Science Diplomacy Case Studies

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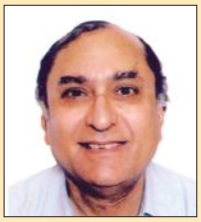
Building Capacity in Electronics Sector and Science Diplomacy

A Case Study of Semiconductor Complex Ltd (SCL)

ASHOK PARTHASARATHI

Forum for Indian Science Diplomacy

ABOUT THE AUTHOR



Professor Ashok Parthasarathi was a physicist, electronics engineer, S&T policy researcher and S&T policy maker. He held important positions in the Government of India – former Secretary in the Department of Scientific and Industrial Research, the Department of Electronics and the Ministry of New and Renewable Energy. He was, for almost a decade, S&T Adviser to late Prime Minister Mrs. Indira Gandhi. He steered and helped in building 14 public sector companies in electronics making hi-tech electronic products ranging from microchips to optic fibre and satellite-based communication systems. Professor Parthasarathi's contribution to the development of the defence electronics sector has been monumental as has been his contribution to solar electric systems. His seminal work to build up the Centre for Studies in Science Policy at the Jawaharlal Nehru University, New Delhi – the only such centre in South Asia – was path breaking in strengthening teaching and research capacity in the country in this key area. He also played important role in promoting technology development among developing countries.

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Core IV-B, Fourth Floor, India Habitat Centre,
Lodhi Road, New Delhi-110 003, India
Ph.: +91-11-24682177-80, Fax: +91-11-24682173-74
E-mail: dgoffice@ris.org.in
Website: www.ris.org.in

CASE STUDY

Building Capacity in Electronics Sector and Science Diplomacy

A Case Study of Semiconductor Complex Ltd (SCL)

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FISD
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The Initial Steps

In the early 1970s, the Department of Electronics (DOE) realised that the Electronics of the 1980s would be highly intensive in Large Scale Integrated circuits (LSIs) popularly known as "micro chips ". Some R&D on such LSI circuits had been done in both the Tata Institute of Fundamental Research's Solid State Electronics Group, led by Professor K. V. Ramanathan and by a corresponding group in the Central Electronics Engineering Research Institute of CSIR at Pilani, Rajasthan led by Mr. Shankar Kumar. However, both these capabilities were only at laboratory scale.

So, the DoE sent a high level Technical Team comprising of Prof. K. V. Ramanathan, and Mr. G. Soni from the DoE, to visit Japan, the USA and Western Europe to meet leading semiconductor companies, hold discussions with their top managements and see if a techno-commercially viable technology transfer could be worked out. However, nothing came out of their visit. In January 1980 the need for acquiring state of the art microchip technology was discussed with the then Prime Minister, Smt. Indira Gandhi. She understood the need and approved visits of a team to USA, Japan and Europe for negotiating a deal with microchip companies. She also approved an incentivization scheme to attract six or seven, Indian origin experts in this field from abroad. Based on these approvals, the then Managing Director of Punjab Semiconductors Ltd (PSL MD), Mr. Virendra Mohan and Prof. K.V. Ramanathan of TIFR started doing detailed home-work and analysis of all the leading microchip companies in the three countries and short listed six. I sent telexes to the CEOs of all six indicating what Semiconductor Complex Ltd (SCL) was to be and what we sought by way of both content and nature of technology licensing. Four of the six replied both positively and in detail. Our evaluation of the four responses led us to short - list three of them – Hitachi from Japan, American Microsystems, Inc from Silicon Valley in California and Solid State Devices Ltd (SSDL) in Boston.

After working out a complete itinerary, the team, including me and Mr. Virendra Mohan, left on August 20, 1980 going first to Hitachi in Japan. Our counselor (S & T) in our Embassy in Japan joined us in Tokyo and participated in the discussions/ negotiations. Our discussions with Hitachi were with a large team, led by Ishikawa Asano, Senior Vice President and Head Hitachi Semiconductor Group and one of the 16 members of the Main Board of Hitachi. I indicated to Asano, who I soon realized was a highly sophisticated person, that we were interested in a microchip manufacturing process that was capable of producing LSI devices of at least five micron line width and, preferably, devices of three micron line width which we knew Hitachi had. As for the range of devices we wished to cover, it encompassed devices for: analogue and digital clocks and watches and several telecommunication chips. Asano smiled and said, "Those are ambitious targets for a company and that too for a company in a developing country to aim for. However, we are willing to cooperate".

Negotiations and Finalisation on Technology

Then started three grueling days of negotiations. The Japanese team fully lived up to their reputation of being tough negotiators. After the first day, Asano wanted our delegation to adopt, along with Hitachi, the principle of "One Step at a Time." We were not agreeable to accept such a "principle." I said: "You underestimate us Mr Asano. The senior most member of our team, Mr Virendra Mohan has fifteen years of experience in the semiconductor area". Finally, it transpired that the Hitachi team was agreeable only to LSI process technology of five micron line width and as for products, only LSI devices for analogue digital clocks and watches. For such a technology license of limited scope – no Telecom Circuits at all - they asked for US$ 10 million plus a 5 per cent royalty on sales for 10 years.

I asked: "Mr. Asano, you had indicated during our discussions that the sales turnover of your Division was around US$ 40 million a year currently. At the same time, you indicated you were spending US$ 40 million on R&D! Where does the latter come from?" He promptly replied: " From Toasters and Turbines. We in Japan believe that it is the responsibility of the mature industries not involving hi-tech to subsidise the sun-rise or upcoming industries". No wonder Japan doubled national income, once in the 1990s, again in the 1990s and yet again in the 1990s! Needless to say, I shared my conversation with the members of my delegation.

We then proceeded to American Micro Systems Inc (AMI) in California. Despite AMI's Sales turnover being in the vicinity of US$ 300 million (compared to Hitachi's US$ 40 million – or perhaps because of it) the CEO Roy Turner and his senior colleagues at AMI were open and constructive from the very beginning. They not only readily agreed to licensing to SCL both their five micron and their three micron C-MOS LSI process technologies. AMI also mentioned that they were willing to proceed as follows:

SCL could choose any and any number of microchips from AMI's portfolio of around 100 circuits; and (b) they (AMI) would undertake Joint Technology Development with SCL of any new LSI circuit. SCL wanted it on a 50:50 cost and personnel sharing basis.

AMI made this offer on the very first day of the negotiations. Our whole delegation agreed with my assessment that, on every count, AMI's offer met our needs superbly.

More importantly, perhaps, the personnel of AMI and our delegation members got on famously as I did with the AMI CEO, Ron Turner. This being the case, we signed a comprehensive MoU of Technology Licensing with AMI on the second day of our visit.

An important matter that was discussed threadbare was GoI (DOE) applying to, and securing from the US Commerce Department's approval for AMI to export its technology "package" to SCL. Ron Turner said he would activate the process and everything was tied up to the full satisfaction of both parties.

With the collaboration with AMI so satisfactorily tied up, our delegation discussed that night whether we should really visit SSDL in Philadelphia. Finally, the consensus was that we should do so in order to have a second string to our bow.

We then turned our attention to the other major objective of our Team's visit, viz. to try and recruit 5-6 mid-to-senior level Indian micro chip specialists in Silicon Valley. Through correspondence, we had made a list of around 10 such specialists who had expressed their interest in joining SCL, particularly after I informed them of the remuneration package we were offering.

We, therefore, started calling them in one by one to our hotel and held detailed discussions with them covering both professional and personal aspects. Although we spent 10 days on this whole exercise, we were successful in enticing upto five experts, practically with no strings attached. Most of the five indicated that they only needed three months notice to leave their present jobs and come to India.

The day after we returned to Delhi, I went to PM to give her a detailed report of our visit and its many out comes. She was particularly happy that we had got five Non-Resident Indian semiconductor specialists to agree to return and join SCL. We then discussed the Export License. She assured her support to it. The project cost had escalated from the originally DOE estimates of Rs 16 crore to Rs. 55 crore as per the detailed project report prepared by SCL. The Commission approved the Rs 55 crore SCL project outlay including the tie-up with AMI on September 15, 1980 and the CCPA (the Inner Cabinet) did likewise on October 10, 1980.

The Next Steps

The next steps were related to getting clearance from US government and obtaining Export License. So a note was sent to Mr. Sankar Bajpai, our Ambassador to the USA in Washington D.C. to have the following two things done:

- Sending the Note to the US Commerce Secretary (as the US Commerce Department dealt with matters relating to Technology and Product Export Licensing, explaining the enormous importance our Government attached to the SCL Project and requesting the US Commerce Secretary to process the Export License expeditiously.
- As a result of these efforts, the License was formally issued to AMI on November 15, 1980.

Chips, SCL and Technological Options

By 1982, SCL had launched design and production of a family of LSI chips. The first was for analogue clocks and analogue watches. The clock chip in a chip-on-board configuration was supplied to the several hundred assemblers of such clocks in the small and medium scale sector. SCL's chip-on-board was well received by analogue electronic clock makers and cash began to roll into the company.

As for the analogue watches, we in DoE had required the two major such watch makers - HMT with technology from Citizen of Japan and Hyderabad Alwyn Ltd with technology from Seiko, also of Japan, to mandatorily procure the complete Electronic Circuit Block (ECB) from SCL. So, HMT and Alwyn passed on all the technical documentation they had got from their technology suppliers relating to the ECB to SCL. As a result, by July 1984, two dedicated production plants had been set up at SCL - one to assemble the ECBs for HMT's analogue electronic watches and the second to do likewise in regard to Alwyn's watches.

About this time, the Department of Telecommunications (DoT) had set up the Centre for the Development of Telematics (C-DoT) to design, develop and manufacture in the country a whole series of Digital Telecom Switching Systems. However, C-DoT needed microchips to drive and control all the Telecom Exchanges. The money value of this C-DoT requirement came to Rs 100 crore at 1984-85 prices, building up to Rs 800 crore by 1990. So SCL was launched techno commercially good and proper.

There was an interesting development relating to a key microchip for a telecommunication equipment called "Pulse Code Modulation Multiplex usually referred to by its abbreviation: PCM MUX. Its function was to interconnect the vast number of C-DoT technology-based Digital Electronic Telecom Exchanges with the total National Telecom Network. The Department of Telecommunication (DoT) keeping in view the large expansion of the overall telecom net work that was coming up, set up a joint DoE-DoT Working Group that had computed that, over the decade 1985-1995, around 30,000 PCM MUX Terminals would be needed at a total cost of Rs. 30,000 crore!! To meet such a huge requirement, the DoT and the DoE did two things in parallel: (a) They asked our premier telecom equipment manufacturer, the Indian Telephone Industry (ITI) to float a global tender for supply of PCM-MUX Technology; (b) reviewed, and further promoted, the indigenous technology for the PCM-MUX designed and developed by the Telecom Research Centre (TRC) of the DoT.

From a technology point of view in the MUX as a whole and the central microchip which controlled and drove it, there was an important difference between the MUX technology which all the six foreign companies which offered to transfer to ITI and the indigenous technology developed by TRC. The former used what is called a "Shared CODEC" while the TRC design was based on "Single-chip CODEC. It was well known even then that the latter was superior to the former in many respects.

The evaluation of the six bids received against the ITI tender led to the short-listing by a joint DoE-DoT Committee of only two technically compliant bids - one from Siemens of Germany and the other ALCATEL of France.

SIEMENS and SCL

At this stage, Mr. Kurt Langer, who was the CEO of Siemens (India) based in Mumbai came to see me. He told me that he had "come to know" that I would be going to the city of Mulhausen in the then East Germany to attend a Scientific Conference from December 20-23 (1982). He had, therefore, been directed by no less than the CEO and Chairman of the Board of Directors of Siemens, Germany to invite me to follow my participation in the Mulhausen Conference by a visit to Siemens Headquarters in Munich. The purpose of that visit would be to give me a detailed technical presentation on Siemens' PCM Multiplex Equipment with particular reference to the type and technology of the Micro Chip CODEC (Code-Decode) used in that equipment.

I thanked Mr. Langer for his and Siemen's kind invitation, but cautioned him that my travel plans for Delhi-Mulhauzen-Delhi had been fully finalized and so the only way I could squeeze in a visit to Munich would be on December 24, i.e Christmas eve! Would that be convenient to the Chairman and CEO of Siemens Germany and his Board Directors? Without batting an eyelid or saying he would "come back to me in a day or so", Mr. Langer replied that what I had proposed would be fully acceptable to Siemens Germany. It was thus that I landed at Munich from Mulhausen on the morning of December 24, 1982 where I was met at the airport by Mr. Langer and the Main Board Director in charge of all the R&D of Siemens in all areas and worldwide.

We then went to the specific laboratory in the R&D Centre where the three – men team undertaking the R&D on the PCM MUX in as a whole and its microchip CODEC in particular were working. The two engineers involved in this project as the R&D Director called it explained to me in full technical detail: what was the objective of their R&D project, viz. to design and develop a cost effective and full performance capitals Microchip CODEC for the PCM MUX at the very earliest. When I asked him what was the month he and his team expected to have such a CODEC ready to introduce them in Siemens Microchip Production Line, like any "politically / commercially" innocent R&D engineer and before the R&D Director could reply, the R&D engineer said: "In April 1984, Sir " i.e nine months in the future.

As he was explaining his R&D work to me, my eye fell on a paperweight on the engineer's table. It was a 4 cm by 6 cm block of glass in which a two chip CODEC - part bipolar and part CMOS - was embedded. So, I picked up the paperweight and asked the R&D engineer whether the two chip CODEC embedded in the glass paperweight, was the CODEC incorporated in their current PCM MUX and he said, "Yes Sir". I looked at both Langer and the R&D Director, standing next to me and they realized what I meant, viz. for the ITI tender Siemens had - and could offer only the two chip CODEC while the PCM MUX designed and developed by TRC in close collaboration with SCL used wholly SCL-designed single chip CODEC.

That night, there was a meeting with the Chairman and CEO of Siemens, Germany with all the fourteen main board directors present, along, of course with Mr. Langer. Throughout the three hour meeting none of the Siemens "top brass" present said one word about the Siemens' PCM MUX Equipment, let alone the key matter of what type of CODEC Microchip would be used in it. The conversation covered: the world political, commercial and technological scene in advanced electronics in including telecom. Why, when Germany had been using the superb international INTELSAT services of satellites for both its domestic and international telecom, TV and all other services, the German Government had nevertheless, placed a $ 25 million contract on Siemens to design, develop, manufacture and get launched a domestic satellite for Germany. The words "chip" or "CODEC" were never uttered, at the end of the evening.

As was to be expected after such a visit to Siemens, and my report to PM on it, the DoE-DoT Committee went ahead to:

- Cancel the Global Tender floated six months earlier by ITI for technology transfer for the PCM MUX; and
- Choose the TRC single chip CODEC - based PCM MUX to meet all DoT and other agencies' needs for PCM MUX.

- It was decided that all national – and indeed also export – of PCM MUX Equipment (single chip CODEC-based) would be met by three Central and the eight State Electronics Corporations using TRC-SCL technology.

SCL and Users' Needs: Schools to Telecom Sector

Later on – around 1985-86 - SCL started supplying Application Specific LSI chips (ASICS) to the Defense R&D Organisation (DRDO) and the Defense Public Sector Enterprises like BEL, and Bharat Dynamics Ltd. Another area from where demand for chips arose, was the somewhat simpler computers used in the CLASS Programme, viz. Computer Applications for Science in Schools which SCL was assigned to build and supply.

An important aspect of setting up and launching SCL was the selection and appointment of Mr. Virendra Mohan as the CMD, SCL. I got Mohan's summary bio-data and took it to Mrs. Indira Gandhi, and convinced her that he was the right person for the job. Mohan took charge at SCL in mid - 1981. He had two immediate tasks. The first was to recruit a core team of scientists and engineers to staff SCL. These were to include the five engineers and managers in microchip technology whom the high level team led by me had selected and given offers of appointment during our visit to AMI in Silicon Valley - of them, however, only one engineer joined as AGM (Facilities) only to leave several months later.

The second task before Mr. Mohan was to plan, design and establish the SCL facility including the Key Wafer Fabrication Plant (hereinafter to be called "Fab"). An excellent architect was first selected. The facility comprising Wafer Fab, Mask Fab, Assembly and Test Systems Utilities (HVAC, High Purity Gas and Water Plants) as well as a separate building for housing the R&D Centre, the Chip Design Centre, Marketing, Finance and Administration was completed in just about 20 months. The Wafer Fab, was to be a four (4) inch fab, i.e. capable of processing circular Silican Wafers of 4 inch, i.e. 100 mm diameter was built as a class 100 facility in terms of cleanliness and using a "Finger Geometry" concept to separate the "white" (Processing) and "grey" (Utilities) areas. The Fab as well as the Assembly and Test Equipment were mostly purchased from the USA. The whole SCL Facility was ready and started up in October 1983.

The first professional microchip made in the plant was a switch selectable tone pulse dialier chip in five micron CMOS technology licensed from AMI as one of the two agreed Technology Transfer Vehicles (TTV) for telecom applications. The other TTV was jointly designed by SCL and AMI to the specification required and defined by SCL. Considerable cost reduction as it afforded an average of 2000 good chips on a four inch (100 mm diameter circular Silicon) wafer as against an average of only 800 good chips per wafer being obtained in five micron technology. Interestingly, SCL was the only company in the world, at whose premises ECBs of two competing companies HMT and Alwyn were at home.

I should mention here, that apart from the chips going into the entire C-DoT family of telecom exchanges, SCL also designed and produced using its three micron technology, developed in house by SCL the Tone Pulse Dialer chip for subscriber and push button telephone manufacturers, SCL rightly chose to address the chip requirements of the range of digital electronic exchanges that CDoT had embarked on development within the country as mentioned earlier. The chips identified for being taken up for production for those Exchanges was mainly the 6502 family of microprocessor chips (with design licensed from the US Giant Rockwell International). The second telecon chip taken up was the single chip CODEC with filter (with design licensed from AMI). The third were Application-specific Integrated Circuits (ASICS) for the line card, signal processing (SP) card and the conference card, all three of which were designed and developed by the R&D team of SCL. Following successful development of these cards the older technology cards using discrete components were given up by CDoT. This contribution by SCL led to great advantages in terms of size, weight and power consumption, higher reliability and steeply reduced cost. Supply of these chips, over the years, to all the CDoT licensee, manufacturers, in both the public and private sectors, constituted a significant share of SCL's chip business.

SCL also made forays into Telecon Transmission Equipment by developing an ASIC chip set for the TRC-developed primary PCM MUX Terminal in 1985 in addition to supplying the CODEC chips for it. As many as three ASIC chips were also developed by the company in 1987 for the E10B digital exchange that were being manufactured by ITI under licence from CIT Alcatel of France.

In all, during the 1984-88 time frame, SCL designed and developed close to 40 products, the majority of them as application-specific IC chips (ASICs), more than half of which were for the strategic sector.

SCL and R&D and Quest for Innovation

It is pertinent to mention here the importance attached to R&D in SCL and the excellent performance of the R&D team comprising design, development and process technology development under the able leadership of Dr Manuji Zarabi who, by then, had been promoted to being Executive Director (R&D) in SCL. He was, as Mohan's immediate deputy, also made a permanent Invitee to all Board of Directors Meetings. While approving the setting up of SCL in May 1976, the Government of India had observed that it was being established with the basic objective of achieving self-reliance both in terms of having domestic control over this fundamental building block technology (for the electronics industry) and in terms of meeting strategic needs. The overriding consideration for setting up of SCL was indeed self-reliance in the strategic needs of the country even with subordination of commercial considerations to the objective of self-reliance in this strategic area. In keeping with this basic objective, while approving the SCL project, the Government had also approved the setting up of a dedicated R&D effort in this area closely linked to the production unit as that would offer the benefit of sharing the infrastructure and facilities which in the area of semiconductors account for a sizeable fraction of the total investment. Indeed, an integrated Production and R&D Corporation, to be named the Semiconductor Complex Ltd. (SCL), had also been recommended by Dr Zarabi in a seminal Report of the Planning Group of the Electronic Commission entitled "Planning for the Semiconductor Industry in India" as far back as in 1972. Dr Zarabi also went on to be appointed as Officer on Special Duty (Semiconductor Complex) by DoE in June 1976 following approval of the project by the Union Cabinet in May 1976.

While as OSD, and thereby being the first employee of the company, Dr Zarabi was associated with all the initial work relating to the setting up of the company. However, given his distinguished academic background and his passion for R&D, he was given the responsibility of setting up the R&D unit at SCL of which mask fab and product assurance were to be a part. The R&D activities were envisaged to span all facets of LSI/VLSI technology including process technology development, device physics and modeling, product design, development of CAD tools (software), reliability testing and failure analysis, R&D activities commenced concurrently with the production activities in 1984. A strong and well motivated team of about 70 Scientists and engineers with impressive academic backgrounds and arguably the best brains available in this area in the country was built up by Dr Zarabi in a short span of time to achieve the various and somewhat challenging and aggressive goals. Over the years, through these in-house R&D efforts, the company successfully developed the next generation three micron, two micron, 1.2 micron and 0.8 micron CMOS technologies as well as certain other technologies such as EEPROM for Non-Volatile Memories and CCDs for imaging applications.

By early 2005, SCL R&D had also designed and developed over 80 products, a majority of which were ASICs for the strategic organizations such as DRDO, DAE and ISRO. Major applications for which those ASICs were developed included encrypted defence communications, a whole range of radars, PCM encoders for a range of missiles, FFT processor and IIR filter for sonar applications for the Navy, an array of telemetry applications, particle detection / dosimetry, multiplexed analog signal processor, 100x100 charged couple device-based multiplexer arrays as ROIC for infra-red imaging, for all three defense services, all the intelligence agencies and even commercial security companies and a variety of CCD imagers for visible spectrum imaging also for all three defense services and the intelligence. Besides telecom, railways, there were other sectors for which those products were designed, developed and produced by SCL and used in a whole range of systems.

The Fire Accident and After

When all was going well for SCL, a major set back occurred on the intervening night of 8/ 9 February 1989. A major fire broke out that gutted the wafer fabrication and the assembly & test plants completely. An enquiry into the cause of the fire revealed that the fire started somewhere in the mezzanine floor possibly due to an electric short circuit which spread all across the plant rather easily due to the presence of excessive fire load.

SCL was now involved in so many critical areas, that the Government allowed the company to work out an arrangement with Austrian Micro Systems (AMS), a company of the Austrian Government located at Vienna whereby SCL would use their facility as a foundry by porting SCL's processes on to AMS Fab equipment to continue its chip manufacturing and development with almost no disruption. Concurrently the Government asked the company to prepare a project report for rebuilding of wafer fabrication as well as the assembly & test facility and put it up for approval of the Government. Fortunately, the superb work done and being done by SCL was widely recognized, not just in and by DOE, but by other Departments of the Government including Telecom, DRDO, ISRO and the Ministry of Defence. As a result, no less than the Cabinet Committee on Security (CCS), that deals with all sensitive and crucial projects, approved rebuilding of the SCL facility. The new wafer fab was envisaged to be fully state of art, with a 30,000 Wafers per annum capacity, 150mm Wafer diameter, class 10 cleanliness level facility as against the 100 mm, class 100 facility that was lost in the fire. The outlay approved for rebuilding the facility was Rs 332 crore. The new VLSI fabrication facility was built this time without any technical collaboration at all such as the one with AMI done earlier. Parallelly in the 1990S, SCL did an excellent job of setting up GAETEC for DRDO at Hyderabad. This plant uses technology developed indigenously and was state of the art in its domain when it was set up. Today this unit is routinely providing devices for defence and space programs.

By this time Dr Zarabi had risen to become the Chairman and Managing Director of the company and he again provided the superb leadership in this exercise of building this new VLSI facility. The new VLSI fabrication facility was dedicated to the nation by the then Prime Minister Mr. I.K. Gujaral on 17th December 1997 and commercial operations from this facility started in April 1998.

Considerable credit should go for the support of a dynamic IAS officer, Mr. N. Vittal, who was the Secretary of the Department of Electronics during the days the SCL facility was being rebuilt. It also happened that around that time I became Special Secretary, i.e. defacto Secretary, of the Department of Scientific and Industrial Research (DSIR). We, in DSIR, had a major multi crore rupee programme of soft money funding of R&D in industry through a programme, that aimed at technological self - reliance (PATSER). Under this programme, we funded manufacturing companies to the tune of Rs 100 crore a year, each project funded with a grant component of up to 40 per cent of project cost and the remaining 60 per cent in the form of a soft loan bearing an interest of only 5 per cent.

So I went over to Mr. Vittal in DoE and told him: "Look Vittal, you have managed to get around Rs 330 crore to rebuild the state of art microchip fabrication facility of SCL Congratulations. However, you may not have enough money left to fund product design and development in SCL. As one of the builders of SCL, let me pitch in to fund, through PATSER, design and development of products, with well defined market demand at SCL with the objective of loading the SCL chip fabrication facility when ready. Vittal readily agreed.

As a result, several products - an electronic energy meter chip for BHEL, a new line card ASIC for the CDoT exchanges, a chip for pagers and a chip for cardiac pacemaker were developed and produced. It is rare in the Government of India for two departments to work together for the national good. SCL was also selected by the DoE to set up a foundry for the fabrication of micro-electro-mechanical systems (MEMS) as an appendage to its existing CMOS facility under the National Programme on Smart Materials (NPSM) approved and funded by the Government of India. This MEMS fab facility was inaugurated on 27 July

2003 by the then Scientific Adviser to the Defence Minister, Dr V. K. Atre. SCL had, among other MEMS products, also planned to design, develop and produce an important CMOS-MEMS product, namely Uncooled Focal Plane Array (UFPA), for infra-red sensing/night vision applications for the Air Force and the Intelligence agencies.

Today we know that the semiconductors are essential part of electronics which is integral to everything that we do. Even a car depends on electronics which constitute 30 to 40 per cent of its cost. Most other human activities like computation, communications, medical services, entertainment, defence and everything else in our life depends on semiconductors. Therefore, the credit should go to the vision of the dispensation at that time which led to the formation of Semiconductor Complex Limited. An important feature of SCL was that an R&D division was started parallel with the manufacturing activity. This R&D unit helped to absorb the technology and upgrade it. This is essential for a company dealing with the fast changing field of semiconductor LSI technology. Most of other Indian companies in this field have closed down their activities not being able to keep up with the changes.

The technologists did their best to upgrade the technology up 0.8 micron. The company was missing the economy of scale and could not compete with international players whose plants were getting bigger and bigger as the technology march continued to spiral the critical dimension down. Any further improvement would have required substantial financial input which was not forthcoming from the government. The finance man was looking only at the bottom line and all proposals to break out were turned down. It was only after the takeover by ISRO, that substantial financial dose could be injected and a new technology could be obtained. Fortunately, the SCL is no longer expected to make profit as it has now become a 'laboratory'.

The Ministry of External Affairs did play important role in setting up of SCL. Several of the functions mentioned are routine (making local arrangements, helping with import licence, etc) and expected to be carried out by the Embassy. However, in view of the increasing importance of technology in our life, it is important that number of S&T Counsellors is increased to beyond current ones. The S&T counsellors can keep an eye on the developments and facilitate contacts with the appropriate Indian counterparts. Indeed it is possible for the Department of Science & Technology to have a parallel channel as it is done by the UK (British Council), US (USIS), Russia (Russian Centre of Science and Culture), etc. From Germany, Physikalisch-Technische Bundesanstalt (PTB) is running several international programmes to collaborate with environmental agencies and metrology and standards organizations. Deutscher Akademischer Austauschdienst Dienst (DAAD) remains in touch with its fellows and so does Japan Society for the Promotion of Science (JSPS). Similar models can be worked out by Indian agencies to continue to influence the opinion makers in other countries.

SCL and the Continuing Journey

Recognizing SCL's expertise and experience in semiconductor operations, the Defense R&D Orgnisation (DRDO) also entrusted SCL with the responsibility of setting up a high importance highly classified GALLIUM ARSENIDE Enabling Technology Centre (GAETEC) at Hyderabad for design, development and manufacture of monolithic microwave integrated Circuits (MMICs) again for both Defense and Space. This facility was completed and commissioned in 1996 and the first MMIC was produced in 1997. The facility was thereafter run by SCL on a contractual basis for design and production of various products required by Defence and Space until the end of March 2004 when it was handed over to DRDO.

Given that the *raison d'etre* for SCL was developing and sustaining indigenous capability in the area of micro-electronics, keeping in mind the broader national self-reliance considerations involved in micro-electronics, the Department of Electronics towards the end of 2004, with the help of the Principal Scientific Advisor (PSA) to the Government of India, explored the possibility of SCL being taken over by one of the strategic scientific Departments of the Government. While both the Departments of Atomic Energy and Space evinced keen interest, it was decided that SCL be transferred to DOS/ISRO given that ISRO had already been using SCL on a major scale and quite successfully. ISRO took over the reins of SCL. Upon the retirement of Dr Zarabi on 31 August 2005 a Plan for upgradation of the facility, that Dr Zarabi had drafted before his retirement, was improved upon by ISRO and an investment of Rs 1000 crore was made to upgrade the facility to 180 mm capability which has been operational for over four years. Under ISRO, SCL has continued its steady progress while holding a great deal of promise. It continues to be the only show-case for VLSI Fab in India and requires to be nurtured and supported by the Government for not only continuing to serve the basic purpose for which it was set up but also help the country to stay in the reckoning in the field of semiconductors.

Role of S&T Diplomacy in the Creation and Development of SCL

A) Work done so far

Involvement of, and assistance provided by, the S&T Counsellors in the USA and Japan in assisting SCL Teams from home going to the S&T Counsellors' countries of posting for:

a) Technology Acquisition;

b) Arranging training at foreign collaborator's, in SCL's case AMI's Plant and R&D Centre to absorb and implement the foreign technology purchased;

c) Securing from the government of the foreign collaborator– in the SCL–AMI case the Government of the USA a licence/approval from the foreign technology supplier Government concerned.

d) Assisting in the identification negotiation of conclusion of S&T Cooperation Agreements in fields/areas of interest/importance to us and between India and the country of posting of the S&T Counsellor.

B) Work that can be taken up and is important

a) Preparing inventories of Non-Resident Indian Specialists working in the concerned country of posting of the Science and Technology Counsellors in industry, R&D laboratories and universities;

b) Providing to our industrial companies, R&D laboratories and universities, "Current/Latest Developments " in the country of the S&T Counsellors ' posting relating to various key areas of S&T, industry, energy, transportation, agriculture, health etc. and in up-coming areas of interest to our country e.g. electric vehicles, artificial intelligence, learning ocean S&T, biotechnology with particular reference to new and more powerful vaccines against major communicable diseases prevalent/wide spread in India such as : dengue, chikangunia, malaria, cholera, typhoid and Japanese encephalitis, etc.

c) Profiles and actual texts of patents and other forms of Intellectual Property Rights taken out in the country of posting of the S&T Counsellor in the kinds of key areas .

d) Identifying in the country of the S&T Counsellor's posting leading S&T personnel, who could be invited by concerned Government agencies, industries, R&D laboratories and universities to come to India to give lectures and participate in major conferences and seminars organized by Indian institutions. While some work in this direction has been and is being done, it needs to be: (i) systematized and carefully planned; and (ii) well published in our country by the Indian organizing/hosting organization/institution.

e) A serious lacuna/gap pertains to bringing here leading S&T personnel from other developing countries in a systematic manner. Indeed we should go further and have at least a cell or unit in each of our S&T agencies/departments/ministries and in our IITs. The Indian Institutes of Information Technology should be staffed by at least 2-3 S&T policy and management professionals with adequate funding in terms of support personnel, a good computerized information system and a substantial travel and substance allowance budget for the invited senior/key S&T personnel from other developing countries who could come to India to:

(i) visit our counterpart Institutions,

(ii) give Lectures, and

(iii) participate in Joint projects and ITEC programmes as it now is woefully inadequate.

Such an innovative new measure/programme, covering a wide range of our premier S&T agencies and operating institutions – as the Chinese have had for almost two decades now – planned, coordinated and "top-up" by the Department of Science and Technology as our nodal agency for international S&T collaboration, would give long overdue "muscle" and "impact factor" for all our rhetoric that we are a leader in South-South Cooperates at least in S&T.

We would also strongly urge that immediate action be taken to design, finance and implement a programme of three to six month duration internships for carefully selected "up-coming"/ "budding" young scientists and engineers from other developing countries in those S&T agencies R&D laboratories, IITs and our "goal" universities working on S&T and intensive development-related areas/problems, viz. agriculture, water, energy of all forms with a particular emphasis on renewable energy (not atomic energy!!), space applications, biotechnology with particular emphasis on agriculture on the one hand and vaccines against communicable diseases and all areas of IT. Such a programme, again planned and coordinated by DST, of course in close cooperation with the Ministry of External Affairs would be of immense value not only to the "beneficiary " developing countries but also to us in political, economic, S&T-wise and from a Foreign policy point of view.

In all the suggestions we have made, we would like to emphasize with all the strength at our command that: (a) a clear set of goals on our part, (b) a strong institutional structure, and adequate and sustained funding are absolutely essential.

Where should our South-South programme in S&T start? In view of the experience in this regard as it comes out of the Case Study of SCL there is urgent need to vastly and rapidly expand our Network of S&T Counsellors. One of us played a major role, when he was S & T Adviser to our late Prime Minister Mrs. Indira Gandhi in the setting up in 1972 of S&T Counsellors in: Washington D.C, Moscow Bern (Germany) and Tokyo. In fact, he worked closely with the then Secretary DST, Dr. A. Ramachandran former Director of IIT, Chennai and later Executive Director the UN Agency called HABITAT in Nairobi in actually selecting our first S&T Counsellors (apart from the old Minister (Education and Science) in our High Commission in London. Today we are in 2018 – 46 years have passed and our S&T Counsellor "Net work"- if we can call it that - remains exactly where it was in 1972! Even an S&T Counsellor in Beijing (so acutely important) has not been added despite having actively pursued the matter with all the Secretaries DST since then and despite the Chinese having had an S&T Consellor in New Delhi since the year 2000! We must urgently appoint S&T Counsellors to capital cities such as Beijing, Brazil and countries such as Pakistan, South Korea, Nepal, Kenya and Israel.

We conclude by pointing out that the SCL case study gives us practically all the above insights if not prescriptions about what is lacking? We would submit that it is urgent but carefully planned action as we have attempted to set out above.

Technology Wars and Science Diplomacy

Recently the *Economist* published an interesting article on 'Chip Wars' highlighting the efforts of USA to block China from accessing key technologies that observed:

"Just as Silicon Valley's rise rested on the support of the American government, so China blends state and corporate resources in pursuit of its goals. It has incentive programmes to attract engineering talent from elsewhere, notably Taiwan. Firms like Huawei have a proven ability to innovate; blocking the flow of Intel chips in 2015 only spurred China on to develop its domestic supercomputing industry." (*Economist*, 1 Dec 2018, P 9). It also points out when S&T is globalized, protectionism and measures to curb transfer of technology are not likely to be effective and for companies like QUALCOMM, China is a major market and so it is for others like Amazon and Microsoft for setting up R&D Centres (*ibid*, P 20). Obviously, China has opposed the proposed measures to ban sale of Chips and other components to Chinese telecom manufacturers.[1]

Interestingly in early 2017, a report to the then President Obama suggested that the U.S government should take steps to maintain the leadership position of USA in semi-conductors and concluded by stating. "We strongly recommend a coordinated Federal effort to influence and respond to Chinese industrial policy, strengthen the U.S. business environment for semiconductor investment, and lead partnerships with industry and academia to advance the boundaries of semiconductor innovation. Doing is essential to sustaining U.S. leadership, advancing the U.S. and global economies, and keeping the Nation secure." (Report to the President: Ensuring Long-Term U.S. Leadership in Semiconductors Executive Office of the President President's Council of Advisors on Science and Technology, January 2017, P 25).

It is becoming more and more obvious that the role of the state in promoting and protecting hi-tech sector cannot be ignored in the context of countries trying to outbid each other in high-end technology and cutting edge innovations. On the other hand it is also clear that private sector alone cannot make sufficient investments in them, nor undertake R&D without incentives and support from the government. But to get access to technology and to collaborate with other companies, companies need an enabling environment. S&T co-operation and South South Co-operation can play a key role in this.

Conclusion

SCL was a pioneering initiative. Those who proposed it and nurtured the project had taken care of the investments and technology transfer required for that project. Hence it was supported by the government with monetary resources and in other ways. It was proposed at a time when public sector was expected to be a pioneer in technology and venture into areas where private sector had neither interest nor the capability. SCL fulfilled the expectations to a great extent. The fire in 1989 damaged SCL heavily. But changes in policies, the opening up of the economy in 1991 and changes in tariffs that enabled cheaper imports in electronics sector and other factors were not in favour of SCL. The Information Technology Agreement, the changes in technology and the rapid spread of computers and consumer electronic goods changed the scenario altogether, resulting in further marginalization of SCL and reducing its role. Hence it could not take into the next era in semiconductors or in chips and its success was limited. Down the years, India's imports on electronics and digital goods have zoomed and we are yet to develop indigenous capacity in this sector to eliminate or reduce dependency on imports for chips and semi-conductors.

So the key lesson from SCL is that such initiatives were necessary but technology collaboration, support in terms of policy and investments, technology foresight and long-term commitment to indigenous efforts in R&D were equally necessary. Science Diplomacy and S&T cooperation can play a key role in facilitating technology transfer and collaboration. But these should be integrated with policies for promotion of this sector. Today we do not need another SCL, instead we need initiatives that would take us forward in this sector in terms of indigenous capacity and capability to innovate. In that sense we need to think beyond SCL while keeping in mind the lessons learnt from SCL.

Endnote

[1] http://en.people.cn/n3/2019/0118/c90000-9538953.html

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Forum for Indian Science Diplomacy

As part of its ongoing research studies on Science &Technology and Innovation (STI), RIS together with the National Institute of Advanced Studies (NIAS), Bangalore has endeavoured a major project for Science Diplomacy this year, supported by the Department of Science and Technology. The programme was launched on 7 May 2018 at New Delhi. Forum for Indian Science Diplomacy (FISD), under the RIS–NIAS Science Diplomacy Programme envisages harnessing science diplomacy in areas of critical importance for national development and S&T cooperation.

The key objective of the Forum is to realize the potential of Science Diplomacy by various means, including Capacity building in science diplomacy, developing networks and Science diplomacy for strategic thinking. It aims for leveraging the strengths and expertise of Indian Diaspora working in the field of S&T to help the nation meet its agenda in some select S&T sectors.

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Core IV-B, Fourth Floor, India Habitat Centre,
Lodhi Road, New Delhi-110 003, India, Ph.: +91-11-24682177-80, Fax: +91-11-24682173-74
E-mail: dgoffice@ris.org.in, Website: www.ris.org.in; www.fisd.in

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