India's Semiconductor Failure Why Can't India Fabricate Any of the Chips They lay out?

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ABSTRACT
India is a semiconductor design powerhouse. Nearly every major semiconductor company has a presence in India, designing some of the most advanced chips in the world. But once those designs are completed, they are sent to the United States, China, South Korea or Taiwan to fabricate. It begs the question. Why can't India fabricate any of the chips they lay out? In the 1980s, the India government attempted to follow China, Taiwan, Malaysia, Korea and Singapore in creating their own semiconductor manufacturing national champion. Things got off to a promising start, but then disaster struck. And the company along with India's entire semiconductor manufacturing industry hasn't recovered since. This paper examines the origin, progress and reasons of decadence for Indian government's biggest Semiconductor Complex Limited (SCL), the national champion that failed.

Keywords- SCL, Semiconductor lab, Fairchild, American Microsystems ltd, Acorn computers, TSMC, Fab city, Towerjazz

I BACKGROUND

(a) Foundation of SCL - Many of East Asia's semiconductor industries can trace their roots to western electronics companies relocating certain outsourced factories there in the 1960s. In the mid 1960s, Fairchild Semiconductor seriously considered putting a factory in India. But the famously formidable Indian bureaucracy scared them off and they eventually opted for Malaysia and the Philippines. As the pace of technology quickened in the 1970s and 80s, the Indian government identified microprocessors and other semiconductors as the potential foundation for a new revolution. They decided that they had to have their own horse in the race.

Thus in 1984, the Indian government founded the integrated device manufacturing, Semiconductor Complex Limited (SCL), a 100% state owned enterprise. SCL's goal was to eventually design and manufacture leading edge circuits and electronics. Their vision was that the company could be the foundation for a naive Indian electronics industry. The government invested somewhere in the neighbourhood of $40-70 million USD into the venture, quite a lot of money at the time. The company was headquartered in the planned city of Mohali in the state of Punjab. At the time, the Punjab economy was mostly agriculture based. **(Table 1)**

Table 1
Sectoral Distribution of Punjab during 1966-67 to 1984-85

Sector	1966-67	1973-74	1977-78	1984-85
Agriculture and livestock	52.85	52.57	50.30	50.28
Agriculture	40.91	36.66	34.85	34.54
Livestock	10.71	15.90	15.45	15.74
Forestry and logging	0.38	0.81	0.80	0.33
Fishing	0.04	0.03	0.03	0.03
Mining and quarrying	0.01	0.01	0.01	0.01
Manufacturing	7.86	9.36	10.67	13.4
Electricity, gas and water supply	0.71	1.00	0.96	1.39
Construction	3.5	7.94	8.38	4.36
Trade, hotels and restaurants	10.96	12.15	13.75	13.36
Transport, storage and communication	1.45	1.89	1.88	2.16
Banking and Insurance	1.43	1.84	1.98	3.21

Real estate, ownership of dwellings and business services	5.78	4.53	3.69	3.73
Public administration	1.52	1.79	1.63	2.55
Other services and sanitary services	6.13	6.07	5.92	5.19

Source: Various issues of Statistical Abstracts, Punjab

But the area was up and coming. It was emerging as an electronics industry centre, with major units like Punjab Wireless Systems and Punjab Communications Limited based there. To fill the ranks, SCL hired young graduates from top technical universities like the Indian Institute of Technology and the Indian Institute of Science in Bangalore. These universities have strong links to the West, and have trained a very strong pool of skilled engineering talents to draw from. The IIT Bombay School in particular, has long had a very good electrical engineering course. They were also able to recruit from esteemed Indian electronics companies like Bharat Electronics Limited, the Indian state owned aerospace and defence Electronics Company.

(b) Building a Semiconductor Factory : Critical Factors - There are a lot of factors that go into creating successful, high performing semiconductor factory; these factors can be summarized majorly into four categories:

(i) Financial Capital
(ii) Human Capital
(iii) Government and Infrastructure
(iv) Manufacturing technology

(i) Financial Capital - First requirement for setting up a semiconductor factory is the need to have the money. A lot of it, so to pay for extremely expensive chip manufacturing equipment, notably in the photolithography space, and chip testing equipment. All of that stuff has to be constantly upgraded and maintained as it is used. That also costs money. In India's case, all of these have to be imported from places like Europe or Japan. Import duties and documents have to be addressed and streamlined.

(ii) Human Capital - After setting up a factory the second imperative requirement is smart, well educated people who run the fab[1]. Skilled labour who can quickly gain familiarity with the expensive equipment and how to use it. Specific requirements include Research Scholars, subjective experts and scientists doing R&D to learn new processes and push the company forward.

(iii) Government & Infrastructure - The fab need to have substantial, near 100% government buy-in as well as stable power and water supply. There are also environmental concerns – the manufacturing process is quite toxic. The government buy in was there, but the infrastructure wasn't. A single power outage or water shortage would've ruin months of hard work.

(iv) Manufacturing Technology - "Don't reinvent the wheel". In a technological fast changing world, to quickly catch up with the rest of the industry, no need to reinvent. All it takes is to acquire older process node technology. SCL wanted to strike a technology transfer deal with advanced company and to get the company to teach SCL how to do it and hopefully before long the student can become the master. World class semiconductor companies know this and so they very closely guard their technology process nodes and trade secrets. Technology transfer agreements are almost always for older processes and never for the leading edge stuff.

(c) SCL climbs the ladder - SCL wanted to be a leading semiconductor manufacturing. The playbook for doing so was well established. They had financial, capital; smart people and government buy in. Now was acquiring the older technology.

At SCL's founding in 1984, they were able to license a 5-micron process technology from American Microsystems Inc. (AMI). AMI was nothing like Intel or Motorola, but it was a Start-up. Shortly thereafter, SCL was able to acquire process technology from two other companies as part of a deal to manufacture electronic components for them. The first deal was with the American Industrial automation company Rockwell, for the purpose of making their 2560G microprocessor.

The second deal was with the Japanese firm Hitachi for the purpose of producing components for their electronic wrist watch. The company also performed third party assembly duties for electronic brands. Notable, they assembled Acorn computer (SCL Unicorn Microcomputer) for the Indian government's computer literacy and studies in the schools program.

[1]A semiconductor fab (short for fabrication plant) is a manufacturing facility where microchips are made. But it's actually the most breath-taking coordinated production imaginable—with thousands of process machines running plasmas, lasers, ultra-precision optics, ion accelerators, and advanced robotics—all synchronized to crank out hundreds of thousands of wafers, each containing hundreds, even thousands, of chips.

These technology transfer agreements allowed SCL personnel to travel to the US and Japan for in-person training and learning. SCL quickly disseminated this info to the rest of the company. They augmented this trade knowledge with university academic partnerships. Using these resources, the company advanced very quickly from the 5 micron process technology down to a 0.8 micron process in the late 1980s. 0.8 microns, or 800 nanometres, was first achieved in 1987 by leading companies like NTT, Toshiba and Intel. So, at this point, SCL was one semiconductor generation behind the leading edge.

It seemed possible that India could achieve its goal of being a global semiconductor manufacturer within a decade.

(d) Lost progress - Those hopes ended in 1989, when a devastating fire broke out at SCL. The cause of the fire remains unknown. A few sources have claimed, without evidence, that it was arson. Which seems to make sense since SCL was making processors for the military at the time. But semiconductor fires are not rare. From 1986 to 1995, insurance records show that fires are one of the most common causes of operational losses in the industry. Many of these chemicals are flammable. Most likely the incident was an honest incident. Regardless of the cause, the fire was a devastating setback for India's semiconductor manufacturing efforts. Fires are so devastating because the burning chemicals are toxic and release corrosive gases. The fire triggers the water sprinkler system, causing even more damage.

It would take until 1997 – 8 years and substantial financial investment well north of $50 million before production finally restarted. By then, new entrants like TSMC (which was founded in 1987) and Samsung had entered the race. And they quickly raced ahead of the rest of the world capturing critical global market share and scale. India lost untold amounts of progress. The government subsequently lurched through failed proposal after failed proposal in order to try to make up for lost ground. They wanted to sell the fab but potential private investors could not come to an agreement with the Indian government on terms. They then retooled the fab from making chips for telephone exchanges to making chips for smart cards. This didn't really take either. Then finally in 2005, the company was restructured as an R&D centre within the Department of Space. SCL would be renamed to mean "Semiconductor Lab".

This finally ended SCL's chances at being a competitive commercial entity. But the company had long been out of the race. Much of its revenue came from government contracts. SCL's offerings were not even competitive in the domestic Indian market, let alone abroad. But even with the government as a captive customer, the company could not turn an attractive profit. There were no economies of scale. In the 2005-2006 financial periods, the company produced 1,000 6-inch wafers, but had 20x the installed capacity. In 1999-2000, SCL made $14 million in revenue and just $400,000 in profit. In 2005-2006, its final year as a company, SCL made $3.5 million in revenue and turned a loss of $2 million USD. The year before, the company turned a stunning $5.6 million USD loss. Its restructuring was a kind mercy.

(e) SCL Today - Today, SCL mostly does R&D work with its old 6 inch wafer fab. Recently in 2019, they announced that they are able to accept chip designs at the 180nm node. This is nowhere near the leading edge. But of course, there are plenty of viable commercial cases for fabbing semiconductors at higher nodes. Skywater Technologies, a publicly traded American foundry runs a 130 nm node. The more critical issue has to do with extremely sluggish development. It tool SCL nearly a decade to reach that 10 nm node. They have been working on it since at least 2011, when they paid millions to Israel's Tower Jazz Semiconductor for a fabrication unit.

II THE INDIA CHALLENGE TODAY

SCL in the early 1980s had the advantage in that everyone else in the rest of the world was not too far ahead of them. Taiwan and China had yet to move into semiconductors and the equipment back then was a lot cheaper. But even back before the fire in 1989, SCL was starting to experience the financial strain of competing in the semiconductor business. The costs of going to 800 nanometres had forced them to drop the BBC Acorn Computer project. Talented SCL personnel were constantly leaving for better jobs in the private sector or abroad. For India, the sheer amount of capital needed to build competitive productive fabs has been cited as the single most significant obstacle in establishing a viable semiconductor manufacturing industry. Today's leading edge chip factories regularly run up the tens of billions of dollars. This trend really started to ramp up at the 14 nm node generation, and it is only getting worse. Even for the biggest private India entities – companies like Tata, Reliance and such this is hard to swallow. Reliance Jio initially spent $ 15 billion USD on their nationwide LTE data network over the span of four years. TSMC will spend $ 20 billion on just one Gigafab over two years and right now they are building three. All that investment has to pay for itself and in the volatile electronics world, that is not always a given.

III ATTEMPTS AT REVIVAL

Regardless, the Indian government has since attempted to revive the country's semiconductor manufacturing efforts. All of these efforts have failed. For instance in 2006, when the country announced a $ 3 billion "Fab City" project for manufacturing. AMD had been interested in putting an assembly and test facility there until bad industry conditions shut it down. In 2013, the Indian government lifted customs duties on all imports of parts and machinery related to semiconductor manufacturing. But this did not seem to have helped to jumpstart any foundry efforts. In 2014, India approved a proposal from two investor groups to build fabs in India. Both projects together would cost about $ 10 billion USD. The government would have provided ample financial support upto 25% of the total cost in interest free loans, tax breaks and subsidies. The first consortium had some notable names – Jaiprakash or JP Associates Ltd, Israel's TowerJazz and IBM. JP Associates is a large Indian conglomerate in the construction, power and real estate businesses. But in 2016, JP and its group pulled out of the project. The firm had a lot of debt and said that a semiconductor plant was not commercially viable at the moment. The second consortia were lead by a company called Hindustan Semiconductor Manufacturing Corporation or HSMC. The investor consortium had tapped chipmaking expertise from European chipmakers ST Microelectronics and Malaysian State-operator Silterra. The second team also did not pan out. In 2019, the government cancelled HSMC's 2 year old letter of intent. The consortium had to submit documents for demonstration of commitment, but failed to do so. An interesting coincidence. A year later, another semiconductor company named HSMC, this time standing for Hongxin Semiconductor Manufacturing Company, raised millions to start a fab in the Chinese city of Wuhan. A similar lack of execution in addition to a pandemic ended up trashing that too. Since then no serious Indian proposal had emerged and that is despite the current market conditions.

IV CONCLUSION

India retains world class chip design capabilities. Tens of thousands of Indian engineers work directly in VLSI design and their chips are taped out in leading edge fabs around the world. Virtually all of the world's biggest fables chip companies have an Indian presence. Since the mid-1980s, the design and manufacture of chips have split apart. It is no longer necessary to do both at the same time. And increasingly few companies and economies are capable of doing so anyway. So India's powerful advantages in design should be commended. With that being said, SCL's failure to stand on its own as a commercial entity has had long term consequences. Today, India lacks substantial semiconductor fabrication capacity. In fact, there is hardly any semiconductor fabrication capacity at all. 100% of India's chips, logic, memory all of it have to be imported from abroad. In 2019, India imported $ 21 billion worth of semiconductors according to the India Electronics and Semiconductor Association. This number is growing at about 15% per year. In 2020, the country fell prey to the worldwide semiconductor shortage, disrupting a variety of critical India businesses. For instance, India is the world's second largest smartphone maker. That lucrative industry grinds to a halt when the right chips are not available. Furthermore, a significant portion of these imports (37% in 2019 or 7 billion USD) come from China. This has critical geopolitical repercussions. Sino-Indian relations today are tense and further disruptions may come about.

To conclude, there is no shortage of ideas and human talent for possible approaches to bring semiconductor manufacturing back to Indian shores. But there must be consistent, long-term direction from the very top and fountains of money committed to that direction. For India, the market has long passed the phase when a private entity can seed a thriving semiconductor manufacturing industry without outside help. The government has to do more to catch up.

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