

# **Global semiconductor industry – India’s path forward**

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## **Speaker(s)**

### **Arogyaswami Paulraj**

Emeritus Professor, Stanford University and Member, Advisory Committee for Semicon India

### **Vijay Kumar Saraswat**

Member, NITI Ayog and Advisory Committee for Semicon India, and Chancellor, JNU

### **Ajai Chowdhry**

Founder, HCL Technologies and Member, Advisory Committee for Semicon India

### **Banmali Agrawala**

President, Infrastructure, Defence & Aerospace and Global Corporate Affairs, Tata Sons Private Ltd

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**Rakesh Mohan:**

A very warm welcome to everyone. We are delighted to hold this session which is in a hybrid mode. So there are people here but also virtually. It is really a great honour for us to have all the four people here in this session. My job is only to introduce everyone. Then Dr Saraswat has been volunteered to chair the session. Because he knows far more on the subject than I do. I hope that you chair and moderate the discussion. What we will do is to perhaps ask you Dr Saraswat to just introduce the topic if you may. And then we can ask Prof. Paulraj to give us his presentation. Then of course we can have the discussion. And you will be of course in charge of the discussion and how to moderate the whole session. Let me just give introductions to everyone here. It is an unusual subject for us because we mostly have economic subjects here. Sometimes political subjects, sometimes foreign policies, security, strategies etc. I think this is the first session we are having on what you might call technology and by technology I have always objected to the use of the word technology for IT. Technology is a much wider and this I think fits in very well with anyone who is interested in technology. Let me first introduce our speaker. Prof. Arogyaswami Paulraj. He is an emeritus professor at Stanford University. Also despite having been a long time at Stanford he has had continuous contact with India and the government. He is also a member of the Advisory committee on semiconductor India. He was actually here a 25 year service with the Indian government before he took off to Stanford. He joined the electrical engineering department in 1991. The only connection I can claim which no one will ever guess is that my first degree was in electrical engineering. But I thought I wasn't fit for that at all even though I could do it. And I graduated and then gave it up immediately. He started his career actually in Indian navy. So quite amazing what he has done through his life. His invention advancement of multiple input multiple output wireless technology revolutionized 4G, 5G mobile and wifi networks, greatly enhancing network performance. Of course multiple input multiple output underlies all broadband wireless access networks. He is an inventor of a thing has completely changed the world. Apart from having been a professor he has founded three wireless companies in the US to commercialise this technology and these were later acquired by Intel Broadcom and HPE. His recognitions have been honoured by receiving the Marconi prize, the Alexander Graham Bell medal and induction into the halls of fame of the US patent trademark office in the wireless history foundation. I won't say more because if... of course government of India has also honoured him with the Padma Bhushan. If I say much more we will be here for the rest of the evening rather than listening to him. We are delighted to welcome Dr Saraswat, a member of the NITI Aayog and also member of the advisory committee for semi-con India. He is also the chancellor of Jawaharlal Nehru University. He retired as secretary DRDO and after more than four decades of government service he retired. He has masters was from OIC Bangalore and PhD from Osmania University. He is a very gifted scientist with vast experience in defence research. He is someone to be feared since he is responsible for developing missiles like Prithvi, Dhanush, Prahar and Agni 5. I didn't know this before. Now I will be very careful in interacting with him. In addition he has also developed a two-tier ballistic missile defence systems, light combat aircraft, nuclear submarine and so on. He is Homi Baba chair professor and consultant to IOCAL R&D and is also currently the chairman and research advisory council of IOCL R&D. He has been awarded the Padma Shri and the Padma Bhushan and he has honorary doctorates from more than 25 universities. We are very honoured to have you here sir.

**Dr Saraswat:**

Thank you for the intro.

**Rakesh Mohan:**

Then my friend Mr Banmali Agrawala who I have known for quite some time. He joined Tata Sons private limited as a President Infrastructure, defence and aerospace in October 2017. He has also been with Tatas much earlier. Prior to his immediate current role he was at GE. He was president and CEO of South Asia for GE. Prior to that he was Executive Director and member of the board of Tata Power. He is the veteran of the energy domain 30 years of global experience. Currently he is the chairman of a number of Tata companies. I won't name them all. Because there are too many that you are chairman of. I don't know how you do your jobs chairing all these companies. I have difficulty enough leading a small outfit with about 50 people at the most. So I don't know how you all do these things. He is of course a member of CII's national council. Mr Ajai Chowdhry is one of the six founder members of HCL. He is also member of the advisory committee for Semi-con India. So we have three members here today of Semi-con India. He has been at the forefront of helping create the electronics industry in India. He has been involved in several government committees since 1999. In 2009 he headed the task force created by the minister of state, ministry of electronics and IT that form the basis of electronic policy. In 2011 in recognition for helping build the IT electronics industry in India he was conferred with the prestigious Padma Bhushan also. So we have a lot of Padma Bhushans here. He has a bachelor's degree in electronics and telecommunication engineering from Jabalpur engineering college. He has attended the executive program of school of business administration in the University of Michigan. And he has also been awarded honorary doctorate DSC by IIT Roorkee, the institute of information technology, design and manufacture in Jabalpur and the university engineering and management of Kolkata. I have now done my job. I now hand over to Dr Saraswat and thank you once again, all of you for coming to this unique occasion.

**Dr Saraswat:**

Thank you. Thank you for the initial remarks. I would first greet everybody, my fellow panellist who are here today, very eminent people. I know Prof Paulraj for a very, very long time. Because he is one among us. I don't know in the part of introduction you missed one very salient point about his stint in DRDO for some time. And he was the one who gave us the technology for sonars in the country. While he was in navy and he was working with DRDO in one of the Cochin Labs I remember. That is the time I was also part of the DRDO. So we had some interactions in those days. In fact I can say if somebody has laid the foundation for sonar technology in the country it is Dr Paulraj. So that is where I know him from and of course he has progressed beyond that. I know Ajai for a very long time. We have been together on many committees and things like that. He is one of the founders as far as the hardware I would say, the electronics hardware, particularly the computers and HCL has made a mark in a time when there was nothing in this country. First time I am meeting Mr Agarwal. I heard him through Dr Nayak. He just mentioned to me about you today. Certainly I have heard about your credentials. So we have a very eminent panel here. The topic today is very pertinent in the light of the fact that India is looking forward to accelerating our journey in the field of semiconductors. I am using the word accelerating because we started the journey long back and we have been probably the first few front runners in this segment. But for various reasons

which many of you are aware our speed has been low. We have had problems and the fact remains that today our semiconductors to the extent of 400 billion dollars we import. So that is the kind of situation. That is why the government of India gave a major, I would say transformational, push to bring in more and more self-reliance in the sector by coming out with a semiconductor policy last year in around the same time in November / December. It is almost a year now. Coming up with about 76000 crores of investment and upfront contributions to those investors who would like to set up foundries in the country. Notwithstanding that we have a significant amount of work being done in educational institutions whether they are IITs or IISCs or Universities where I think design capabilities of VLSI designs and all that are fairly in advanced stage. And large number of MNCs have opened shops in Hyderabad, Bangalore, Chennai, Bombay, Gurgaon and so many places where a lot of activities are on. But the net effect is still not significant because we cannot boast of having an Indian major semiconductor which has been commercialised and things like that. So that is our present situation. In that context I think the talk by Dr Paulraj will be very significant because there are three aspects of what we need to do. Number one to strengthen the ecosystem both with respect to the demand and supply. Second one is to bring in the kind of human resource which is essential for running this industry of semiconductor. Number three is certainly it cannot be done without international collaboration. That is because of the kind of acceleration we are talking of and our efforts to do it all by ourselves have not yielded significant results. The technology has really grown significantly today and we have to catch up means we can't do it all by ourselves. So it is important that we collaborate. So I think the colour of collaboration which is needed to be done, Dr Paulraj with his vast experience in the international circuit both in America and China will certainly be of great help in giving us direction in that cause. With these few words I would now request Dr Paulraj to initiate his speech.

**Prof Paulraj:**

Thank you. Dr Rakesh Mohan and president CSEP, Dr Saraswat, Mr Banmali and Ajai Chowdhry. I know all of them, Rakesh for many, many years. Of course Dr Saraswat and I were colleagues at DRDO. Mr Agarwal I generally knew the Tatas and I began to meet him more recently and in fact he spent some time with us at Stanford recently. And of course Chowdhry goes back many years and I have worked with him with the University in Chhattisgarh. So all very eminent people. I am really humbled to have them all here. My talk today it is build saying the 'semiconductor industry and road ahead in India. I am not going to talk about India because for one thing is we have launched some mission and I am involved with it in a small way. So I think it will be improper for me to talk about what is going on. But I will talk little bit about what a country like India should do. The details I would keep away. I am actually here to meet both the ministers. I have been sitting on some zoom calls from the United States. Just a little context. In 2018 the secretary of DOT was one Aruna Sundarrajan. So she convened a meeting of a lot of senior people in our country. So I sort of saying that this is such an important industry, we need to get it done. Then I came about 10 or 8 times after that. Including I met the P M suggesting some format. But nevertheless now we have launched this mission and I am happy to be involved and provide some service. So I am not going to talk about India. But broadly about what I see internationally. I should also say that what I say is probably only half truths, it is such a complex industry. It so many ins and outs. Whatever I say will be over simplification. Also my connection in industry is largely on the fabless side. I build chip companies. I still sit on some boards of chip companies. Fabless designs. Fab side,

I have only worked with them to get chips manufactured mostly TSMC. So my understanding of fab in depth is really not very good. So you have got to forgive me for that. Stanford has always had a strong fab R&D structure. I think it is not where it should be. Investments are lower but all the pioneers I know very well at Stanford and I will talk a little bit about them. So I am sort of connected to the industry at my age only mainly through people who are still very active. But I am sort of not very active personally in terms of the technology. So with those caveats let me start. So the origins. I am really assuming that people here are not from the industry. They will know that what I am saying will not sound right because I am flying at 30000 feet. But sort of just to give a feeling for what this industry is about. It all started actually with the invention of the transistor. It has done at Bell labs in 1948 I think. That is a picture of three people Brattain, Bardeen and Shockley. Shockley is the guy who is sitting down. He was actually more of a manager but he liked to take the limelight so that famous picture was Shockley sort of running the show. But that was the first transistor. Those days of course thermionic valves were already in place. And the world was run by thermionic valves. But then they had this idea of transistor. Took a lot of fundamental research. From there Shockley moved to the Silicon Valley. I think he wanted a job at Stanford but finally landed up setting up his own labs called Shockley labs. The picture right below the right extreme is the black and white picture is Jim Gibbons. Jim Gibbons was prof at Stanford and close colleague of mine. Jim was a Stanford and Shockley was in that company Shockley labs. So they collaborated. So Stanford kind of tracked that area more for basic research and some teaching. Shockley was trying to build a commercial company. He had some very well known gang of seven. But Shockley was not known to be a good manager. So they all quit. All the top people quit and formed or joined and got Fairchild camera those days to invest in them and they formed a company called Fairchild semiconductors and began to grow the company. But finally Fairchild wouldn't quiet understand them, it was headquartered in east coast. So they broke away and formed Intel. The three founders of Intel are Robert Noyce on the left, Andrew Grove on the right. And Gordon Moore in the centre. I did get to know Grove and a little bit of Gordon Moore. But I was much more close to Jim Gibbons. He is 87 years old but still very strong. Intel was a really a lead company in the Silicon Valley and they were building the chips and TTL type chips for MSI, LSI and also memory. The big breakthrough came when two guys Federico Faggin and Ted Hoff kind of made the first Microprocessor 1972 I think. I know both of these people well. I still sit on committees with Faggin. Ted Hoff also I meet him occasionally. That launched really the semiconductor influence in this world and everything began to grow from there. Then later because I was involved with wireless and I had this foundational idea called MIMO. MIMO as Rakesh mentioned it underpins all wireless in the world. Everybody in the world uses wifi, 4G, 5G. So I think just on MIMO amount of equipment manufacture is in trillions of dollars. So it is huge. But initially when I proposed it everybody said it will never work. But it took a long time, it took about 15 years before to enter... the WiMax standard in about 12 years and in LTE standard in about 15 years. So that was the long journey for me. Then I sort of got to know the wireless people in Qualcomm, dot com, some of them acquired my companies. I am still in touch with all the leaderships. Most of them like me are now retired. My real strength I have is the connectivity I have in the United States with this community. But not really active in research. So semiconductors has really become the key enabler. It is the military, economic, geopolitical power, particularly our underlying geopolitics is built on the foundation of semiconductor industry. Some of you may know that the four crown jewels of an advanced country which United States is kind of there. But sometimes losing little bit of its grip. China

is rising is these four areas. One is R&D intensive manufacturing. So the first one of those I would put them as semiconductors. That is number one. Number two would be a branded pharmaceuticals. That is a new molecule pharmaceuticals. Semiconductors of course India has not yet entered. India means India headquartered companies. It is yet a no show. But I will talk more about it later. In branded pharmaceuticals on generics we have done very well. 40% of medicines shipped in the world are from India. But in branded side we still very small. A little bit from Sun pharma and Biocon, but still very small. So that is the second crown jewel that America, Europe and now increasingly China have ability to do work there. The third is advanced instrumentation. A prime example that many of you are familiar with is machines used in manufacturing semiconductors called lithographic machines. The lithography machine today to get semiconductors to five Nano-meters which is the ruling technology node and I will explain that later. It uses extreme UV and very high technology, enormously complex optics. One box which is probably size of half a container is about 160 million dollars. It goes back to 100 years of experience to sort of able to produce that. And they dominate the world. So precision machines particularly for in lithography, in semiconductors here and even for bio research and manufacturing of biology and pharmaceuticals is also very complex. So that is the third crown jewel. The fourth crown jewel is aerospace. The Boeings and air buses of the world. So these are four issues and this is where the west is dominating. And of course China is rising in all four of them. But among these real crown jewels is semiconductors. Because semiconductors under pin everything else. Without it you can't do pharma, you can't do aviation and you can't do instrumentation. So for any country in the world and any country of our size of India, this is absolutely foundational. We don't get into it and play a role it is... we have to make it happen. And I think it will happen. Little bit again I am talking to the people who are not familiar with the industry and trying to explain what the industry looks like. For the first part or one segment of the industry is called the design of chips or the chip design. I myself have run chip design companies. But the dominant companies are Nvidia which is probably the largest chip design company. They don't manufacture anything. They only design the chips. The chip company gives the money to the fab and fab does the job. Of course there are lot of interactions in that process. But it is all manufactured and the design is done by a separate company. Qualcomm dominates wireless, Broadcom which I worked for because they acquired one of my companies. Intel does both manufacture and design. Then of course I could give you examples in China. We have in high silicon quite a few companies in China, maybe four or five. In Taiwan it is Mediatek. There are about 10 dominant companies in this area. And design is a big part. The total volume of revenue in this industry is 600 billion and the revenue of these design companies who do no manufacturing is about 300 billion dollars. I will talk about who dominates it later. The second part is then the foundry piece where you actually get the chips manufactured. There are two sections there one is the Foundry or the front end where you do actual diffusion and make the wafers. And there are two types of companies there. One is pure play that means they only do manufacturing of the chip, they don't do any design. So typically like in my company, we own the trademark, we own the IP, and we would just get it manufactured by Pure Play foundry. So Nvidia, Qualcomm, Broadcom, all the giants don't have foundries, they get it done by going to the foundries. The big name here is TSMC. 50% of revenue in the world today is TSMC, one company. UMC in Taiwan, then Chinese have about eight or nine companies. Hongguang group and they have SMIC and quite a few others and I will mention the names later. Of course Samsung in Korea and so on and so forth. Then there is a back end. Once the wafer is diffused or you are dicing the wafers, testing it,

packaging it, sometimes it is called OSAT – out sourced assembly and test. It is another big segment. There are many companies there mainly China and Taiwan. I think they dominate it. So that is the manufacturing part. Finally when the chips are fully ready they get into phones and they get into laptops and so on and so forth. That is the assembly and test part which is not the semiconductor part but it is where the semiconductor is going to land up. This is where the first three layers where the semi-con industry is. I will talk about the revenue there. Today the players there are US, China, Japan, South Korea, Taiwan and a little bit Israel. And a little bit in Europe. Israel and Europe are pretty small. Now I am only talking about the three layers. A total 600 billion dollars. As I mentioned 300 billion is for the chip design companies and about 300 billion or a little more than 300 billion is for the foundry companies. Let me talk a little bit about these numbers. 600 billion. On the fabless side it is about 300 billion and it is completely heavily dominated by United States. Nvidia, Qualcomm, Broadcom, and Intel of course they also do manufacturing and then of course many others smaller companies, there are probably about hundred companies in billion dollar plus. But these two or three or four people pick up most of it. So that is the fabless side. On the fab side I mentioned TSMC amazingly again in 50% of the world market is with them. They have the top technology fine animated technology and the result what happens is that nobody else can or has that and they are able to command huge pricing and leverage on pricing. All the top small phones need that technology. So TSMC, UMC and also in Taiwan and a bunch in Korea, Samsung is very dominant also for memories. And Intel in United States. Intel along with design and manufacturing very dominant in service computer chips and have a big share of the market. The total market cap of all these companies is about 3.35 trillion dollars. That is the market cap. While this is the semiconductor segment the supporting segments required to make this happen, first is electronic design automation. Companies like Cadence and Synopsys and there are few others which make the design tools to help you design the chip. These are very, very complex designs. So these tools are very sophisticated and that itself is a multi... maybe as much as 30 billion dollar industry. Then manufacturing equipment. This is the equipment required to actually manufacture the lithography, the CBDs. So the companies there are, the top one is ASML in Holland which has a market cap is not a big company and is 450 billion dollars. Then there is Lam research in the United States, Applied Materials in United States, Tokyo electronics and then KLA semiconductor. The local electronics in Japan, others are in US. Without this equipment you cannot build a fab. A lot of this is controlled by the US and the geopolitics today is all about these companies. I will explain that later. Then of course you need supplies, you need silicon ingots and you need gases and so on and so forth. So that whole industry is probably about 150 billion dollars. So in terms of market share it is 600 billion. As you can see US is the bottom green. That probably goes back to 2000. If you go back to 1970s everything was US. But by 2000 US had come down to about 50% and then Japan was very dominant at that time in memory. US is very worried about Japan those days. Then Europe and then we had South Korea and China and then Taiwan. You can see slowly the US has been declining, China has been growing. South Korea has done very well through Samsung. I think Europe share is also slightly dropping. And Taiwan, I would say Taiwan has a lot of fab but not Fabless. To me that doesn't look right there. There should be more than what it shows there. The big takeaways there are really is China has been rising and US has been dropping. If you look at all the literatures, technology means node. Node means the size of the lines that you use, the gate size which sort of determines the technology. The size of the gates are shrinking and that is made for example from 1970s when industry was born, the number of chips or the number of gates



you can put in a say, square centimetre of a chip is run up by 10 million times. It is huge improvement in performance. Initially it turned out that when you actually made the gate smaller you can also reduce the power. It called Dennard scaling. That sort of disappeared about 8 to 10 years ago. So now making the size smaller requires more lithography, it is very, very high technology and the power play is not yet there. So now the problem with the chips is that even if you squeeze a lot of gates into it, they start to generate so much power, I mean hotter than the nuclear reactor I believe. So the lot of management around was around making sure that the temperature is not too high. So you can be sure that millions of lines of codes monitor the temperature and regulate the chip and the clocking and all that. It is a very, very complex area. But today the dominant technology where all your phones where the main \_\_ is made is five Nano-meters for Apple and Samsung. But that is still probably only five percent of the actual market. The real work \_\_ are lower. Seven Nano-meters is pretty good. 7, 14 and in fact I would say 80 to 60% of the actual sales are at 16 Nano-meters. It is much more relaxed and 16 Nano-meters was done some 12 years ago. And they still have a lot of the stuff that automobiles that Tatas use and quite a lot of chips in your laptops are all 16. I did my chips probably at 16 or maybe even at 19 long ago. Now the claim is that three Nano-meter is going to happen. So TSMC is I think is working on that. Probably that will be available soon. This node is the source of embedment of technology and this is really, really difficult stuff. The complexity of these chips is enormous. I would say typically in a standard ASIC today computer chip it is many billions of gates. But there are AI chips now which go to trillions of gates. I mean I have seen a Chinese chip at 1.6 trillion. So this is incredible complexity. This is a technology area with enormous amount of knowledge that is needed to make all this happen. Just an understanding of how these chips are important is that your standard I Phone... let us assume you buy a phone for 600 dollars. By the way these numbers are very rough and I could be somewhat wrong. So please forgive me. If I buy for 600 dollars Apple picks up 300 that goes for their R&D, their profit and you know sales and marketing and all that sort of stuff. Then the phone is actually manufactured by one of their ODMs. For example a big ODM for them is Foxconn and Foxconn also operates in India. Foxconn has two assembly lines in India. So Foxconn gets 300 dollars from Apple to ship the phone to them. In Foxconn the structure is, for 300 dollars they get, they probably spend about 75 to 80% on semiconductor chips which they have to buy from TSMC, UMC and from the Chinese guys, maybe some Samsung. Display is about 12%, mechanics and batteries is about 9% just a little assembly line labour is about 3 to 4%. Typically it is all dominated by China in terms of the assembly. But now it is coming out to Vietnam and Thailand are doing well. We are trying to grow it here. We now built 300 million phones in our country now. But our participation is only in the lower 3% label level. I think a little bit mechanicals, I was talking to Josh, the guy who runs Foxconn. Little bit mechanicals. We are trying to move up the value chain but very quickly we hit the semiconductor level that of course we cannot play. We don't have that. So the labours is there we do it. But still I think 300 million phone generates about 4 or 5 billion dollars of labour for us. These are usually women who are housed in dormitories and they do a very good job. I think Tatas have not announced anything but they are looking at getting probably into OSAD business. Banmali will know more about it than I do. I want to talk a little bit about the industry. I mentioned out of 600 billion revenue 300 billion dollar come back into R&D. So you can see the amount of R&D that goes into the system. So it is a big cyclic machine and that R&D keeps the technology moving forward. So no government can actually invest and match anywhere near this. Whether US or China, it is the profitable basis of these industries that actually make

drive R&D forward. You need the profitable industries. And that drives the technology power. I mean the governments can only play a very small role. Then the general numbers are that if you believe all the statements over the next ten years we are going to put two to three trillion dollars in investments in this industry. I think it is probably exaggerated, everybody sort of over pitches it. I would think it is probably 1.5 trillion dollars next ten years. I would say half of that is China. Another half would come from US and South Korea and Taiwan. The current ruling node is 5 Nano-meters. Three has not yet happened. A 5 Nano-meter is fab of reasonable size, I don't understand the details. About 20 billion dollars. 20 billion to build that fab. It is lot of investments. Also it is very important that no country is self-reliant. So it is a very big global supply chain. I would say the supply chain for a fab may be about 1000 companies. Primary supply chain. They are talking to thousand companies for individual pieces. Of course there are some big guys like ASML. So supply chains is layers and layers below it. But 1000 companies or even more cutting across Europe, United States, Japan, Korea, China who are in it. So we in India could never and certainly not the United States, not China, can ever think of being self-reliant. It is just so much knowledge and technology spread across the world. So that we too can participate in this industry and buy technology and sell technology. We cannot be self-reliant completely. It will take trillions of dollars. Once you are really a player, a multinational company, you are spread across the world, when India builds this companies, we are successful when we build multinational companies. I mean headquartered in India but selling and doing R&D all over the world. It is a very competitive. Only the toughest survive. In fact in a book by Andy Grove which says that only the paranoid survive. It is very hard. I myself have gone through on the fabless side, very tough situations in getting those companies up and huge entry barriers including the geopolitics now. Nobody on top wants anybody else to come in. So they are going to compete. Once you become successful you will get targeted. I am going to go into geo politics a bit. I think the numbers hopefully are right. In fabless US is very dominant. In one thing which I have been part of that, is the source of US dominance was our top universities. Stanford, MIT, we produced some excellent people. I will also say to those of you who may not be aware, that the chip design for ambivalent wireless is very, very mathematical. It involves lot of deep mathematics. So that happened. But now I say we can get all that done in India today. Not by Indian companies but by MNCs. I will talk a little bit more about that. US dominates and it is Nvidia and Qualcomm. I would say that all these dominant companies probably have at least half if not more of the designers in India. India houses about 80000 chip designers for all these companies. The head of Qualcomm R&D today is my former student Stanford PhD and Broad com bought one of my companies. At that time I was quite involved with what is going on in India. So US dominates there. China is much smaller. 9% will be I think an exaggeration, maybe less. They have few companies like Vchip and so and so. And Taiwan is pretty small. Only Mediatek. But in foundry US is now declined. 9% would be the number. They established node probably... there are lots of claims... China has been claiming 7 Nano-meters, I don't think it is quite there. US probably is 12 Nano-meters. China probably stable at 14 or 16. They are not at 5. Only Taiwan is at 5 Nano-meters. When the US looks at this industry they look at that picture and that is what worries them. This is from the semiconductor industry association graph and I think it is somewhat exaggerated and there is a joke and it is probably true. In the 1960s when US industry wanted to build more rockets they would always show the senators all the soviet rockets which is huge and make the Indian and American rockets very small and they get lot of money. So this is probably that kind of chart. But the fact is today in fab share or foundry share I think China and US are almost same. So it

is worrying for the United States. General feeling is that China will overtake the United States. It is hard to say. So where the source of US is worries? One is the fab competitiveness which is really in US it is Micron most likely run by NRI and Intel, Pat Gelsinger I have known for many years. These are the two fab capabilities in the United States. Both are local IDMs – integrated design manufacturing. They feel that US now is losing ground to Asia Pac. Taiwan certainly, China and South Korea. Then of course they worry about that the third grade Taiwan is so dominant now, if there is a merger between Taiwan and China which of course all of you know about that. That is a huge issue for United States. Of course US also there is some assets in Europe and in Japan. US basically now started to target China and trying to get cooperation from their partners to make sure that no transfer of technology kind of happens. It is not also very easy because of lot of sanctions going on. Also the thing about US is it is very market driven and it is very difficult as US never invest. We do a lot of investment in R&D. Like I myself got lot of money from national science foundation and maybe a little bit from DARPA at Stanford. But once you become a competitive company US does not invest in you. For good reason they don't want to pick a losers and winners. Now finally we decided we had to do it. There is Chips act and we are putting in some 45 billion dollar. But still we can't control the market so well but China what they have done is they basically searched for all these fluff companies. Internet, media, even fintech, edu-tech. They kind of said this is all worthless. They are pushing all the investments towards the next generation deep type quantum, semiconductors, AI, Brain sciences, propulsion, fusion which US cannot do. Now we don't have that kind of... the government doesn't play a role there so strongly. Those are all worries for United States about China. So the various responses that is going on in the United States I would say one is there is a CFIUS system. It is a law by which there can be no investments by Chinese companies in high tech US companies. Every venture capital firm, any corporate investments have to certify this. So this has been going on for few years. Then the Chips act was passed in June July, there is about 52 billion dollar of US support for fabrication. A lot of it is for training and building up universities but the direct money going into the fabs. I think Intel, Micron will benefit and of course TSMC and Samsung are going to build one fab today in United States. There is some 5Gs where I am heavily involved a little bit with the politics too. Some money coming from 5G and just about 5G a little diversion. If you look at all the core technology of 4G and 5G it was all invented in US. MIMO by me and that dominated everything else but even 5G, the milli-metric band. But we don't have any market share today. Today you buy equipment in US it is only from infrastructure. Taiwan it is either from Samsung, Nokia or Ericsson. So we are trying to build up US ecosystem, something called **Orion** ecosystem. It has not quite come together. I am little bit involved in that part of it. Of course recently we announced sanctions on the semiconductor. So basically we said that US or its partners cannot ship less than 40 Nano-meter technology which is to China. So no chips of that and DRam which is memory in less than 16 to 18 Nano-meters and Nand Flash that is actually the flash memory that is very important less than 128 layers. So you cannot ship. Of course this is for US government can enforce it on US companies but we also are trying to get partners to enforce it. Also it restricts the ability of US residents whether citizen, noncitizen to support Chinese semiconductor industry. So this has become very, very... I mean they are really cracking down. The third is also the code to the fab is the equipment. Of course the king there is ASML, the Tokyo electronics. So they are restricted from transferring technologies anything less than 14 Nano-meters to China. This is very recent. This is cutting both ways because these people are losing revenue. So ASML probably had 30% revenue in China. So

they are going to lose that. Nvidia we are going to lose 20 billion dollar revenue thanks to the sanctions. So some of the companies are pushing back. So we will have to see where it all goes. All this is very new. I am not going to talk about India. But certainly India is a huge country and we really have to enter this thing. We do not have a presence in this industry today. When I say we have a huge presence of MNCs operating in India but no Indian headquartered companies. It is close to zero. So we have to enter. Without getting into specifics broadly, intellectual property and people who build it are the key. Without the people you cannot build this industry. I am talking about the top level. If you want to do manufacturing assembly it is easy. If you want to lead like TSMC and Intel and Samsung, we need the top people. They are the key. And what has happened is this is how it has all been built. Originally all the people were in United States. Japan came and stole people. It picked up people in western. They built their memory industry. Later on Taiwan came and they picked up a lot of key people including Morris Chang and they built the industry in Taiwan. When China began to pick up people a lot from US, this is about ten years ago, many from Taiwan, many from Samsung and that kind of swapping still goes on. But people make the industry. Any country wants to enter we have to go after those people. Otherwise those people have strong PhDs, 25 years of experience, enormous knowledge and we cannot build it on our own. Impossible. It will take us a billion years. That is important to understand. So that has been the pattern and I think we may have to do that. Building the industry is finding those people. I can't underline it more than that. High investments, it is probably for any country to get about 5% global market share I would say about 100 billion dollars, private sector, government and we can even bring investments from outside. 10 to 15 years to get 5% from starting from a very low base. We can only join the club. We cannot be completely self-reliant. I am sure the political level understands this very well. But we have to join the club where we also have our own IP but we are selling that internationally and we could buy IP from others and manufacture. Also I can say I know that India can absolutely do it. Just we need sustained political will that is now there. But we also need... one comment I have for the government is that this needs industry experience people to help guide us. It is very critical. This cannot be done in another government program. This is the true source of success of all these countries because they went and got those people to help them. I am sure we are going to do that too. As far as India is concerned I think we are on a path and there is a Chinese saying 'journey of ten thousand miles starts with the first step we take'. We have taken the first step, we have got to keep marching forward. I am sure we will succeed. With that I will close. Thank you very much.

**Dr Saraswat:**

Wonderful. Excellent overview of what is happening across the globe. Particularly in US, and China. I think your talk has made us to think that the gap which I talked about is really wide. It is an eye opener. We thought we knew something. But I think after listening to you and looking at the way the world has gone into this segment it is really scary at the moment. If we have to bridge that gap certainly it requires some very phenomenal efforts which are not only within the domestic resources but global resources.

**Prof Paulraj:**

I have one comment there. On the fabless side we have some absolutely extraordinary talent in the country. They are working for MNCs but they are there. One of my students I pulled him out and it is now a billion dollar company. Still US had got it. One of the challenges that we

have is that when we start building companies we don't want to get flipped into a Chinese company or a US company. We have to hold on to it. But that core talent in fabless is very strong actually.

**Dr Saraswat:**

I know this fabless is one positive point as far as India is concerned. That certainly gives us some foundation to start with. But I can only give you one counter on that. We have tried from 2016 to build some major microprocessor devices for ourselves for strategic applications and so on. We started with single core, dual core and then a quad core microprocessor working. It is now seven years, I am struggling to get the single core. So if I have such an immense talent in my own country for design I should not have taken seven years. That is just the kind of scenario I am trying to quote in front of you. The benefit of this MNC fabless ecosystem in the country is not directly coming into any of the programs in the country today. Whether it is the private sector or the government sector. I don't know what Tatas or Birlas or others, but none of them are in a position to say that 'look I will take a design for a microprocessor of this application and take right from the design requirement to final'. That kind of a capability I still have to see. But I go with you.

**Prof Paulraj:**

I would say just that the latest Qualcomm R&D is basically an island of Qualcomm sitting here. Completing the tunnel there with zero interaction with them.

**Dr Saraswat:**

Since you have been too long in US and other places and you have seen this. I have been an Indian all through. I want to tell you the fact of life as far as this particular segment is concerned. None of my fabless designers sitting in the MNCs have the view of the whole of the chip. As you said they are sitting in the tunnel of the design. The tunnel is so many segments that are running in parallel or in series, that they have no view of what is happening in that tunnel. As a result when I go to them 'will you please design a chip for me for a rocket or a missile or a communication segment?' they said I can do maybe the communication interface. I can do maybe the memory interface. But you ask me to make a memory I will not be able to do it.

**Prof Paulraj:**

These are for profit companies. They want to sell chips worth billions of dollars. If you give them a five million dollar order they are not interested.

**Dr Saraswat:**

Now I think this economics if we continue to propagate I think this country will never be able to make headway. We have to do that 5 million thing and if you are an Indian you better do that. If you have turned into an American just because you have lived there too long and now you are being fed your salaries to the American MNCs then yes I agree with you. I think you have to get into that. There is no point in saying that India has got 80000 fabless chip designers available in my country where I am taking seven years to design a chip. Afterwards we can have a discussion. I just made a comment because Paul has mentioned that. We will have a discussion on that. Now with this we can start with Mr Agarwal to give his views.

**Dr Banmali Agrawala:**

Thank you so much Dr Saraswat. I think that was very interesting point at which you have asked me to come in. First, sir I think you made an excellent and wonderful and brilliant presentation. The last slide that you put up captures it all beautifully. But just to go back to the point that Dr Saraswat is making, so if I look at it from the ground as a practicing manager on the ground, engaged in actually manufacturing and building these things... incidentally one of the things that I look after in the Tata group is our foray into electronics. I think we have got to get started somewhere. I would start by saying that first the opportunity that we have staring us in the face is simply massive. Given the geopolitical shifts and so on, the kind of shift that is happening to India is simply substantial and I would just say that we need to grab it with both our hands as soon as possible. I wish it could be even more the private sector would participate even more keenly and deeply than I think what is happening right now. I can say with our experience, the government policy framework and so on (interruption by Dr Saraswat) First I think we just need to recognise that there is a massive opportunity that we have for ourselves. Second I think we need to recognise that the nature of manufacturing in today's world has changed. Without manufacturing I don't think any of this is going to come to bear. We have got to make sure that our manufacturing base and footprint... I think the point that you also made that ultimately it is the money that you would make out of manufacturing etc. and so on will get ploughed back and that is how the circle kind of gets started. Dr Saraswat I do take your point that someone's got to take the lead, someone's got to be bold enough and put those investments without having a complete spreadsheet etc. laid out and see what will come out of it. But I will just come to that in a second. My second point therefore I am making is that the nature of manufacturing has changed. I don't think we in India have seen three things come together in manufacturing. One is scale. The kind of scale that we have particularly in electronics, I don't think we have seen that. The second precision. Now we have seen precision. We have seen it in aerospace, we have seen it in other places. But precision that you need in electronics along the lines of what Prof mentioned I think is really something else. The third is finish and quality of finish especially when it comes to consumer items and so on. Now we may have seen these three things independently in different industries. We may have seen scale in the auto sector. We may have seen precision in aerospace. We may have seen finish maybe in watches and jewellery and all that. But all of these three coming together in the scale that I think one is talking about, I mean making something like 5 lakh phones a day or something of that kind is something that we haven't seen. I think therefore we need to understand that the nature of fundamental nature of manufacturing has shifted...

**Dr Paulraj:**

300 million phones in India...

**Dr Banmali Agrawala:**

That is right. I meant that if you kind of translate that to how much per day and the opportunity it is substantial. So we need to recognise that. I am linking it to the point that do we therefore have the people who understand how to do it? The systems and processes that would support something like that? The mind set to be approaching something like that. I think having been through that process over the last three years I would just argue that we need some distance to cover and the faster we do it the better it is going to be. The third I would say that when we talk about and the point that Dr Saraswat is making, I think we need to recognise that we in India can be the leaders in a few segments. And I am not saying this to be jingoistic. But I think

we need to understand this. The first is electric vehicles. The number of electric vehicles that will be produced in this country in very soon, if you just see the transition that is happening, it is phenomenal. It is time that we started designing those electric vehicles ourselves rather than simply fitting lego boxes. If we do that then I think we control the design, it goes back to the point that Dr Saraswat is making, I think that we build that ecosystem. I think that thought process has started. We need to hasten that and pick that up even better. And if we connect design and R&D to a specific application and use and the commercial dimension that I think was just mentioned, then you get a perfect fit. The second area where I think this will happen is in communication networks. Again the need in the country, the pace at which the country is moving and the price points at which we need to deliver those I think will to my mind encourage innovation of a completely different kind and that is happening and it will go even further. The third. One of the largest segment of all the electronics industry are mobile phones. And the manufacturing ecosystem of that phones is indeed shifting to India in a very substantial manner. Here, I would frankly not quibble about do we have enough value addition in it right now. It doesn't matter. Let us start even if we are putting them into boxes we know how it looks like. How it feels like. The moment you see that happening the rest of the ecosystem comes into play and it will evolve. I can tell you from my own experience, that the moment you see a plant come up, you have the rest of it, the people who are supplying tools, the people who supply components, and everything develops. I am talking in the context of electronic items. So that is another massive area where I think we can make a change. The fourth one is in defence and aerospace. I would say that the capability that our country has in aerospace is understated, is not recognised and it needs to be scaled up and commercialised like never before. Just take even commercial aviation. The number of aircrafts that this country is going to order or will require is going to be humongous. Why would we not make use of the need that our own country has. Both for commercial as well as for defence aerospace. Translate that into a manufacturing ecosystem. I am saying that specifically in the context again of electronics and so on and so forth. The last I would just say, when we are making the energy transition, when we talk about renewables and all of that, again I think the scale and pace at which these things are happening it requires a different kind of chips, it may not be the 7 Nano-meter and the 4 Nano-meter. But it still requires maybe a different kind of chip. Maybe later on we get to that discussion, I believe that in our country we are developing the compound chips and gallium nitrate and all of that, where again I think we can indeed be the leaders particularly when it comes to power electronics. If you put all this together what does it mean? I would just say that the sooner we get started and make, yet it has to be bound in something commercial, there is no question about it. But we need to connect those dots as I was just explaining. And just be bold enough and brave enough to get in there. We cannot be vacillating about this. We cannot be timid about the scale and size at which... this is not a game for playing in incremental steps. This is not a game for the faint hearted. This will require a lot of commitment of capital, there is no doubt about it. I would therefore argue and I will finish at that, I think it is the onus upon the larger corporates to step forward and take those initiatives and then the rest of the ecosystem with smaller corporates will follow. Let me just stop there. I hope I have made my point.

**Dr Saraswat:**

Thank you. I think the idea of scale is very important. I fully agree with you on that. We will have now Dr Ajai Chowdhry, his views and we will have discussions.

**Dr Ajai Chowdhry:**

Thank you Dr Saraswat. I think a lot has been said about the whole industry. So I would like to take up a few points on the whole area. First of all I would agree with Paul that probably the next wars will be fought with semiconductors. And this is something that Ben Sasse who is the U.S senate intelligence committee chief said that a few years ago. So I think we better realise that that is really where the world is going. When I look at the whole plan for the country Paul one area that me and Dr Saraswat have been discussing in our own separate committee in NITI Aayog is that the gap that we see today is the gap of not having the proper R&D capability being developed for semiconductors. Like the IMEC in Belgium. So this is a weakness among our whole strategy and this is something that we will all work towards, pushing the government to make this happen because this is an area that we must invest. Unless we invest in R&D we really cannot have a long term strategy for semiconductor design and manufacturing. The other most important part which sort of Banmali also referred to is scale. And scale comes from volume of the requirement of the country. If we look at the volume of requirement for the country we should identify large volume products that are required for India. Those large volume products can then be converted from system to chip. If we want a semiconductor plant to be successful in this country they need customers. Where are these customers going to come from? In this country we don't have electronic brands, they have all vanished. Everything is Chinese today. So if we don't design in India and we don't buy components in India where is the customer for the semiconductor plant tomorrow? So we need to go backwards slightly and say – we need to start with products and then from products to go to chips. I think that is really where we will be able to create volume for our semiconductor plants which will in any case come up in three to four years. They are not going to come up tomorrow. So we have time today to do something like that. In our non-profit foundation 'EPIC' we identified certain products like this and one of the first products that we focused on is to look at the driver for the LED bulb. Now this LED bulb in India is made 100 crores bulbs every year. All LED chips are imported from a single party in China. During covid they increased their prices three times. So we went to the industry and said why don't we look at designing this in India. We are actually now working with a fabless company in Bangalore and we are designing that chip. We have talked to a company in Rajasthan who is actually setting up the first plant for packaging and they are going to do the packaging. We went to the government and said why don't we upgrade SCL and make those wafers here. But that did not happen. So we went to a company in Taiwan and we have got the wafers from there. So nothing is going to stop us if we actually think in terms of creating products in India. I think Banmali specifically talked about the geopolitical situation. What used to happen till yesterday was that if anybody wanted a product they went to China, they got it designed in China, they got it manufactured in China and they brought it back to their own country and branded it and sold it. That has been the model. I think as a country we need to move towards being a product nation whether it is software or hardware or semiconductors. All three areas we need to work on. Software a lot of work has happened in the last ten years. We have seen the results of being a product nation in software. But product nation in hardware we have not even started. I think that's something that my foundation and we are working with the government and various state governments to start to work on creating products in India. And really design to manufacture. That is where the requirement is. If you look at chips for example, volume exists in LED, volume exists in microcontrollers for appliances, volume exists in smart meters, volume exists in automobiles and volume exists in so many areas. Like for example, Tatas are now going to be doing the passport. The passport chip itself is a huge number. So each of these are opportunities for India to actually design to



manufacture. That is really the kind of volume areas that we can identify and work towards. In my presentation to the government I have said why don't we identify 500 products that we should make in the next five years. And from those products we can actually come back and start making chips. But if we don't have products how are we ever going to enable the semiconductor plants to succeed. I think that is really where the issue lies as far as my mind is concerned. The other thing is a very nice thing that the government has done, is to create a design linked incentive scheme for fabless companies. I think there fabless companies will get benefit from 15 crores to 100 crores. Each project can be funded up to 15 crores. You can do many, many of the upgrades of that and get up to a 100 crores from the government. I think that is a great scheme. But we need to look beyond that. If you look at product companies in India in hardware or we look at product companies for semiconductors the funding is going to be a very major issue. We do not have a VC industry in India which actually looks at hardware or semiconductors. So it is an absolute disaster. That is something that we need to put together, the funding part. The other part is that we don't value investments by angels or large investors into companies which are unlisted. If you look at the United States they support something like this in a very big way. They have a program called QSBS, you must have heard of that. If you have a 50 million dollar asset company you can invest up to 10 billion and if you make 10 million, you don't pay capital gains. In India we really get stuck in this whole issue of trying to pay capital gains for very, very small things and a lot of angel funded companies have had trouble in the last five years. In addition to looking at certain areas like this we should also look at creating a very good model of funding all these companies as we go forward. If we really want to have a long term vision and Paul was talking about how China looks at thousand years at a time. That is the way to look at it. Do we want to create a Qualcomm in the next 20 years? If you want to then we need to do something about it. We need to fund them, we need to create them, we need to support them and make them happen. Because unless we create champion product companies from India for both hardware products and semiconductor products we really don't have a long term plan. I think that is really where I would like to stop and say there is a great opportunity for India. We have few things that are in place. But a lot of things need to be still brought together. Thank you.

**Dr Saraswat:**

Thank you Ajai.

**Prof Paulraj:**

Can I say a few words? Do we have time? I think all very, very good comments. My remarks are only about semiconductor industry. Focused on that. There it doesn't matter if Qualcomm has got 50000 people here or 10000 people in France, headquartered company is where the leverage is. Qualcomm is a headquartered company in United States and it gives them enormous leverage. So if we get the leverage when we have Indian headquartered companies. So we have to be absolutely clear about it. Whether 80000 or 8 million people are designing chips in India in MNCs we get some salaries but nothing much else. So it is important to understand that. The second thing is Mr Banmali's comment about scale, I think it is happening, it going to happen in many, many areas. Yes. In semiconductors we are trying and this mission it needs a lot of fine tuning and I have a lot of comments and that is why I am sitting in Delhi. But there is also an idea, if we are buying say so many aircrafts from the Boeing why can't we demand that suppliers actually add... I am not talking about low level labour... add real value

in this country. Why can't we demand it? In fact I would say in China at one time they would come and assemble their aircrafts here. But the things changed. It said you form a company in this country. Chinese headquartered, you can own the company, headquartered, 15% IP in the next plane 10 years from now must be from China. Only IP. They are not interested in labour. We have the same leverage. We are buying stuff. So apart from bootstrapping ourselves, those are all complicated policy issues and I don't know whether we can do it, but nevertheless leverage is absolutely true. We cannot flip and suddenly become self-reliant in some form. We are going to buy from outside, leverage that in some form to create Indian headquartered companies. So that is one comment on your side. You made some excellent comments. With regard to Ajai Chowdhry's comments. I would pick up a couple of things. One is just on the fabless semi industry. You mentioned that the Indian VCs are not there. Back in 98 and 2002 in my 25 years ago I was raising 100 million dollars per company to try and make something of it. Today I am in a company where we have raised 400 million dollar in semiconductor hopefully in a venture capital. So that kind of cheque writing is not available in our country. Mostly those cheque writers are sitting in the United States. One road called Sandhill road not far from my house. Rakesh Mohan knows that place. They want to come to India and find these... they are trying to make money but many things we can do with those people who can bring the investments here. But they want something back. We got to engage with those people. I will bring them here. Engage with them and they can write the cheques. They know that out of 10 companies they invest one or two will survive. But they will make their money on that. Today the ecosystem for VC is very limited. In fact just talking about semiconductors, they have been Indian headquartered companies, there is some budding companies and one of them is... Vinayak, I don't want to embarrass you, he is doing a great job. There was a company called Cosmic circuits, Ganapathy Subramaniam that got acquired. Recently Steradian is a radar company acquired by Renaissance but again they became American companies. Nevertheless I am saying that over the next ten years we could be able to create hundreds of such companies, hopefully... some of them will get flipped but that is fine... hopefully one or two of them will grow to global scale. That is the time we arrive. So Venture capital is really required. I think that U.S venture capital should be brought to India and I think they are willing to do it. So those are the two comments that I have. But I am absolutely certain that finally we have political will. I see that very strong. If that can be sustained and then we need advice, this is not the industry that the government can enter without knowledge of the industry. We got to bring them in otherwise we will not succeed. That is one thing I want to emphasise. I spent many years and many visits trying to dig that in. But I am still trying to make it a point. This is not something that can be done by the standard government cadre. You have got bring people from outside who have lived that industry, known the failures, got arrows in their back, none of this is going to be easy. It is very, very hard.

**Dr Saraswat:**

Thank you for the good comments. We have two options unless you have any hard stop on time. I think there are some people who want to discuss. I am very happy that all aspects of what is required for India to leapfrog or get into a participative mode as Paul says into the semiconductor industry have been touched. I just want to give a brief background of what is our country's take on this. I don't know whether many of you have had the historical background of this. Because I have lived through it. In 1970s we used to have transistors being manufactured by Bharat Electronics and ECIL.

**Prof Paulraj:**

Continental devices also. They are still there.

**Dr Saraswat:**

These are the agencies. Then came the era of integrated circuits and all that. Suddenly we found that none of them were venturing into that area. There were visionaries like Dr Arunachalam and others who said – no, we should do solid state physics. Unless we do the solid state physics we cannot capture. So we had courses in many universities to work on semiconductors, work on solid state physics, where even a lab in India called SSPL which was supposed to develop all systems. The situation was that this transition from science to technology in none of the places took place. Except where the products were being done. The SSPL continued to do the materials in a scientific manner and the products were not coming. To the extent that when I was looking for a pin diode for one of my altitude switch at that time. When I was looking for that it was not there and unfortunately US put an embargo on it and I had to struggle. That was the situation as far as 70s and early 80s are concerned. From that time onwards we took a stand and we had SCL coming in, very major decision I think. At that point in time there were very few foundries, very few semiconductor systems in the country and in the globe. But India had a foundry in 84 if I am not wrong. The Chandigarh foundry came. Although it was 350 Nanometer or something of that class, but it was relevant at that point in time. We went into ups and downs. From that time onwards we are trying to see whether we can catch up with this semiconductor journey which the globe has performed. Different efforts have been made and we have not been successful. Reason is R&D in this particular sector as Dr Ajai Chowdhry has mentioned has never been our major forte. We have lived into the science of materials and material semiconductors but we have not translated that R&D into anything worthwhile till very recently. Now of course some IITs and all that has started doing that. We have been living in a very interesting kind of an assumption that India is importing 400 billion dollar worth of semiconductors. We are forgetting that we are not importing semiconductors, we are importing boards on which some ICs are sitting there for different commercial and strategic applications. Actually our import if you say chips or ICs or AMICs or whatever that is it is very limited. And that is precisely happening only in some strategic sectors. The DRDO imports specific devices which they use for design, DAE imports, and space department imports and maybe some other IITs and things like that for design. So when you look at the product which is what Dr Ajai has mentioned actually we are not designing products. If we are not designing products the question of consumption of those chips is not there. That is where always we had this catch 22 situation. What for? We don't have a market. If we don't have a market how are you going to scale up anything? How are you going to produce? So SCL could never be scaled up. Even when we got into the renewed SCL I think some time in 2000 and all. We still went on with 118 Nanometer but with limited production capability. We never thought of enlarging the wafers for month or something like that. We did not do that. Now coming to the present scenario where we want to do that I think all the suggestions which have come out and where we see the pitfalls, I personally put one factor even there. Because Dr Paulraj mentioned very clearly in his first statement R&D led manufacturing. I think this is the one point which you have to take from your talk today and which I have been insisting even with my semi-con committee which I am chairing. That while we are on the one hand we are trying to shake hands with the international partners who can come and set up foundries along with us I think the first major step that has to be taken is to create an R&D ecosystem in the case of semiconductors. To that

extent I think the PSS office did a very good job. When we with the help of IIT Bombay we came out with a full document on R&D fab and R&D what is to be done... of course some people said it is useless, it is not worth looking at it and things like that...but even today I feel that whether the document is good or not, whether the need for R&D fab in whatever form we can say... he mentioned that should in the form of IMAC, I am also feeling that it should be in the form of IMAC. We India should push that and all the actors who know this, whether they are in India or abroad, they should be made a part of that. I think there is a small difference I would like to mention on this about the Indians who have been trained in US and Chinese who have been trained in US. The way Indian government deals with them and the Chinese government deals with them, there is a marked difference. That is where I am not able to make use of the Indians trained in the US and other countries effectively for meeting the demands of India. Whereas China follows a different rule. I think all of you know it. I am not going to elaborate on that. But if you don't use the diaspora which has been trained, the human resource which is needed for running this kind of a system will never be available. Our skilling machines which is there in the IITs and IISCs and all that is very limited. After all there are only four Nano science centres in IISC, IIT Bombay we have one, IIT Chennai we have one, IIT Hyderabad we have one and I think one or two more in some universities where we can say that this kind of training which is being imparted. SCL has sort of remained static in creating a new human resource. So second part which is needed for doing ecosystem as I mentioned, the human resource part. The third part, we have imported about one billion laptops and 70% of them for the government purpose. Don't you think we have a demand? I am sure we import so many millions of setup boxes, so many millions of energy meters, so many millions of cell phones... I am keeping it aside because most of it is MNC done. So I am not keeping that \_\_. I also want to give you an information that India has already come out in its policy today that if anybody for example Apple is going to set up a shop in India will have to do over a period of three years 50% localisation. That has been made part of the foreign direct investment agreement. I think many of you may be knowing this. This is the reality today. Initially we didn't do it. But NITI Aayog persisted and it happened. So demand aggregation certainly is important and if we do the demand aggregation and I request the industry, don't worry about the semiconductor. Please worry about the product. If you design the product here, if you design it here, semiconductor automatically will be available. If it is not available tomorrow with the help of government's policy if we succeed we will be able to provide that. The demand for semiconductors Dr Ajai Chowdhry's idea of aggregating that in terms of all that is very important. We need to have the same approach like IMAC have. I will give you an example. Most of my designers are having problems of IPcos. And they are not able to get it for many reasons. Cost is very high or government is not able to afford. IMAC has been able to do that for this entire thing. They are able to provide for all the researchers the kind of IPs which are needed. So we said that this similar system why can't we have it? So I personally believe that the academia, the industry and industry has to certainly make a major role to play in this. I am saying the government will invest which has already been decided. But industry if it doesn't come forward we are likely to run into problems. I will without naming the company, I had a dialogue with one of the corporate house. Major corporate house in this country. I will tell you my response to attract them despite the government announcement of 76000 crores as an investment from their side was very lukewarm. Well, we will look at it. We will see what the market is. We will see if we can acquire some ATMP company abroad and things like that. At the end of it, it is almost six months, I am not able to persuade them. So if the industry giants,

if they are not going to come forward, you know the kind of money which is required. 76000 crore is nothing. What is needed is billions. He says about 4 billion dollar or 6 billion dollar. You have talked about 52 billion dollar is U.S's chipset which is investing now. Unless the industry comes with an equally matching investment and come forward to set up this kind of a thing, merely saying that government should come, government should come... government is coming. It is ready to even increase this input from 76 to 116 thousand crores also. That much I can tell you. I think industry has to take the weight. It has to be run by industry, it has to be maintained by the industry and marketed by them. Then only the ecosystem will flourish. These are my comments. If any questions are there, we will be very happy to answer. The panel is ready to take on.

**Dr Montek Singh Ahluwalia:**

Thank you very much. Really fascinating presentation. You had a very stimulated discussion among yourselves. I want to sort of step back a little. Because as the discussion proceeded a couple of things struck me. One is there seems to be general endorsement that in the design area we have the human skills. We don't have corporations headquartered in India. That is a fair point. Now the question arises if we have the skills...

**Prof Paulraj:**

Montek, I will just pick that point. Those skills are sitting inside MNCs and assuming that we arrive and we have Indian headquartered companies, our goal should be to pull some of the talent out. That has been very difficult. I have been trying also. It can be made to happen by some more policy measures.

**Dr Montek Singh Ahluwalia:**

So the key thing there which appeals to me is that these guys have already demonstrated an ability to produce up to the quality needed for the global market. What is happening is our own headquartered companies are not able to step in and I think both of you two very distinguished members who know what the constraints are on that side. Here is a case where we have the skills and we have the market. So it seems to me that that should be the highest priority. Let us have one or two Indian headquartered companies that do a good job in this area. The rest of the discussion, the sequence seems to my mind a little wrong if I can be provocative. Because you are going forward and saying where is the scale. And we are importing these things. In the government the logical thing will be stop the imports. So really the question is if all these products everybody who is succeeding in this area is not producing for a protected domestic market. They are producing for a global market. So the question that to all of you I would like to pose is that are we going to design policies which will be based on the assumption that the ecosystem in which it will develop is people will not be denied the right to import. But we will support people so that they can become competitive. Otherwise the argument keeps going on. I think Mr Saraswat said we are importing all these computers for the government. Some joint secretary in the finance ministry can solve that problem by just saying stop the import. This is been the source of 95% of our problems since the 1970s. So what I want to hear from you guys is, is there some way in which you can put forward something that will reassure sceptics that that is not how we are going to go. That is my only question.

**Dr Saraswat:**

Can I reply to your last point? (Break in video) ... for the domestic market or the global. This kind of a product is for the global market number one. Only domestic thing comes into picture this way. We are late starter in the game. The world is already producing millions and millions of products. And if my country is going to start producing similar products, it has to be competitive. If it is not competitive then the Indian industry will close down. This is what has happened in the case of many sectors. India had a thriving component industry, electronics component industry in the country. Thriving. We used to have passive components, registers, capacitors, inductors, everything. Many companies. What happened? When the Chinese import was permitted in a big way, all those companies have become traders today. So we have to design a policy in such a manner that you demand aggregate so that at least there is a certain level of domestic demand without imposing major duty structures on the import can be met through the government procurements. So that that scale can be increased at the later stage. Today what happens, scale cannot come immediately. I can understand manufacturing one billion immediately, it is going to take time. So this gradual progression will come. Don't stop imports, but at least have secured demand coming from sectors which are well within our control. That is all what we are making.

**Dr Ajai Chowdhry:**

I would like to add a point. Including HCL we have a whole bunch of engineers who actually do semiconductor work, Indian companies. So TCS, HCL, Wipro and all of us have close to about 30 to 40 thousand people who actually design products for the world. We only do for the world. We don't do for India.

**Dr Montek Singh Ahluwalia:**

I don't understand that. Are you saying that they are making products for the world?

**Prof Paulraj:**

Services. They provide design services to multinationals.

**Dr Montek Singh Ahluwalia:**

Indian companies who do that?

**Prof Paulraj:**

Wipro, HCLs all. Absolutely. But let me come back to the core. The core is let's talk about fabless. To fab. We need Indian headquartered companies. One of the core to make it happen is talent. Really, really good talent. A lot of them are sitting in MNCs. Maybe some are sitting in HCL also. I know many of them. Come out and start a company, where is the money? They need a track of 100 million dollars of investment to have a chance of succeeding. There is no such money in our country. We have to solve that problem. It can be solved by building a U.S India corridor and all other things. That needs a lot of fine tuning, but can be done. The second thing is, in general, the point that Dr Saraswat mentioned is, we know these people are superb engineers but all marketing, product management, those kinds of skills are still not here. They are all sitting in headquarters in the United States. Typically an Indian headquartered start-up will be to start it here, have an outlier to do some of those functions, we can hire people there. A good sales guy is half a million dollars. It is expensive. We find some team there in U.S or wherever you want. Engineering absolutely we can do it here. The only missing ingredient is

venture capital. I am happy to go into it and that too can be solved. But one thing is it will probably be U.S venture capital but Indian government can also participate. There are lots of models. UK model, Australian model, if someone listens to me I am prepared to tell them.

**Dr Banmali Agrawala:**

If I may just make a point. I think we are painting this with a very broad brush. Meaning, if you looked at the spectrum and there was a slide that professor put up which is all the way of let us say the equipment that makes chips to the actual act of making chips and then further downstream. I think why can't we get started in places where we can at least plant our feet, stick something in the ground and get started, rather than looking at this with a complete spectrum and going for the most difficult end right on day one. That will take some time. It will happen, but it may take some time. Perhaps we need to pay a little bit of attention in the downstream things that we can get moving, get a feel of it, touch it, feel it, know what the ecosystem looks like and then move upwards. I am not suggesting we go sequentially, but it will happen sequentially because these are more doable. Maybe we need to get started with that.

**Prof Paulraj:**

I would absolutely agree. I will also say my focus is... I am from Stanford and I am only talking from the commanding heights... but I would agree that things can be done there. Therefore for example in foundry the OSAT segment is something we can really enter. And I am hoping that people like Tatas will enter there.

**Dr Saraswat:**

Somebody there wanted to ask something?

**Audience no 1:**

I had a small question more specifically around the R&D ecosystem in itself. One anecdotal example that you gave was you got a student of yours outside the system who set up his own factory but still chose...

**Prof Paulraj:**

He was a company doing AI, chips and all that.

**Audience no 1:**

His own company but still chose to set it up headquartered in the US rather than in India. So in terms of business environment for someone who wants to foray, there is clear preference towards the west or towards that. What can India do in terms of structural changes to actually get people to set up businesses in India?

**Prof Paulraj:**

I have been involved with a lot, in fact in Bangalore last week I met with about 25 companies. In fact they started they flipped to U.S because they see a lot of issues on taxation on repatriation and a number of issues. Those we have to fix. Even have to bring 100 million dollars company, they will flip. Other countries like China has solved it. Korea has solved it.

We can solve it too. But it needs government to understand what the issues are and solve those problems.

**Dr Saraswat:**

I can add to this. The Indian ecosystem for setting up business in our country, we have been debating in NITI Aayog for many months on this. Not just for semiconductors but generally for any industry. There are four major handicaps which we have. India's cost for say power, India's cost for land, India's time delays for various clearances, India's interest rate on capital cost and India's logistics cost. All these factors are adversely balanced today towards opening any business in India. Successively we have not in a position to handle most of them. Sometimes if we tweak this, sometimes we tweak that, as a result we are not able to actually... in fact if you look at the FDIs, now we are in a position to relax many of these things as part of this. If you look at today's semiconductor policy many of these factors have been taken into account while releasing this semiconductor policy. So improvement is there but much more is required to be done.

**Audience no 2:**

I have invested in semiconductor companies in India as well as in U.S. the companies in the US thrived and the ones in India didn't. I think the biggest challenge that we have in the fabless industry in India is two-fold. There are a lot of worker bees. There are not enough people who are experienced and can do an innovative architecture. That is the only way you can actually have a start-up in a fabless system. Second in order for money to come you need the venture capitalists who are actually used to seeing some profit in investing in the semiconductor companies. They don't exist in India. It takes too long a time to train them to do that. So we need to basically figure out a way of attracting those kind of people to invest in companies based in India. That is where a government policy should be focused on. Get the intelligent people from U.S and get the money from U.S and that is how it is going to work.

**Prof Paulraj:**

Some of them are sitting in India. But inside Qualcomm and dot coms. But I agree. But there we have some excellent talent there. Let me introduce Vinayak. He has got a semiconductor company Indian headquartered I believe. He is able to actually get market from United States. It is an amazing story.

**Vinayak:**

Thank you so much. Great discussion. Dr Saraswat and Prof Paulraj and others. I will speak on the fabless chip design aspect of things because I have some experience on that. I think from an Indian perspective I do believe that it is one of or should be one of our sweet spots. We do have manpower there. There is as Dr Saraswat pointed out is however is correct, that we have about 20% of the chip design manpower in India. But because they are let us say working at Qualcomm in Bangalore or St Micro in Noida and what have you, they are not trained to do a full ASIC. I hire from them. I have to train them for a year before they are ready. I am speaking from that lived experience. Point number one. However I think fabless chip design is our sweet spot. To build a company from India I think three points that I have learned. One is I think the thing that we should leverage here is it has to be dual use. Aerospace and defence is an extremely interesting valuable sector where a lot is anyway happening under make in India



under Athmanirbar bharat. If we try and leverage the microelectronic mission, semiconductor mission along with the dual use components I think it is a way to get started. Military and aerospace can never be in itself a final and only market but it is a very good starting market. The second point is you have to think global from day one. Whether that means us selling in the US, us having a board of advisors who are sort of international. We have partnerships with IMEC by the way. We have on our board people from Stanford and others. What happens there is, in India we have always made the mistake of thinking about tech transfer. I think what matters more is knowledge transfer. Problem with knowledge transfer in the eyes of government is it is not a book, it is not tangible, so what is the blueprint and what am I gaining. But actually knowledge transfer is far more sustainable long term than tech transfer. If you learn from the Chinese actually knowledge transfer is what they were obsessed with. If you don't focus on the headline of IP being stolen etc. but knowledge transfer is what they care about. So that is the first point. I think we are also poor negotiators. When it comes in, I think this is probably the best time I have ever seen the government to do anything pro start-ups, pro deep tech, pro make in India, but there is a lot of fine tuning required. Whether it is design linked incentive, whether it is the lot of the other make in India initiatives there is a lot of fine tuning that is required. What I mean by that is from the governments perspective they are very good negotiators when they are dealing with an Indian corporate or an Indian start-up. The same people become very poor negotiators when you have to deal with the west, when you are dealing with Israelis, when you are dealing with the French, when you are dealing with the Germans, you do not negotiate properly. Whether it is in your procurement, whether it is in your aerospace. You are talking about the passport chip, I don't know how many people know most likely that contract is going to go to a European company. There is only one company in the world which can design and fabricate that technology. So European company and we all know the name. Did the government think or should the government think about... that company has a landed Indian entity, it has a landed Indian office, it has Indian employees, the government should negotiate – ok, in ten years X% of the IP should be in indigenised like the Chinese. I think that is something we don't think through when negotiating with western companies. We do a good job negotiating with our own companies. Because we look at our own companies as vendors and guilty till proven innocent, we don't do that with the west which is what we should be doing. SCL is a great example with a badly negotiated deal. Very, very badly negotiated deal. I don't know who did it, but you were negotiating on digital technology, you didn't even talk about... 180 Nano-meter on digital, not even analog. These are the few points. I think dual use, better negotiations and thinking global and fabless is our sweet spot, in my opinion again maybe I am biased, are the way to go about things.

**Dr Saraswat:**

Very good. Excellent.

**Anshuman Tripathi:**

Anshuman Thripati, I am a student of Prof Paul, Stanford GSB, I was part of the team of students who started the 'incubator, accelerator at campus' at Startex, sold companies to Apple Google in semiconductors, done over a billion dollars in fabless activities. Sirs know me here. I presently work with the national security advisors office as a NSA member of National security advisory board. To come back to the point on the fabless side of why we have not been able to do, the expectations that one person would make the full chip is wrong. Because as Sir

was talking about it takes a village to bring up the child, we have a lot more people. So the expectation from a start-up or a product company to say that we hired one person and India doesn't do it, having done chips myself having U.S patents I can say Indians can do a full chip, there are people who have done it. There are start-ups which actually work with Chinese companies to make the designs for them. And then that is exported and imported into India. Just a clarification on that point that we have and as HCL and TCS has, a big group of people doing the chip design. Full chip. But the expectation that one or two people that we hire into a company and they will do it would probably not correct and is a wrong expectation.

**Prof Paulraj:**

Once you get the leader, he will pull out other people. I mean 20 to 15 years ago I was doing entire full chips, everything in Bangalore.

**Dr Saraswat:**

I just want to correct you on that. There is no such expectation that 'A' will design. A company will design and they will have their tentacles, they will have all pulses to attract people of different disciplines to make this happen. It has been corroborated by a person who has come out from that kind of an oven himself. So you can see that. Even companies like HCL, Wipro and TCS and all that, I know from the point of view when I was in defence, I used to ask them to make devices for us. We did not get. If they had the design capabilities I was ready to take those designs to UMC, TSMC. Even that is what we did in our SITAR. Sitar was one of our... Anurag was one of the place where we used to design. And we used to get them manufactured in the foundries abroad. But none of the companies... now only slowly the fabless sinks like youngsters like him slowly they are coming up and they are taking up the task and I agree with him when he says that he can attract people to do a certain job. That is the kind of ecosystem we are trying to develop now. Certainly we have people. No doubt about it. In fact fabless is our sweet spot. No doubt about it.

**Dr Ajai Chowdhry:**

Actually Paul you talked about flipping of companies. And I was talking to a very, very major investor from U.S. He told me about this program called QSBS. He said this is the reason. I am a nationalist. I want to invest in Indian companies but I only invested Indian companies who have flipped. Because the kind of benefits that I get from the U.S government on cap-gains are phenomenal.

**Prof Paulraj:**

So I think the whole taxation laws... By the way there are couple of companies now going...The Indian stock market is liking the technology. So we can actually go public here. But nevertheless we need to deep think through that because if even we put lot of government money and create companies and they all flip, then we have nothing left.

**Dr Saraswat:**

Anybody else? Any other points? If there is nobody else, I would like to say that we had a very fruitful discussion and excellent overview given by Prof Paulraj. Participation by all the members was excellent and outstanding. Both my esteemed panellists have also given their view. I would only request because many of you have vast connections across the globe. India

semiconductor program which has been given major push by the government with the investment policy which has been given now, requires, I will quote from what Dr Paulraj said, 'you need people made industry'. And China has been swapping from the U.S, Taiwan, Korea and so on. We are looking for Indian Americans and Indian French and Indian Taiwanese and ...

**Prof Paulraj:**

Yellow, black, white, whatever it is.

**Dr Saraswat:**

Yellow, doesn't matter. If they can be made part of this journey I think we will be able to achieve what we are talking about. Because those people will only make the Indian semiconductor program successful.

**Prof Paulraj:**

I agree absolutely.

**Dr Saraswat:**

I request all of you to facilitate that. Thank you very much.

**Rakesh Mohan:**

Let me first give a few comments and then of course thank everyone. First I think maybe it is because I am a simple economist that this has been the most fascinating discussion that we had since I came to CSEP two years ago. So absolutely exciting for me, particularly because I have always been very interested in manufacturing and those of us who participated, Montek is here, in the 1991 reforms and onwards, the whole reform, the industrial policy etc. was really to ramp up Indian industry of manufacturing. Somehow it just seems to have lost steam in the last 10 to 15 years. It's been a source of big puzzle to me which I really don't understand. So I think lot of the emphasis Banmali and all of you actually talking about manufacturing is extremely important and I think that many of the people in India which is I think majority including economists and so on say we missed the manufacturing bus. We are a services country. I think this is just utterly wrong. Hogwash when I use an un-parliamentary word. One of the things that I talk about in that is that – look there are about four billion people in ASEAN, plus three, China and South Asia. If you are going to grow at four or five percent a year or something of that order in terms of GDP over the next ten twenty years huge demand for products. As opposed... of course services will also be there. So we have not missed the bus in every category of product actually. So Banmali yourselves, Mr Chowdhry who are in business, who are in the private sector, particularly of course in the large conglomerates, somehow the conglomerates have also gone off into services. I won't name him. But one of your previous chairs when I went to ask him – look what are Tata's plan in manufacturing. He said we are into services now. I was depressed for the next one week when I heard that. Really, I think this is extremely important.

**Dr Saraswat:**

My depression has not gone ever.

**Prof Paulraj:**

But I think Chandra has got it.

**Rakesh Mohan:**

It wasn't Chandra. This is one of the earlier ones. That is why I am very excited and anything Dr Saraswat that we can do to help. Even just generating discussion, interests, convening, you know whatever we can do to take forward this interest, not just semiconductors, but manufacturing as a whole. I think this is extremely important because apart from that we need to do that... but employment is the biggest issue in front of us. R&D again I am absolutely delighted on the emphasis on R&D. Again something that I have been interested in since I was doing electrical engineering and science policy and so on. My good friend Naushad Forbes we have been working together... not working together... but he wrote a chapter in a book 'India transformed' where again the biggest disappointment in the last 30 years is that neither the private industry nor public sector have increased the investment in R&D as a portion of GDP. In fact report R&D portion of GDP today is lower than it was 30 years ago. It has come down. So again I don't understand. We had thought that we are bringing more competition to industry which we had in terms of policy. They will invest more in R&D but they have not. I just don't understand. Except pharmaceutical industry where they have invested a good amount in R&D.

**Dr Saraswat:**

Because private sector invested.

**Rakesh Mohan:**

Banmali Tatas I think you should tell Tata sons to set aside X% for R&D come what may. And connected with that the people issue. Montek is here and many of us who came back from the US at 95% cuts in our salaries when we were asked to come back. That is because of the excitement of working here. It was not a sacrifice at all. I am much more comfortable here physically as well as otherwise than I would have been there. But it is just because that Dr Manmohan Singh rang up and said come home. My point on that is that if the industry leaders kidnap in some sense... these 80000 designers in MNCs, labs in India, they will come. You just have to be little more daring. I think this is a really very exciting things for us. Chairman of the UIDAI is here. Saurabh Garg. What we have done in Aadhaar in the whole payment system, in my view, CBDC is completely irrelevant for India because we have done a fantastic job in the payment system. Everyone has electronic money actually. Everyone from the fruit seller. When we go and buy fruits he says pay me on PayTm on the cart. The things that we have done on a very large scale we just haven't done a lot of it in manufacturing. I can go on a lot. I thought I would just express my excitement of this discussion and if we can from CSEP if we can launch programs to help this... we have been wanting to... we will be excited. Just remains for me to thank Professor Paulraj for a start for taking the time to be with us and having this great discussion. I have certainly received a big education today. Dr Saraswat for agreeing at a pretty short notice actually to do this. So thank you very much. Mr Ajai Chowdhry, Mr Banmali Agrawala, we have known each other for some time. But not very critically. Because I was out of India for almost ten years. So, thank you very, very much indeed for a very exciting session. Thank you.