanghai, China | Foundry | CMOS, BiCMOS | 1996 | Originally established by Philips in 1991, the fab was converted into a foundry operation jointly owned by Philips, Northern Telecom, and several Chinese parties. |
| Anam Industrial/Texas Instruments | Seoul, South Korea | DSPs, foundry | CMOS | 1997 | The joint venture fab is expected to begin production in 1997. The technology will be provided by TI. |
| Chartered Silicon Partners | Singapore | Foundry, ASICs | CMOS | 1999 | Joint venture between Chartered Semiconductor, Hewlett-Packard, and the government of Singapore. |
| Hexawave | Hsinchu, Taiwan | MMICs, Linear ICs | GaAs | 1994 | Taiwan's only GaAs IC manufacturer. |
| Hitachi-Nippon Steel Semiconductor | Singapore | DRAMs | CMOS | 1998 | Joint venture between Hitachi, Nippon Steel, and the government of Singapore. |
| Huahong Microelectronics | Shanghai, China | Foundry, EEPROMs, SRAMs, MCUs | CMOS | 1999 | NEC is a partner. |
| InterConnect Technology | Sarawak, Malaysia | Foundry | CMOS | 1999 | Malaysia's first major front-end wafer fabrication facility. |
| Mimos Berhad | Kuala Lumpar, Malaysia | R&D, ASICs | CMOS, BiCMOS | 1998 | A government funded company that will provide ICs for Malaysia's internal IC needs. Plans to open a manufacturing facility in late 1998. |
| Nanya Technology | Taipei, Taiwan | DRAMs | CMOS | 1996 | The Formosa Plastics subsidiary began processing 1,250 200mm wafers/week in July 1996 in a new fab. |
| Powerchip Semiconductor | Hsinchu, Taiwan | 16M and 64M DRAMs, logic ICs | CMOS | 1996 | Joint venture between Mitsubishi and Taiwan's UMAX group, a scanner maker that took over Elitegroup, Taiwan's second largest motherboard manufacturer. Mass production of 200mm wafers began in 4Q96. Full capacity is expected to reach 5,000 wafers/week. |
| ProMos Technologies | Hsinchu, Taiwan | DRAMs | CMOS | 1997 | A joint venture between Mosel Vitelic and Siemens AG. Initial production will begin with 64M DRAMs and move to 256M in the future. |
| Submicron Technology | Bangkok, Thailand | Foundry | CMOS, BiCMOS | 1998 | Alphatec, traditionally a contract chip assembler, is building an $800 million wafer fab in Bangkok. Plans call for 6,000 200mm wafers per week capacity. |
| United Semiconductor | Hsinchu, Taiwan | Memories, graphics chips, foundry | CMOS | 1996 | Located at UMC's manufacturing complex, this company is jointly owned by UMC (50%), Alliance Semiconductor (20%), S3 Inc. (20%), and local investors (10%). |
| Vanguard International Semiconductor (VISC) | Hsinchu, Taiwan | 4M and 16M DRAMs | CMOS | 1994 | Purchased from the Taiwanese government by a consortium of companies including TSMC and Winbond. The consortium planned to build a second fab, at a total cost of $1-1.45 billion |
| Worldwide Semiconductor Manufacturing | Hsinchu, Taiwan | Foundry | CMOS | 1998 | Building a 200mm wafer fab with a production capacity of 3,750 wafers per week. Production will begin by mid-1998. |

*Source: ICE* 18544L

**Figure 2-41. Recent and Upcoming Asia-Pacific Startups with Fabrication Facilities**

## Spin-Offs

Not all startup companies develop from scratch. A recent trend has been for large, established companies to spin-off certain groups or divisions into new, autonomous companies (Figure 2-42). The result is a company who can specialize in a certain product area and focus all its resources and support on that one area. One recent example is AMD, which spun off its PLD business.

Pure foundry company, UMC, has also used this practice. By spinning off all its standard IC product groups into separate companies, UMC is now able to focus its efforts on its foundry business, while its standard IC subsidiaries focus on their respective product offerings.

| Subsidiary | Location | Products | Parent Company |
|---|---|---|---|
| Amic | Sunnyvale, CA | Memory ICs | UMC |
| Davicom Semiconductor | San Jose, CA | Communications ICs | UMC |
| Fairchild Semiconductor | San Jose, CA | Logic and Memory ICs; Discretes | National Semiconductor |
| HolonTech | San Jose, CA | Network Computing Software and Components | NEC |
| Integrated Technology Express | Milpitas, CA | PC Chipsets | UMC |
| Mediatek | Hsinchu, Taiwan | Multimedia ICs | UMC |
| Novatek | Hsinchu, Taiwan | Consumer ICs | UMC |
| Vantis | Sunnyvale, CA | PLDs | AMD |
| VSIS | San Jose, CA | Multimedia ICs | Mitsubishi |

*Source: ICE* 21723B

**Figure 2-42. Sampling of Recent Semiconductor Manufacturing Spin-Offs**

National Semiconductor also recently spun off a product division into a separate identity. Fairchild Semiconductor was established (actually, reestablished) in 1996 when National broke off its general-purpose logic and memory IC business, along with its discrete operation.

## SEMICONDUCTOR CONSORTIA

Increasingly, survival in the fast-paced semiconductor industry is dependent not only on how well a company competes, but also on how well it creates new technologies to maintain its competitive edge. Some of the technological prowess, whether in design or in manufacturing, originates in the facilities of consortia around the world who, in turn, pass along their findings to member companies, regional companies, or to the industry in general.

Provided below is an overview of activities and highlights at several semiconductor consortia around the world.

### North American Consortia

#### Sematech

Sematech was established in 1987 to improve U.S. competitiveness in the semiconductor industry. Sematech (Semiconductor Manufacturing Technology Consortium, Inc.) now consists of 10 major U.S. semiconductor manufacturers: AMD, Digital Equipment, Hewlett-Packard, IBM, Intel, Lucent Technologies, Motorola, National, Rockwell, and Texas Instruments. Up through 1996, the Department of Defense was also a member and provided the majority of its funding. Annual funding of Sematech by the U.S. government continued declining from a high point in 1992, dramatically affecting the consortium's annual budget (Figure 2-43). In 1994, the decision was made to phase out government funding by 1996. In 1997 Sematech's budget was entirely funded by private financing and contributions from member companies.

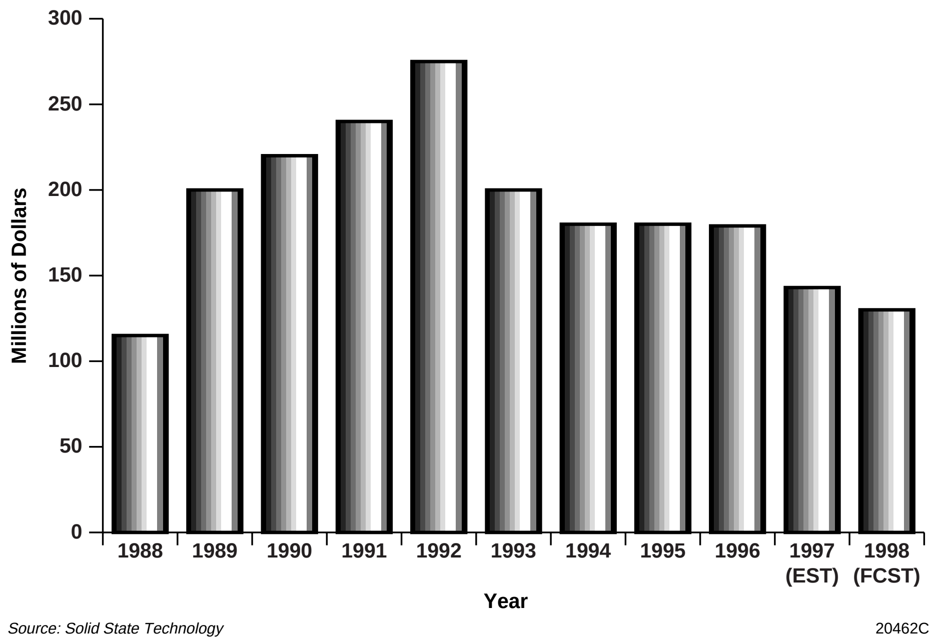



**Figure 2-43. Sematech's Budget**

Sematech expanded its membership in an effort to promote participation from non-U.S.-owned companies. With the end of U.S. government funding, it is more feasible for international companies to join. However, full membership in Sematech from a non-U.S. company has yet to take place.

There have been many successes at Sematech including increased equipment reliability, improved software, and the development of standards for equipment safety, cleanliness, and integration. Its wafer fabrication facility has become a lab for advancing new technology. Also among Sematech's successes is its involvement in the development of the periodically published Semiconductor Industry Association (SIA) National Technology Roadmap for Semiconductors, which serves as a blueprint for many semiconductor technology developments.

Listed below are some of the key events at Sematech from 1997:

- Sold its minority stake in San Jose-based equipment company, Silicon Valley Group, earning a profit of $6.7 million.

- Named Dr. Mark Melliar-Smith as president and Chief Operating Officer, effective January 1, 1997. Smith was previously CTO with Lucent Technologies. Beginning in 1998, Smith will take over as CEO. Current president, CEO and chairman, William Spencer, retired from the positions of president and CEO at the end 1997.

**International 300mm Wafer Initiative (I300I)**

I300I was formed in 1995 by Sematech to develop 300mm wafer fabrication technologies. Participation in I300I is open to U.S. and foreign companies with wafer fabs located in the United States. Activities in 1997 continued to focus on standards requirements, silicon supply, performance metrics, demonstration methods, and 300mm wafer process support. The organization plans to begin 300mm pilot equipment demonstrations as well as begin defining requirements for 0.18µm manufacturing technology in 1998.

I300I has 13 industry members: AMD, Lucent Technologies, IBM, Intel, Motorola, and Texas Instruments from the U.S.; Siemens, SGS-Thomson, and Philips from Europe; Hyundai, LG Semicon, and Samsung from Korea; and TSMC from Taiwan.

**Semiconductor Research Corporation (SRC)**

The SRC was formed in 1982 by the Semiconductor Industry Association to strengthen and maintain the vitality of the North American semiconductor industry. It is a non-profit organization that plans and implements an integrated program of basic research conducted by faculty and graduate students at leading universities in the U.S. and Canada.

More than 60 companies fund research in five major areas: manufacturing systems, manufacturing processes, design, microstructure, and packaging. Research at SRC accounts for more than half of all silicon-related research conducted at U.S. universities.

**The Fabless Semiconductor Association (FSA)**

A group of 40 companies formed the Fabless Semiconductor Association late in 1994. The group cooperates with IC producers that have fabs on forecasting capacity and process technology trends.

It is not surprising that IC foundry companies like TSMC and Chartered Semiconductor are working with FSA. With fabless IC companies representing an increasing share of total IC sales in North America each year, the creation of the FSA seemed appropriate.

**Virtual Socket Interface (VSI)**

The VSI alliance was formed in 1996 to develop technology and standards for systems-on-a-chip, as well as focus on developing standards that will provide a simple, cost-effective way to mix and match intellectual property (IP) blocks from multiple sources. The alliance is made up of EDA, semiconductor, systems, and IP manufacturers. The alliance has over 80 members who are divided into six working groups—system level design, implementation verification, manufactured-reacted test, on-chip buses, IP security and encryption, and mixed-signal design standards. Though it is encouraged, companies are not required to contribute their IP.

**Strategic Microelectronics Consortium (SMC)**

Canada's SMC is seeking to help the nation's semiconductor industry achieve its objective of $1 billion in sales by 2000. The consortium is funded 50 percent by its members and 50 percent by the Canadian government. Several key projects have included the development of image resizing DSPs, the achievement of very low power signal generation and clock recovery at data rates exceeding two gigabytes per second, and work in asynchronous transfer mode, radio frequency, and ferroelectric structure technologies.

**SyncLink**

SyncLink is a consortium made up of thirteen companies including 12 of the top DRAM suppliers. The focus of the group is to work together to develop an open, royalty-free industry standard for high-performance DRAMs. The SyncLink standard is a step beyond synchronous DRAMs (SDRAMs). SyncLink ICs, called SLDRAMs, will be targeted at applications in the main memory of personal computers and workstations. The first SLDRAMs were expected in late 1997.

Current members of SyncLink include Apple Computer, Fujitsu Microelectronics, Hewlett-Packard, Hitachi, Hyundai Electronics, IBM Microelectronics, IBM, Micron Technology, Mitsubishi Electronic America, MOSAID Technologies, NEC, Nippon Steel Semiconductor, Oki, Samsung Electronics, Siemens, Texas Instruments, and Toshiba

**Japanese Consortia**

**Semiconductor Industry Research Institute Japan (SIRIJ)**

SIRIJ, based in Tokyo, was established in 1994 by ten leading Japanese semiconductor makers: Fujitsu, Hitachi, Matsushita, Mitsubishi, NEC, Oki, Sanyo, Sharp, Sony, and Toshiba. In late 1996, Texas Instruments Japan, Nippon Motorola, and Rohm joined SIRIJ. The institute serves as an independent organization, maintaining cooperative relations with the semiconductor industry, the government, and academia. It focuses on research concerning the development and promotion of semiconductor technology, world environment problems, international cooperation, and technology exchange.

**Association of Super-Advanced Electronics Technology (ASET)**

The ASET project is a long-term, government-funded project to develop the basic technologies required for future process generations. The organization will receive a total of about $300 million in government funding over the next five years, which it plans to use for semiconductor, magnetic storage, and display IC research.

ASET has already received its first year budget of $100 million, of which it plans to spend $78 million on semiconductors, $20 million on magnetic storage research and development, $1 million on display IC R&D, and $1 million for facility and administration costs.

Advanced lithography, including 193nm optical and synchrotron-based x-ray, will be ASET's main focus.

ASET has 21 member companies including all the top Japanese semiconductor manufacturers and the Japanese subsidiaries of Texas Instruments, IBM, and Merck.

**Semiconductor Leading Edge Technologies (SELETE)**

SELETE consists of Japan's ten largest semiconductor companies and is expected to receive $350 million between 1996 and 2000. The research projects for SELETE are focused on 300mm wafer equipment, CIM software, factory design, and issues related to deep-submicron process development. SELETE currently operates a laboratory in Yokohama, within an existing Hitachi cleanroom. The fab facility began pilot production in mid-1997. In early 1997, participation in SELETE was extended to include international companies; however, to date no international companies have joined.

**Super Silicon Crystal Research Institute (SSi)**

SSi is a newly established consortium made up of seven Japanese materials suppliers and a Japanese government agency. The organization was formed to explore silicon materials technology, specifically examining key technologies for production of 400mm silicon crystal growth and 400mm wafer production. A second focus for the organization is to examine the technical uncertainties of large wafer development.

## European Consortia

### Intra-University Microelectronics Center (IMEC)

IMEC, a consortium based in Belgium, has become one of the most influential research organizations in the region and is committed to the design, production, and testing of ICs. It is a major contributor to both Europe's ESPRIT and MEDEA projects.

Major research projects for IMEC include the development of 0.25µm and 0.18µm CMOS technologies, the development of VLSI methodologies for real-time data processing, and the development of new ASIC design tools for use in commercial products.

Other projects underway focus on such technologies as ultraclean processing, silicides and interconnects, software development, compound semiconductor processing, materials processes, packaging, and microsystems.

### Micro-Electronics Development for European Applications (MEDEA)

A follow-on to Europe's JESSI project, which ended in 1996, MEDEA is a collaborative industrial R&D program targeting two basic fields—IC technology and systems-on-a-chip (Figure 2-44). The members of MEDEA will focus on two core competencies: applications and semiconductors.

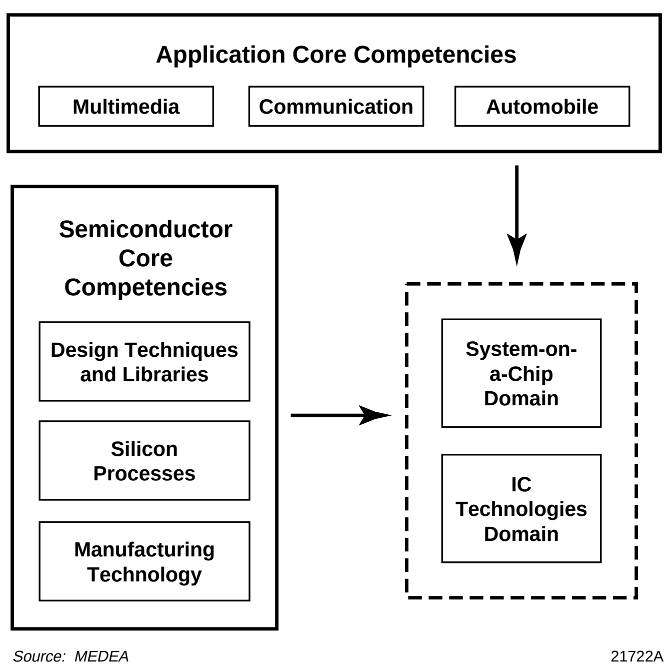


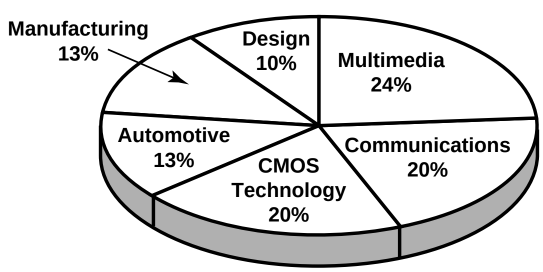

**Figure 2-44. MEDEA Consortium Domains**

In the semiconductor core area, MEDEA will focus on three areas—design technologies and libraries, silicon processes, and 0.25µm and 0.18µm manufacturing technologies.

In the second area of focus, application-related development, MEDEA will support application-specific product developments in three areas—multimedia, communications, and automotive electronics. MEDEA's application-specific ICs will not be exclusively ASICs, as its application-specific area is focused on standard products as well.

MEDEA is made up of a limited number of participants who are required to submit their proposals for approval, and are selected for their ability to contribute significantly to the strategic and technical goals of MEDEA. European IC makers will provide basic technology platforms and specific contributions relating to IC technology equipment, and design will be contributed by other companies.

The program began January 1997 and will continue through December 2000. The total cost of MEDEA is estimated to be about two billion European Currency Units (ECUs). MEDEA will receive half of its funding from participating companies and the rest from the EU and national governments. Figure 2-45 shows the distribution of funding into the six core areas, and Figure 2-46 shows a timeline for MEDEA's development goals.




Source: MEDEA 21721

**Figure 2-45. Distribution of MEDEA Funding (2000 MECUs)**

| Milestone | Year |
|---|---|
| Successful beta-testing for selected 300mm equipment in 0.25µm technology | 1997 |
| Successful beta-testing for selected 300mm equipment in 0.18µm technology | 1999 |
| CMOS basic logic processes such as 0.25µm 3.3-1.8V available | 1999 |
| Commercial delivery of 0.25µm CMOS on a chip with high density logic and memory | 1999 |
| Test chip for 0.18µm logic on an industrial line | 2000 |

Source: European Semiconductor 21720A

**Figure 2-46. Planned MEDEA Consortium Milestones**

**Open Microprocessor Systems Initiative (OMI)**

OMI was launched in 1992 as part of the European Union's ESPRIT program. OMI membership is open to all organizations carrying out R&D in Europe, including foreign companies with R&D facilities in Europe. Motorola, IBM, Apple Computer, and Sun Microsystems are among the non-European members of OMI. The list of European members includes Advanced RISC Machines (ARM), SGS-Thomson, GEC Plessey, University of Edinburgh, Matra Hachette Multimedia Systems (France), Gemplus (France), Syndesis (Greece), Etnoteam (Italy), and IMEC (Belgium). In all, there are more than 400 companies, universities, and research establishments working on more than 40 projects under OMI.

OMI's original mission was to challenge U.S. dominance of the European microprocessor market by providing European manufacturers easy access to current and future generations of microsystems architecture. This would be accomplished not by developing new microprocessor technology, but by forming a technical bridge between European and non-European technologies.

**Sub-Half Micron Process for European Users (SHAPE)**

SHAPE is made up of seven European companies including Austria Mikro Systeme International, SGS-Thomson, GEC-Plessey, Matra MHS, Alcatel Mietec, Philips Semiconductors, and Siemens. The focus of the group is to develop mixed analog-digital high density ICs using 0.35µm process technology.

**ROW Consortia**

**Taiwan Semiconductor Industry Association (TSIA)**

TSIA is made up of 57 member companies who have joined together to boost Taiwan's competitiveness within the semiconductor market. Several key areas TSIA plans to focus on include trade, intellectual property, and research and development of 300mm wafer technology.

**Taiwan Submicron Consortium**

The Taiwan Submicron Consortium operates under the leadership of Taiwan's Electronics Research and Service Organization (ERSO) and the Industrial Technology Research Institute (ITRI) and is supported by both the local semiconductor industry and the Taiwanese government.

The consortium's Submicron Process Technology Development Project was instituted in 1990 with the goal of establishing Taiwan as a major force in the global semiconductor and electronics industries. This project played a major role in developing the country's first 200mm wafer fab and achieving 0.7µm process technology, which was transferred to UMC and TSMC. The consortium also developed 0.5µm 16M DRAM and 4M SRAM technologies, which were provided to local IC manufacturers in 1996.

Early in 1994, ERSO began searching for investors to spin off its R&D fab facility, including process technology and research personnel. In July 1994, it was announced that the 200mm wafer fab would be acquired by a 10-member consortium, led by TSMC. The consortium turned the fab operation into an independent commercial DRAM company—Vanguard International Semiconductor (VISC).

In 1995, the Taiwan Submicron Consortium started a new program called the DEEP Submicron Joint Development Project, which is geared at uniting local IC manufacturers, research organizations, and equipment suppliers to develop 0.25µm process technology. Future research efforts directed by ERSO include the development of 0.18µm processes.

**Korean Cooperation**

Although no details are publicly available, it is believed that the Korean semiconductor industry is receiving substantial indirect financial support from the Korean government. Rather than supporting its industry through the medium of joint cooperative R&D, the Korean government has expressed its commitment to the IC industry by making capital investments in wafer fabrication facilities.