ALUMNI CENTRE™
BENGALURU

saturday
WEBINAR

THE WEBINAR BOOK

VOLUME 2 | AUGUST 2021

edited by
ASHOK KAMATH

A WORLD OF INNOVATIVE MATERIALS

PROF. ASHOK MISRA | JUNE 20, 2020

Prof. Ashok Misra is currently a NASI (National Academy of Sciences, India) Distinguished Professor at the Indian Institute of Science, Bangalore. Earlier he was Director IIT Bombay; Chairman-India Intellectual Ventures and at IIT Delhi. He is a Director on the Boards of Jubilant Life Sciences Ltd., Jubilant Pharma Ltd., Kirloskar Electric Company Ltd. and Higher Education Financing Agency.

Earlier he was on the Boards of Reliance Industries Ltd., NTPC and RCF. He has held several responsibilities with MHRD, including Chairman of the Standing Committee of the IIT Council. He is a Fellow of National Academy of Sciences India and was its President from 2006-08; a Fellow of the Indian National Academy of Engineering; Founder President of the Polymer Processing Academy; member of several professional societies and the Founder President of IIT Alumni Centre, Bengaluru.

Dr. Ajit Sapre is Group President R&T, Reliance Industries Ltd. He has over 40 years of experience in hydrocarbon business, and new business development based on cutting edge technology commercialisation. He received his PhD from the University of Delaware, MBA from Cornell University and BChem from ICT Mumbai.

His experience includes technical and managerial assignments in research, engineering, business, manufacturing, licensing and corporate planning. His experience includes oil & gas production, refining, petrochemicals, polyester, lubes, renewable energy, materials and synthetic biology areas.

Lecture at IIT Alumni Centre, Bengaluru, by Prof. Ashok Misra, President, IITACB, June 20, 2020.

Link to the webinar : https://www.youtube.com/watch?v=bk9VI-aCqB4&list=PL0zMQ-70IHIX-df3u2Tto6dkKHCRC6iFL&index=11

Mr. Ashok Kamath: Good evening. I am the Secretary of the IIT Alumni Centre in Bengaluru and this is our 11th consecutive Saturday Webinar which we started after the pandemic lockdown. We started in the middle of April and we have had a variety of talks on a variety of subjects. Today's topic is very innovative - you normally think of Polymers as something that you don't want to have because of plastics and the environment and all those concerns, but it turns out that it is a world of innovative materials and we have with us today two of probably the best known people in the world in this area. It is my pleasure to introduce Professor Ashok Misra who has in his career been across pretty much every IIT in the country, starting as a student of IIT Kanpur, Faculty Member of IIT Delhi, Director of IIT Bombay and Chairman, Board of Governors of IIT Roorkee and as a Member of the IIT Council, so he knows the IIT world better than probably everybody else. Prof. Misra's work has been in Polymers; he has been on the Boards of several companies in the past including Reliance Industries and NTPC. Needless to say he is a Fellow of the Indian National Academy of Engineering, Fellow and President of the National Academy of Sciences (2007-08), Founder President of the Polymer Processing Academy, and, of course former Director of IIT Bombay and Founder President, IIT Alumni Centre, Bengaluru. Along with him we are fortunate and excited to have Dr. Ajit Sapre, Group President (R&D) of Reliance Industries and has spent over four decades in polymers, beginning his education at what was then called UDCT, now called ICT in Mumbai, then doing his Ph.D. at the University of Delaware and following it up with an MBA at Cornell and he has been at Reliance for a long time and Dr. Sapre, we are delighted to have you on this webinar. I would also like to introduce to you my colleague, Dr. Susheela Venkataraman who is the Joint Secretary of the IIT

Alumni Centre, Bengaluru and she will help both Prof. Misra and Dr. Sapre navigate through all those questions from you. I am now handing it over to Prof. Misra to start his talk on Polymers A World of Innovative Materials.

Prof. Ashok Misra: Good evening everyone and it is actually a pleasure to be able to share some knowledge about polymers, etc. which has been part of my life. As Ashok Kamath mentioned I went to IIT Kanpur and then for my graduate studies I went to Tufts University, USA and one of the reasons I chose Tufts was because there were two Professors in Chemical Engineering who working in Polymers and then very soon I realized that the University of Massachusetts was almost in the backyard of Boston which had the finest Polymer Science & Engineering Department and also currently is in the world. So that took me to UMass and then polymers has stuck with me in my life. I worked with Monsanto and then I worked with IIT Delhi and IIT Bombay and so on. I would like to take you to the world of Polymers, no equations in my talk, very little bit of science but mostly to give an idea of the breadth of applications and the kinds of innovative materials this family of polymers can produce. So I will go with that and then you will see that bunch of slides which are quite large but it is a little show intense so you can ask questions as you go along obviously.

POLYMERIC MATERIALS

- Polymerization is one the biggest contributions of Chemistry in the 20th century
- It involves the conversion of a large number of small molecules to form long chain molecules:

  POLYMERS or MACROMOLECULES
- The variety of materials possible in the family of Polymers is very large
- Polymers modified for attaining specific properties
- Blends and Composites to attain higher performance

I have been saying this for some time that polymerization is the biggest or one of the biggest contributions of chemistry in the 20th century. It is a hundred years of Staudinger's (Hermann Staudinger) mention of long chain molecules - he is one of the founders of polymers in the world and so we are celebrating that this year. What it involves is the conversion of large number of small molecules which are joined together to make a very long chain like a thread, a very long thread at a molecular level of course and we call them polymers or if you prefer we can call the macro molecules because they are macro nature which I will describe a bit. The variety of materials is of course very large because there are many different kinds of small units that can be linked together and the properties can be modified; we can have blends; we can have composites; we all hear when you say FRP people just say FRP is the material of some product but what

WHAT IS A POLYMER?

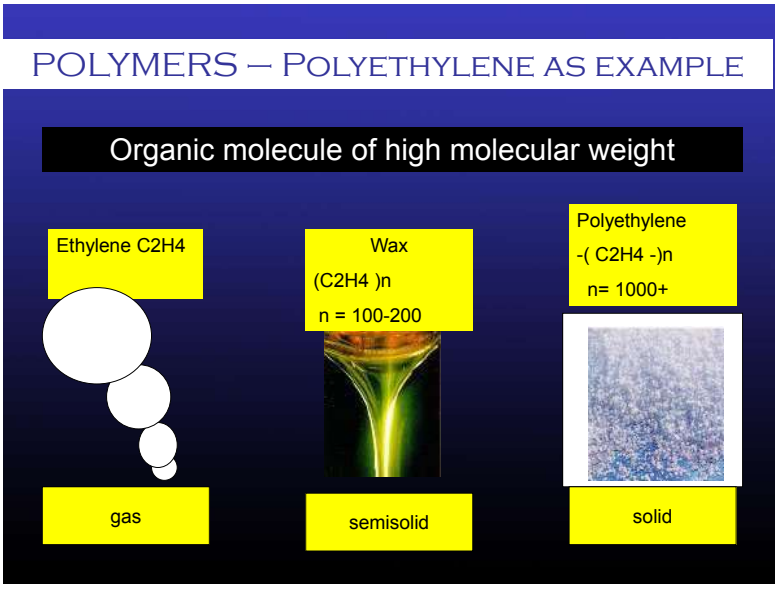
It is a large molecule made up of repetition of small simple chemical units (MERS) – It is a macro-molecule

Poly	-	Mer	-	Units
Polus	-	many	-	Meros

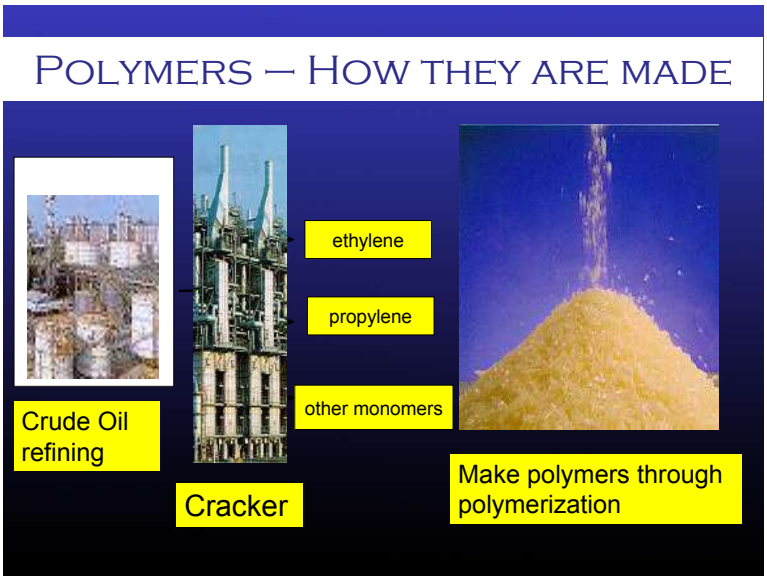
e.g.	Polymeric sulphur	(-S-S-S-S-S-S-)
	Poly (M)	(-M-M-M-M-M-M-)

Synthetic polymers:	polyethylene, polypropylene, polybutadiene, polyvinyl chloride, polyester, polyamides, polyisoprene, polytetra fluoroethylene, etc.
Natural polymers:	Wood, silk, cotton, rubber, skin

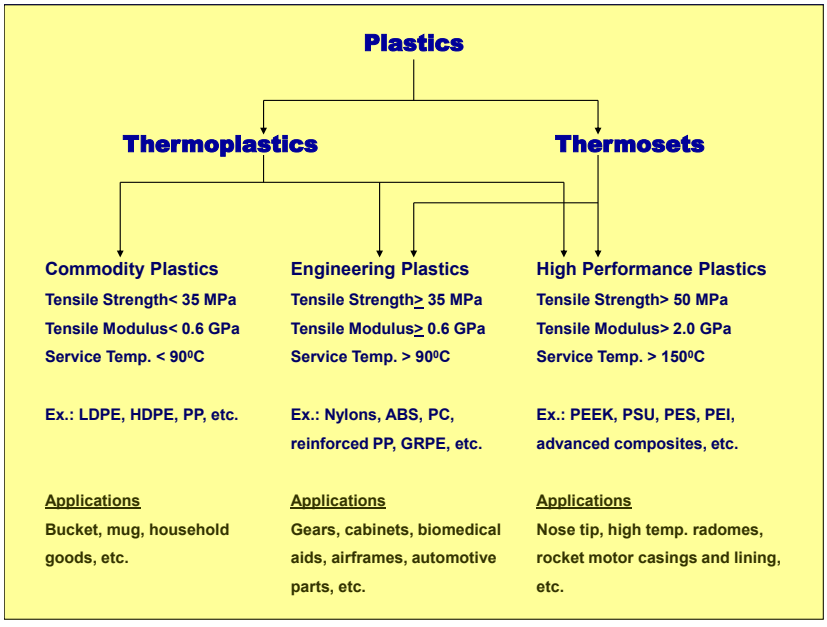
it is, is nothing but fibre reinforced plastic. I know there are lot of people from the polymer field attending but those who are not, for them just a little idea of what polymers are, what it is all about. Basically there is a simple chemical repeat unit that we call MERS, it is Greek word, poly means many, so many units are linked together we get a polymer. If you link sulphur which happens in nature that sulphur can be linked together we call that polysulphur, if you have M whichever M may be we will call it poly(M), if it is ethylene we call it polyethylene, if it is vinyl chloride we call it polyvinyl chloride and so on. These are what we call the manmade polymers that we are dealing with. But nature also makes polymers - wood, silk, cotton, rubber, skin, bone and so many other things are polymeric materials which means long chain molecules which are linked together, DNA, I forgot to mention that, these are all made by nature and we have not been able to fully mimic nature, and so on. So there are natural polymers and synthetic polymers.



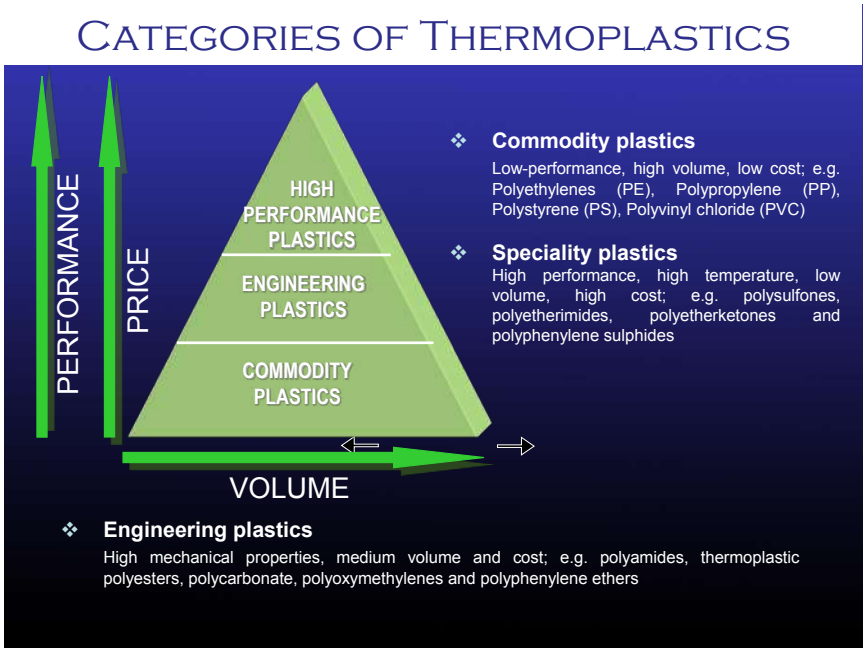
What happens when you say many, what is the meaning of many. Ethylene as you see it, ethylene is a gas and it has no properties in that sense, if you link up three or four units it becomes a liquid and if you have about 100-200 units linked up together we get wax and the candle that you burn in the house or the wax that you use for polishing a car is nothing but a polyethylene of a very low molecular weight doesn't have strength but if you have n number of units which is thousand or



greater, now you have long chains which start to get entangled with each other just like if you take a lot of strings and put them together, it becomes a mess to actually separate them so this is what happens at a molecular level long chains are inter meshed with each other and give the strength. So what happens, you take crude oil, it goes to a refinery and then you take some part of it and take it to a cracker and on the cracker you can get its headstream ethylene, propylene or many other monomers and then through a polymerization process for a reactor you make polymers which looks like granules which was shown on the initial slide and if you put colour they become green, yellow, red or whatever colour you want to give them and these are the polymers of granules, chips or whatever you want to call it which make the final product. So if you break them up there are several kinds of polymers and I will go through them briefly,

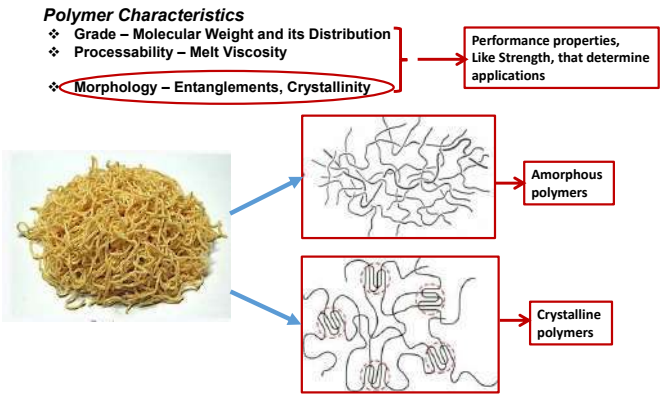


throw more plastics which can melt in and can be reused again and again and there are some thermosets like the melmoware that you have sometimes in the house, these are thermosets and they can only be processed once, they cannot be processed again because they go into crosslinked mode. Since thermoplastics consist of a large number of polymers, a family of polymers, I will concentrate on that a bit and this could be divided into commodity plastics which we see every day,



polythene bags for milk, polypropylene chairs and articles that are made or PVC hose pipes that you use outside in the garden or you can have speciality polymers which have special properties and there are a whole bunch of names which I won't read out. Then there are engineering polymers which have load bearing capacity, so they can withstand impact and can carry a little bit of load and a classic example of that is in the car bumper which can take quite of beating before it actually cracks so that it comes into the engineering plastic and as everything else in life, if the performance is more the price is more with the more specialized polymers are more expensive, the commodity polymers obviously are a

Amorphous and Crystalline Polymers



little bit less expensive. So now we have amorphous and crystalline polymers, on the left side of the slide we see that, this is what on a molecular weight, it look like spaghetti but longer than spaghetti or noodles which are all mixed up together and sometimes not easy to separate out and if they remain in that fashion that means in a disordered fashion as we see here on the right side, then we have them as amorphous polymers but sometimes they have the ability on a molecular level to orient themselves in such a manner that they fold back and forth and form crystals and these polymers becomes crystalline polymers and because of these crystalline regions the strength of these crystalline polymers normally are much higher than amorphous polymers. Just to give you a little idea, amorphous polymers, therefore, has only one phase and therefore it is clear. So if you are using some polymers for eye contact lenses or for headlights, headlamps in a car, then they would be clear. Many times you see a politician, a Minister or so speaking at functions, who has a plastic shield in front of him, it is basically made of polycarbonate which is of a certain thickness which will be bullet proof but being amorphous you can see through it. Crystalline polymers because of two phases would generally be hazy in nature because there are two phases so light gets scattered within inside. One of the examples is that if you have a PET bottle, it is made in such a manner that it is amorphous but if you put it in boiling water it will crystallize and then become hazy, you can try that experiment at home.

The other thing is that when you are making these long chains, the process is such that you will not make all the chains of the same length, some will be longer, some will be shorter because they don't terminate and they keep on growing and they don't terminate at the same time and therefore you get these curves, you can either have a narrow molecular weight distribution curve as we show here in the red or a little broader molecular weight distribution curve and when you want to tell somebody that my polymer has a molecular weight you have to do an average.

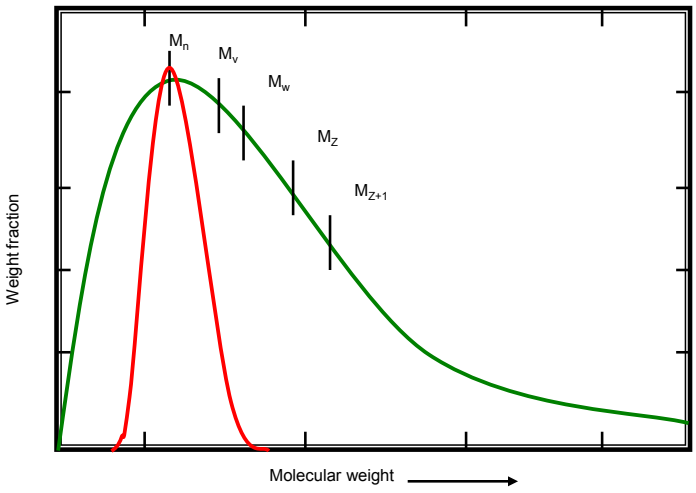
Molecular weight and its distribution

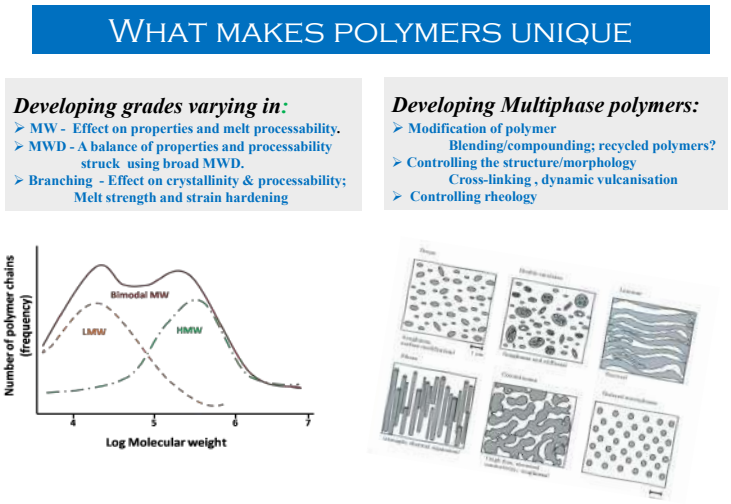
$$\overline{M}_n = \frac{\sum_{i=1}^{\infty} M_i N_i}{\sum_{i=1}^{\infty} N_i} = \frac{\text{Total weight}}{\text{Number of polymer molecules}}$$

$$\overline{M}_w = \frac{\sum_{i=1}^{\infty} N_i M_i^2}{\sum_{i=1}^{\infty} N_i M_i} \cdots\cdots (N_i = N_i M_i)$$

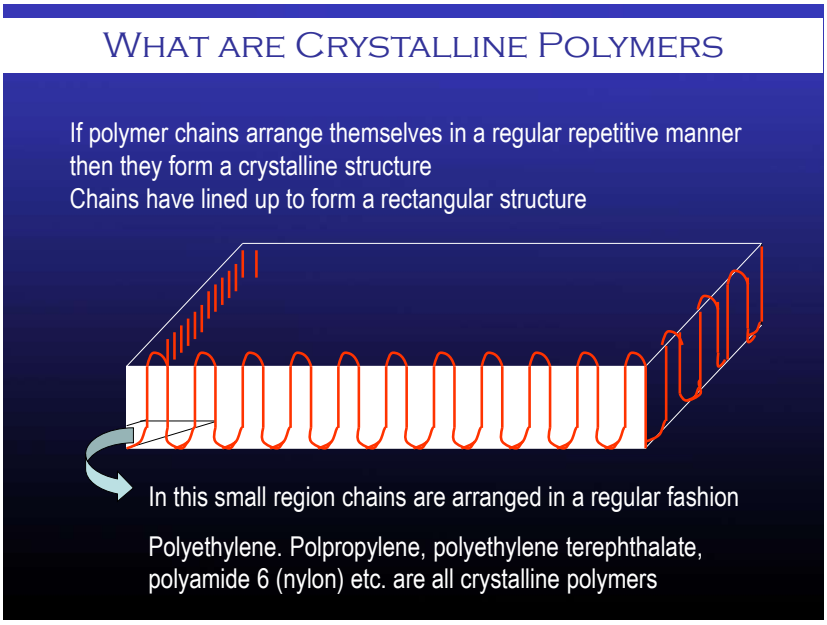
$$MWD = \frac{\overline{M}_w}{\overline{M}_n}$$

Weight average MW is most common. MW and MWD determines the performance properties of a polymer

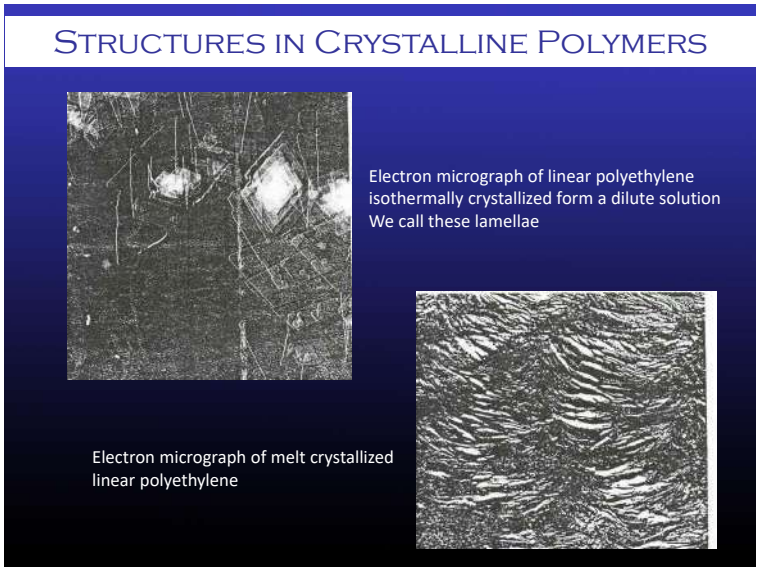




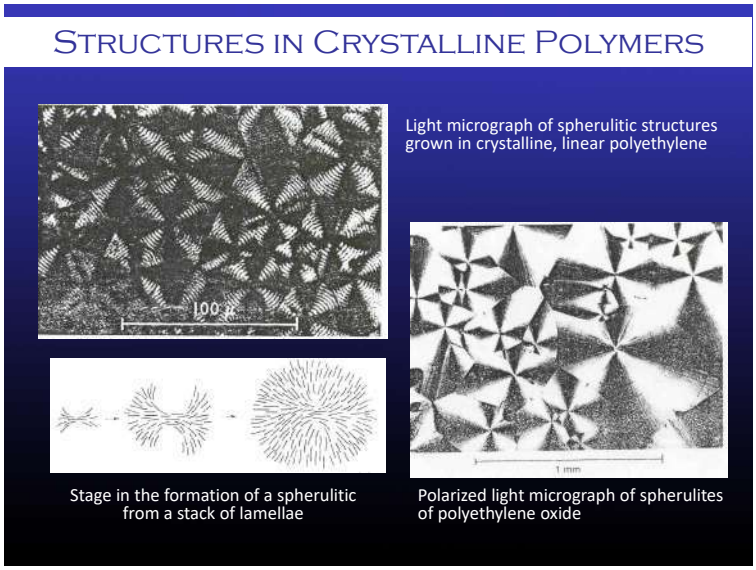
These are the only equations that I have to describe the average, which is based on either number average molecular weight or weight average molecular weight, weight average being higher. Then what we call a molecular weight distribution, there is a molecular weight distribution index, we can take two ratios weight average, number average and if it is a narrow one it will be 1 but if it is not it will be more than 1. So what we do is we can develop various grades of materials we can have bimodal distribution polymers which will have two molecular weights mixed together one in the lower side and one in the higher side one will give you ease of processing and the other will give you the strength so these are the things you could play around with normally common people will not know that but I am just mentioning that. We can also blend materials or cross link them to produce and give different morphologies. We can control these morphologies which

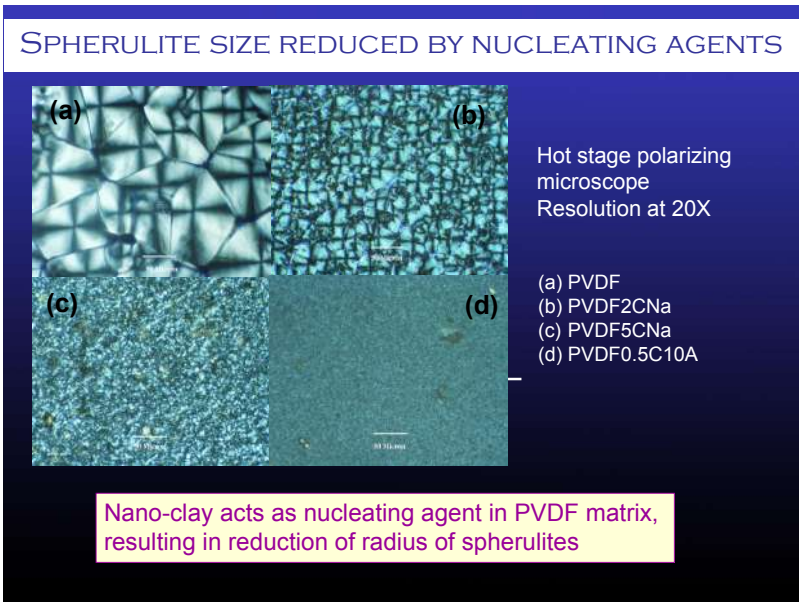


actually control the properties. So what you see as a user, is the final product but you don't see what is inside.



Now crystalline polymers are important so I will spending a little more time on this. The polymer chain fold back and forth in what we call as a folded chain array and examples in your daily life of polyethylene, polypropylene, polyethylene terephthalate, polyamide – this is how a crystal is formed and these crystals form a lamellae and you can see these diamond-shaped lamellae by an electron micrograph and very beautiful and this is if you would make these crystals from a solvent. When you make them from a melt you can see the lamellae which are sitting next to each other and these lamellae then organize themselves into a sheaf like fashion and then a spherical fashion. So the polyethylene bag that you have in which you get the milk in the morning if you actually analyze it under a polarizing microscope you will see these beautiful spherulites, the two kind of spherulites that shown here



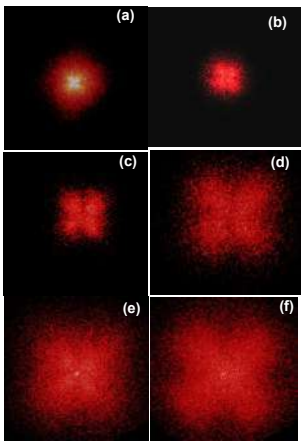


and there are ways to control the size of the spherulites and so on. I will mention it a little bit which control the properties. So this is an example that polyvinylfluoride one of the polymers, it doesn't matter what is it anyways, big spherulites and we wanted something to make the spherulites smaller, so you put a nucleating agent and you can see this spherulites some smaller and very small and this can then affect the kind of properties that you get.

I have spent a lot of my time doing light scattering of polymers so therefore I just thought I would show it, the beauty of this way of looking at spherulites is that you pass light through a polymer sample and it gets scattered – we see patterns which are quite beautiful looking – these are using a red laser light. The beauty of this is the bigger the spherulites smaller is

SPHERULITIC SIZE BY LIGHT SCATTERING

POLYMER LAYERED SILICATE NANOCOMPOSITES



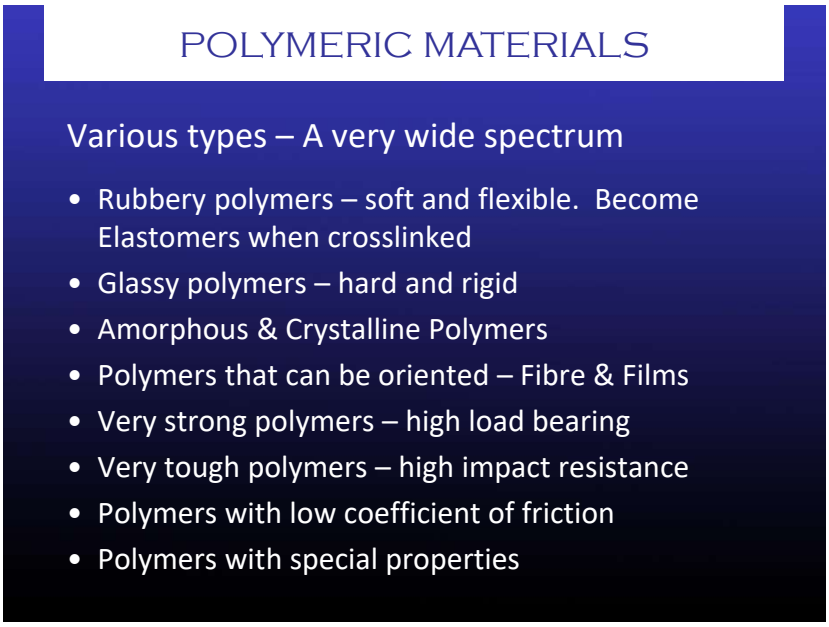
$$R = \frac{1.025\lambda_0}{\pi n \sin(\theta'_m/2)}$$

R = average shperulitic radius,
λ_0 = wavelength of the light in the air,
θ'_m = corrected scattering angle for maximum intensity
$\sin\theta'_m = \sin(\theta_m)/n$
where n = refractive index of sample

Sample	Average spherulitic radius, R (μm)
(a) PVDF-iso*	22.8
(b) PVDF#	18.8
(c) PVDF2CNa	13.3
(d) PVDF5CNa	8.1
(e) PVDF0.5C10A	9.7
(f) PVDF0.5C18P	4.6

*PVDF crystallized at 156°C
#PVDF film prepared using compression mold at 200°C and air-cooled.

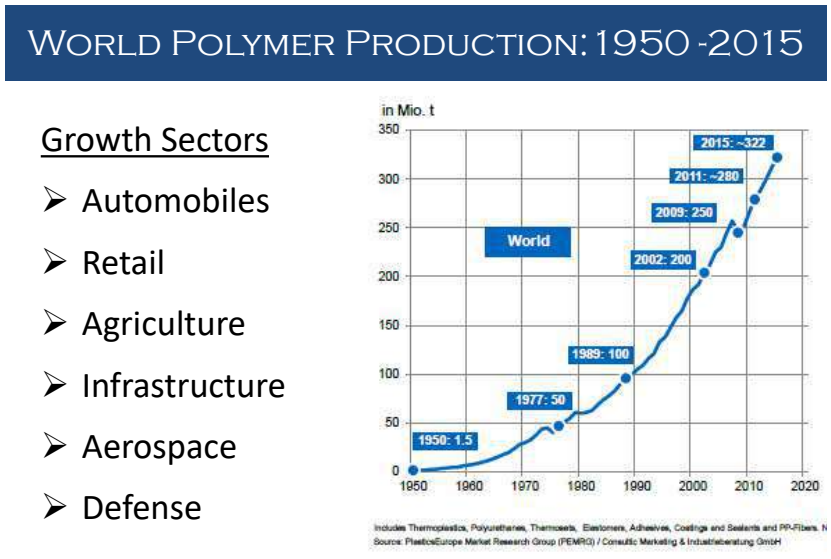
the pattern but smaller the spherulites bigger is the pattern whereas a microscope you are stretched to see very small spherulites but like in this previous case the light scattering pattern smaller spherulites gives you very big patterns and you can analyze them.



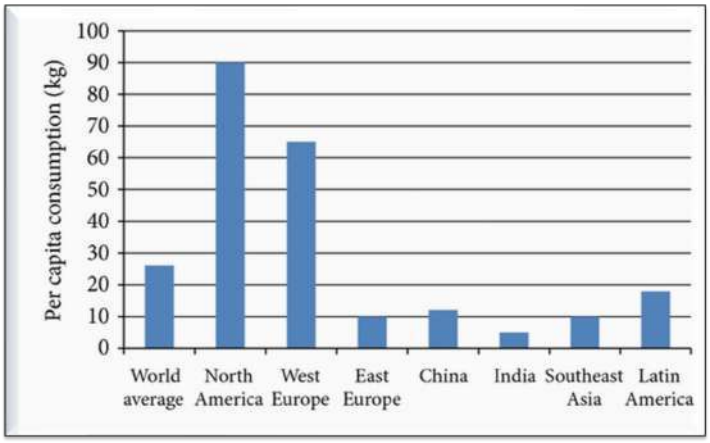
The spectrum of polymeric materials is actually very large, there are rubbery polymers which are soft and flexible and they can become elastomers when you cross link them. If you take a chewing gum and then what happens is at the room temperature it is what we call as a glassy polymer but when you put it in the mouth, mouth temperature takes it into through this glass transition and becomes a soft rubbery polymer. If you are in a crunch for any adhesive you can actually take a chewing gum chew it and use it as an adhesive, you must have seen that people stick the chewing gum on the bottom of the desk and very difficult to remove it. Then there is amorphous and crystalline, there are polymers which are specialized for making fibres like nylons and polyesters and so and then there are very strong polymers very tough polymers like polycarbonate that it is bullet proof and so on then there is low coefficient, you must have heard the word Teflon, tetrafluoroethylene, and this provides you very good lubrication

Commercialization of Selected Polymers		
Polymer	Year	Company
Bakelite	1909	General Bakelite Corp.
Rayon	1910	American Viscose Co.
Poly(vinyl chloride)	1927	Goodrich
Styrene-butadiene copolymer	1929	I. G. Farben
Polystyrene	1929-30	I. G. Farben and Dow
Neoprene	1931	DuPont
Poly(methyl methacrylate) (PMMA)	1936	Rhom & Haas
Nylon 6, 6	1939-40	DuPont
Polyethylene (LDPE)	1939	ICI
Poly(dimethyl Siloxane)	1943	Dow Corning
Acrylic fiber	1950	DuPont
Poly(ethylene terephthalate)	1953-54	DuPont/ICI
Polyurethane block copolymers (Spandex)	1959	DuPont
Poly(phenylene terephthalate)	1960	DuPont

and so on. I am not going to read through it but just to give you an idea that the first polymer which were made was in 1909 called bakelite and rayon later on and then polyvinyl chloride and styrene and so on and so forth and after 1960 there are many many polymers but this was the main era in which new family of polymers were developed and the companies which developed them. Just to give you an idea the growth of polymers, uses of polymer are such that other materials may be following a linear path but polymers are following an exponential path as you can see, this data is only up to 2015, I couldn't get more recent data, but this is about 350 million tons per year which is a huge amount and on the left side there are various sectors in which they use – Automobiles, Retail, Agriculture, Infrastructure, Aerospace, Defence and so on. Then there is another term that we



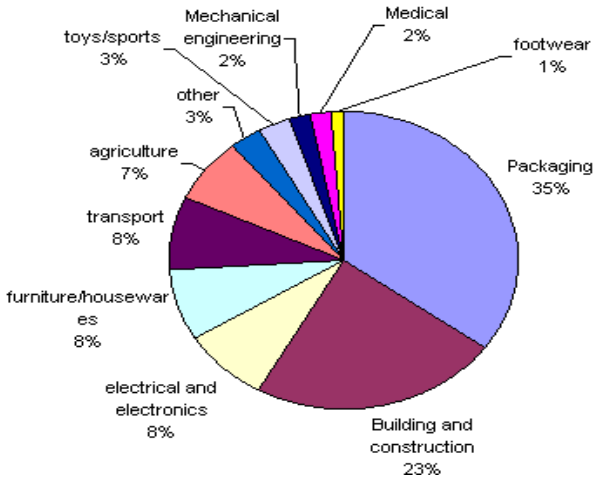
Per capita polymer consumption



use in the polymer field is per capita consumption, how much is the usage by an individual of plastic materials. Whereas in North America, USA, Canada and so on it is about 90 kg/person, in Europe it is about 60 plus and in India we are still as Ashok said we keep saying no to polymers, we are the lowest users of polymers in the world or one of the lowest.

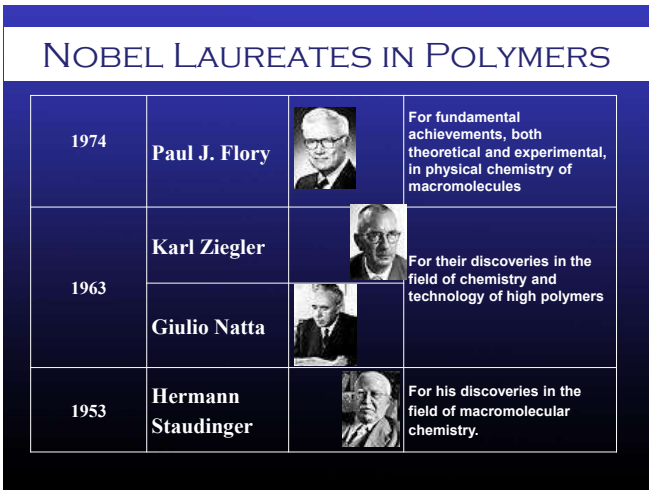
The uses of polymer sector wise, packaging is a huge sector followed by building, construction, electronics, transport, mechanical, sports and sportswear, footwear and so on and so forth, in fact talking about the footwear, today almost every footwear you buy has a sole which is not of leather but of some sort of a polymer or the other and has a huge market in India as we are one billion plus people and two billion shoes/footwear the

Uses of plastics – Sector wise



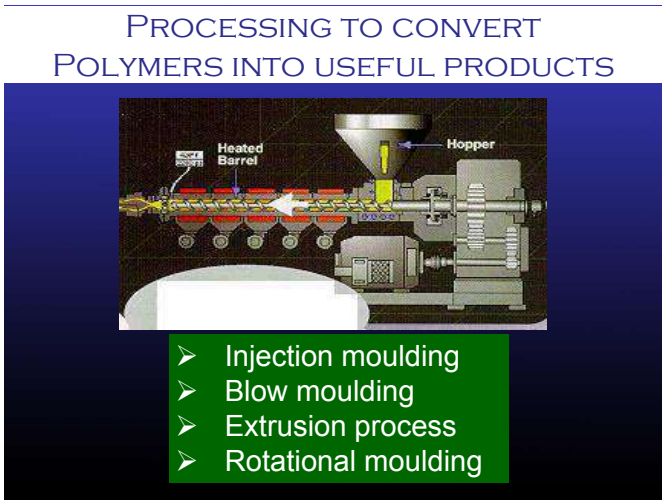
Today's Reality: Plastic products have become an integral part of all our lives, and play an irreplaceable role in our day-to-day activities

least if everybody has only one pair of shoes/footwear that is the kind of volume that we talk about. It is packaging which is little bit critical for the disposal and so on and I will talk about that later.



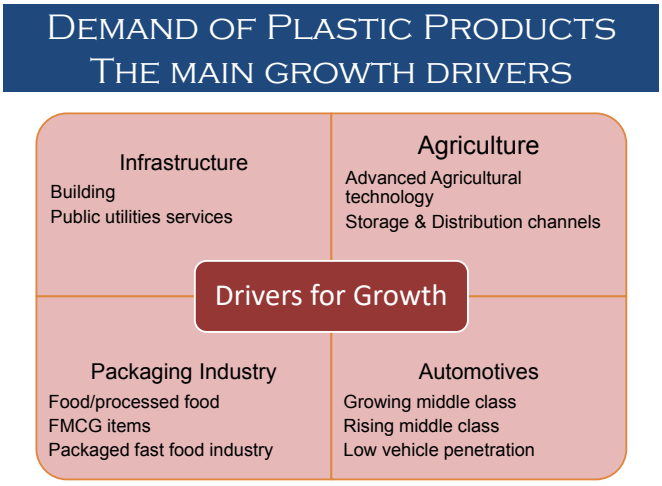
I just wanted to flash the names of some of the people whom we hold them in very high esteem and we consider them Gods of polymer science – Paul J. Flory, Karl Ziegler, Giulio Natta, Hermann Staudinger who specialized in developing some unique methods for making polyethylene and there are several others but I have taken only four of the several Nobel Prize winners.

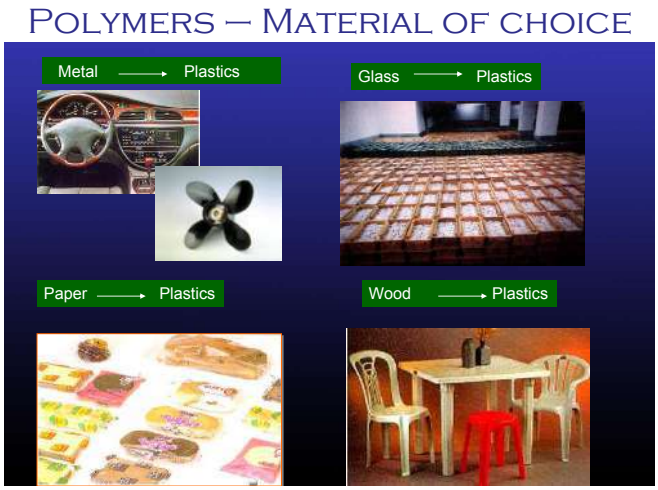
Now let me take to the realm of applications from carry bags to use in cars, planes, rockets, ports and so on. First of all these are granules that you saw in the first announcement slide, they have to be somehow converted into a product and there are several processing methods, injection moulding, blow moulding, extrusion and



so on through which they are converted into products and I just have this slide as I just saw it on one of the roads in Bangalore going by, look at the guy, he is carrying about twenty matkas/pots each on both side and I can't think of any other material that he could carry this many number of things just on his shoulder and then he takes it and sells it in the villages or wherever and the ladies take it for filling water from the river and they carrying it and if it falls down, it won't break like an earthen pot.It is not heavy and so on. So it has a huge advantage of strength and light weight.

So demand in several sectors: infrastructure, agriculture, automotive, packaging as I mentioned little earlier, the material of choice, they are replacing metals in many applications so I am just giving a few examples. The fan that you have in the motor

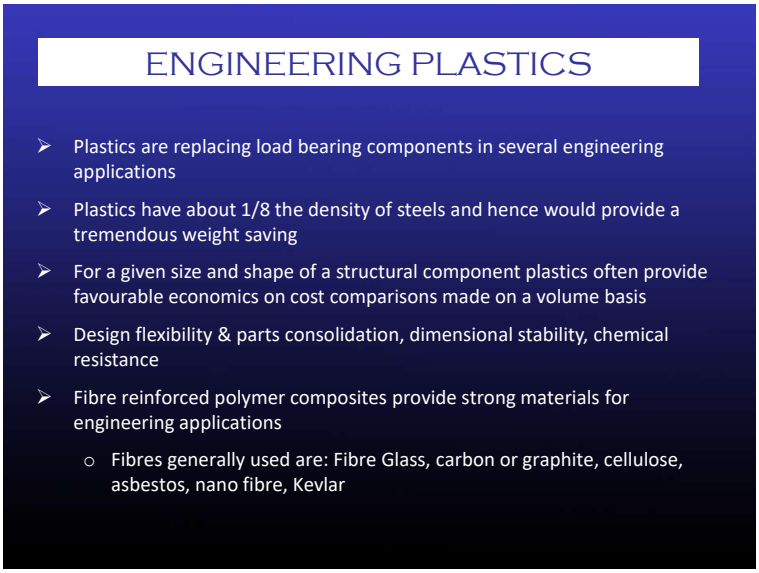




car as an example, it was metal for years, the car bumper that one had used to be metal for years/decades and also dashboards. With the advent of new materials and new technology, polymers give the strength and make the cars much lighter and for seven odd kg of reduction in weight, you increase fuel efficiency by a kilometre or two per litre and so on. In many places instead of glass now plastics and now being used which helps you to not have breakage and so on, wooden things are replaced by plastic outdoor furniture for example, it is very much involving plastics, they don't warp, they are not attacked by termites and so on. Paper to plastics, packaging and there is a whole bunch of products that you see in everyday life the cell phone cover, the pots, pans, pipes; water pipes used to be metal

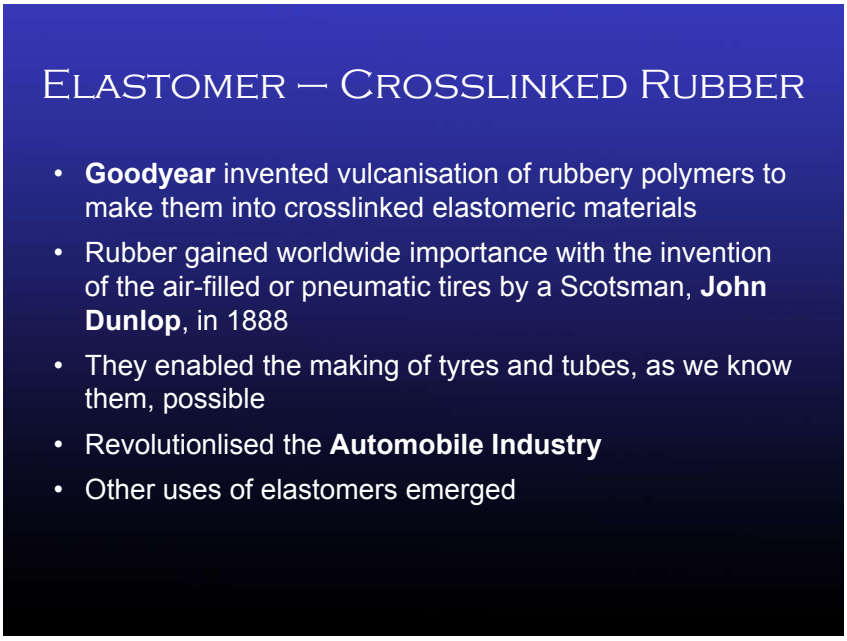
galvanized steel. Today, practically no one buys pipes which are of galvanized steel anymore, home pipes are all PVC but for larger transportation of pipes there are high density polyethylene and so on. Further, children's furniture, packaging etc. are huge volumes where plastics are now used. One of the bigger things which has not come to India is the currency. Australia was the first country to use polypropylene in currency notes, advantage is it doesn't get wet, it doesn't get torn easily, of course you can cut it but it can't be torn so easily and of course there are challenges of making them so that people don't have counterfeits.

Engineering plastics are replacing load bearing components, they are about 1/8th density of steel and therefore a huge weight saving advantage for a given size and shape. The structural components of plastics provide favourable, economical



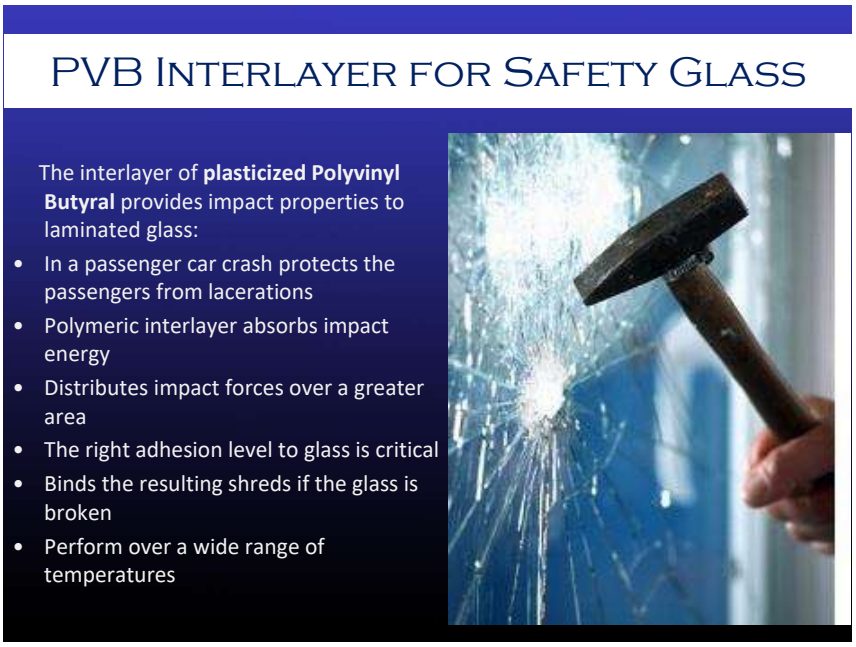
design flexibility parts consolidation like a car bumper - in one injection moulding step you can make a car bumper but whereas when it is still there are several steps that were involved, they have dimensional stability and overall chemical resistance, they are not attacked by acids. Then there are engineering plastics made from fibre reinforced composites to make polymers even stronger materials. Fibres can be fibreglass carbon, graphite, cellulose and so on. Therefore, there are the several application areas and I won't read them because they will be coming later slides. In Automotive applications, as I mentioned earlier, there is a car bumper, there are headlights even in my time when I was buying cars if you had a little accident the headlight will break you have to change it – now these are made of plastics. There are several other application – inside cover, the dashboard, back lights, are now all made of plastics. One of the greatest thing in automobile sector is the crosslinked rubber. Mr. Goodyear invented the vulcanization process where rubbery polymers which means the soft polymers that I was talking about can be cross-linked to make a net like structure. So it is to describe it the easy way, you have strings but if you put them together you make a net of volleyball or for tennis and those nets you can stretch on one way or the other and then he will come back

to the original shape. On a molecular level the cross-linked materials gave a great worldwide importance to



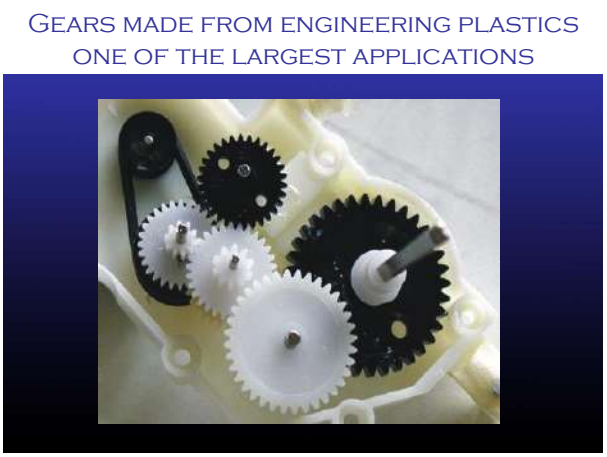
rubber based materials. Mr. Dunlop made the tires and the air filled tubes – between the two of them they revolutionized the car industry. Earlier there were horse carriages that ran on wooden wheels and so on, now cars could be run on tires which are made of rubber, you don't feel the bump of the road and so on and so forth. It is huge thing and people just take it for granted of course these days and you still have the names Dunlop tyre and Goodyear tyre and so on and so their legacy goes on.

Another very big example, some people may know it but many of you may not know is the safety glass that you have in the windshields of the cars. This is actually a three-layered material with inter layer of polyvinyl butyral so you have glass on the outside polyvinyl butyral (PVB) in the inside and glass on the inside so when you are looking through the windshield you are actually looking through a composite of three layers – glass PVB and glass. What it does is that the interlayer of plasticized PVB provides impact properties to laminated glass. In a passenger car crash, protects the passengers from lacerations, the passenger doesn't go flying through the glass because the glass will not break and keeps stuck because of the plastic in between or the polymer material in between, the polymeric interlayer absorbs the

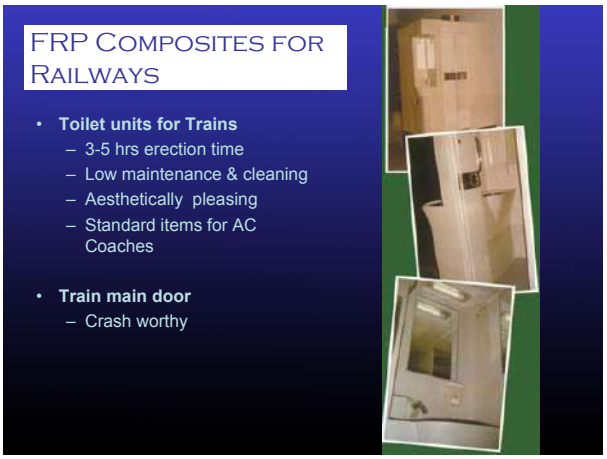


impact energy, it distribute impact forces over a greater area. Of course such windshields work on a wide range of temperatures from India to North America, Russia and so on, it is a beautiful material, it gives you that safety factor which is much needed. This sort of safety glass is also used in architectural buildings and if you ever notice in airports and if it is open on the glass side you will see this glass and there is inter layer of polyvinyl butyral. This is the beauty of this polymer, you see it every day but you don't know that it is in front of you. If you take it to the next level that in between this you put a layer of polycarbonate, so there your glass, PVB, polycarbonate PVB and glass again, now you have the glass which is safety glass which is used in cars of politicians. For example, when President Trump came to India he had this bullet proof car, all its glasses, all around were five layered, glass and the PVB which does not let the glass shatter and polycarbonate which makes it bullet proof. There was talk about using this sort of thing in prisons but don't know it is true, so if you have this sort of glass the prisoners cannot break and escape

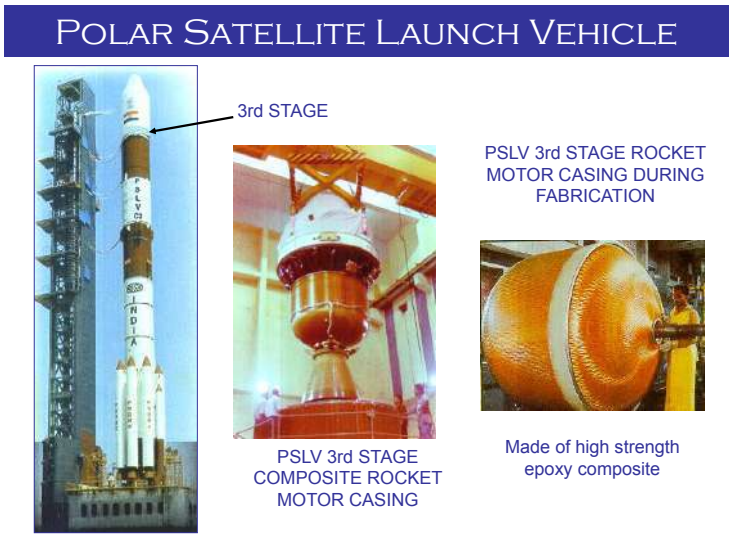
from prison and you don't have bars so therefore it is like a feel good factor that you are in a prison but you are not so called behind bars.



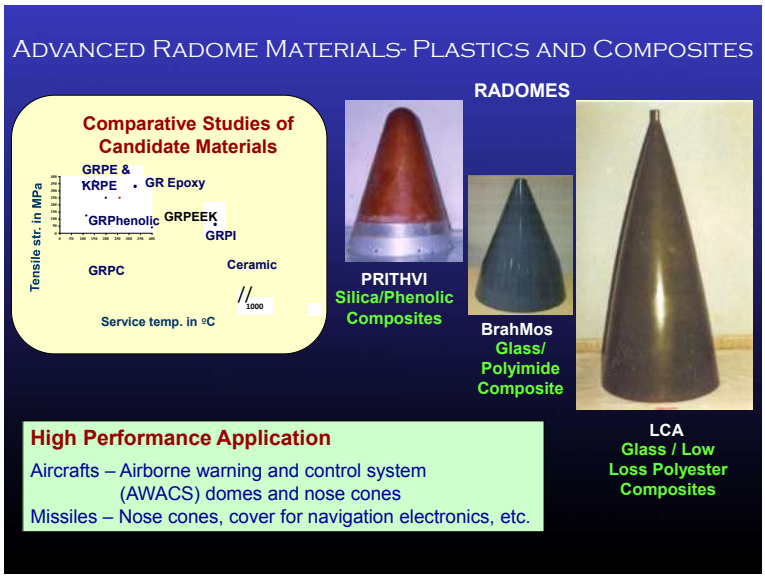
Gears is a very huge application area, almost all gears for small appliances, cars and so on and so forth are made of plastics today. In the railways there are lots of use of plastics, especially in the AC compartments, toilet units that are once piece moulded together by fibre reinforced plastics and can be erected very quickly, the train main door can be crashworthy and can be replaced. In aerospace industry, of course in a passenger aircraft, next time when you fly just notice everything around inside the aircraft is plastic, the seat, the window shade you have, the luggage compartments above, the toilet, everything is plastic which makes it lighter and better. We have the light helicopter which is made by HAL, it has Kevlar-polymer bodies, blades, rotor head assembly etc., space shuttle has several internal parts made of plastic and I will show them, what is the



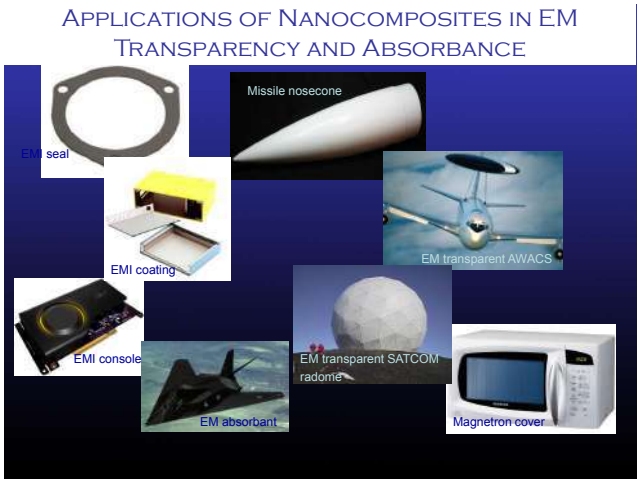
advantage is that you don't have so many rivets and fastners, etc. and these rivets actually gives you drag reduction, therefore efficiency of usage in terms of drag which will slow you down because of rivets will not be there, number of parts required as I mentioned for the car bumper are much less and easy to assemble, easy to replace and so on and so forth. Aircraft bodies in passenger planes are still aluminium and their alloys but in combat aircraft they are already plastic bodies. The current slide shows the light combat aircraft which is it's final stage of development and if you go around Bangalore, you will see units of Tejas, at HAL. The body of Tejas aircraft is made out fibre reinforced polymers, very efficient fibre reinforced plastic which makes it lighter, makes it also make it invisible to radars, it cannot be detected because it is plastic and not metal, so it doesn't reflect the radar signals and therefore it has a really good electromagnetic shielding possibilities. In the PSLV as ISRO people call it, the

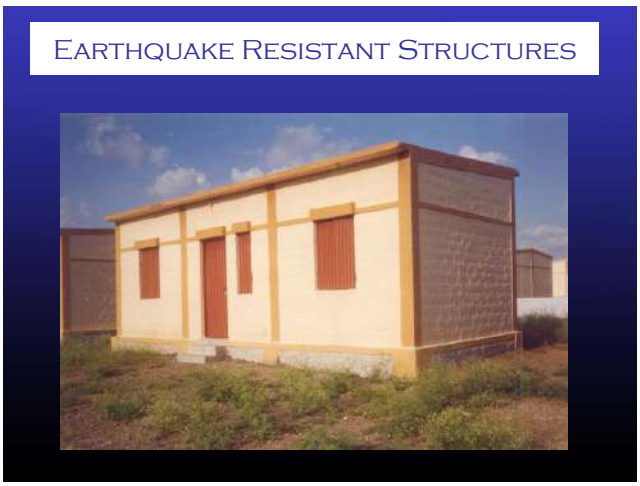


Polar Satellite Launch Vehicle, there are several parts of plastic material again to make them better and cost effective, one of the big things in a Space Shuttle is fuel and normally we have liquid fuel petrol, diesel, aviation fuel and so on, on cars and aeroplanes but this is solid fuel which means that it is a polymer which burns. So actually if you burn a candle it is also fuel, it can give you some energy, candle burns



and you can heat something with it so in this you have solid fuel because you cannot afford to take so much liquid fuel which can be very favourable so huge amount of applications in the radome materials plastics and composites in all missiles where glass reinforced plastics are used and several other transparency and absorbent materials made of nano-composites, EMI coating, in shielding and of course in the microwave ovens that you have in the house. In building and construction, floor and roof slabs, fibre mesh, bridging, construction of water overhead tanks (in India we have huge amount of overhead tanks), canal lining (when you use plastics in canal lining you don't use water to the ground due to seepage), precast concrete for pipes/walls,





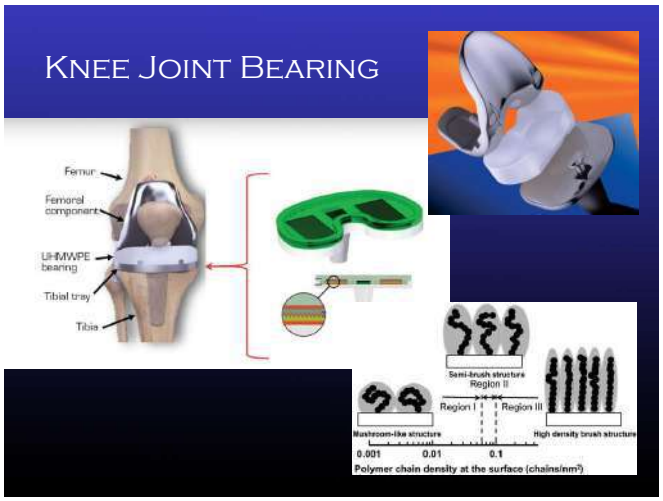
highway, street and highway pavement overlay, mining and tunnelling and so on. Earth quake resistant structures, they may not look like huge houses but they are in areas which are prone to earthquakes, like in Latur. These were deployed and they work very well. In agriculture, drip irrigation as you may heard, plastic materials have made huge inroads in terms of better irrigation and of course can make greenhouses made out of plastic films which is shown on the left side of the screen.

Sports Applications

1. Tennis/squash racquets
2. Fishing rods
3. Golf clubs & carts
4. Skiing equipment- snow & water
5. Protective helmets for racing
6. Baseball bats, cricket bats etc.
7. Canoes and kayaks

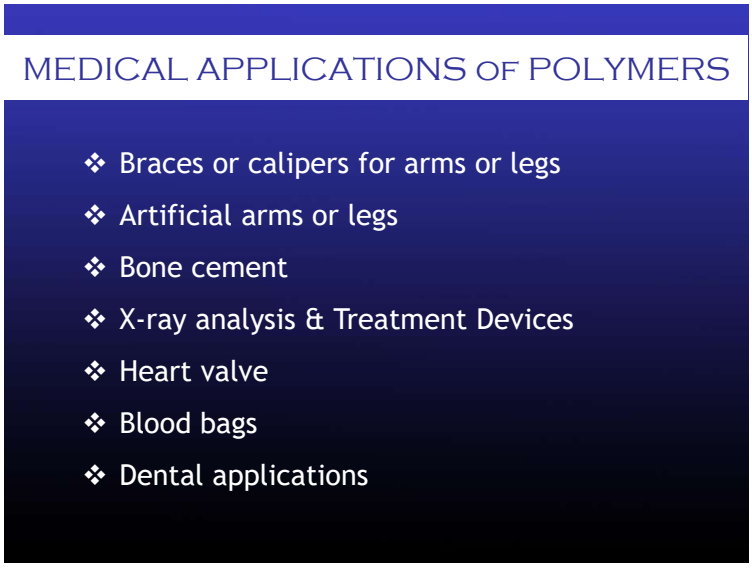
In sports, I started playing tennis way back in the 60s with a wooden racquet, today's children will not even realize or know that tennis was ever played with wooden racquets because now we have all fibre reinforced graphite racquets etc. and they give you better playing strength and last longer and you will never go back to wooden racquets. Baseball bats, some golf clubs, ski equipment and so on have converted to plastic materials and we are still waiting for cricket to change from wooden bats/stumps to the composite bats/stumps, cricket probably is one of the few sports left where we use wooden bats etc. in the larger sense, in tennis courts whether it is a grass like or whether it is a hardest court, they are all polymers, 4-5 layers of polymers are used there. In badminton courts the surfaces are not wood any more, better on the feet. On the right side, you see the racing track, earlier racing tracks used to be red sand/red clay, people used to run on that and now it

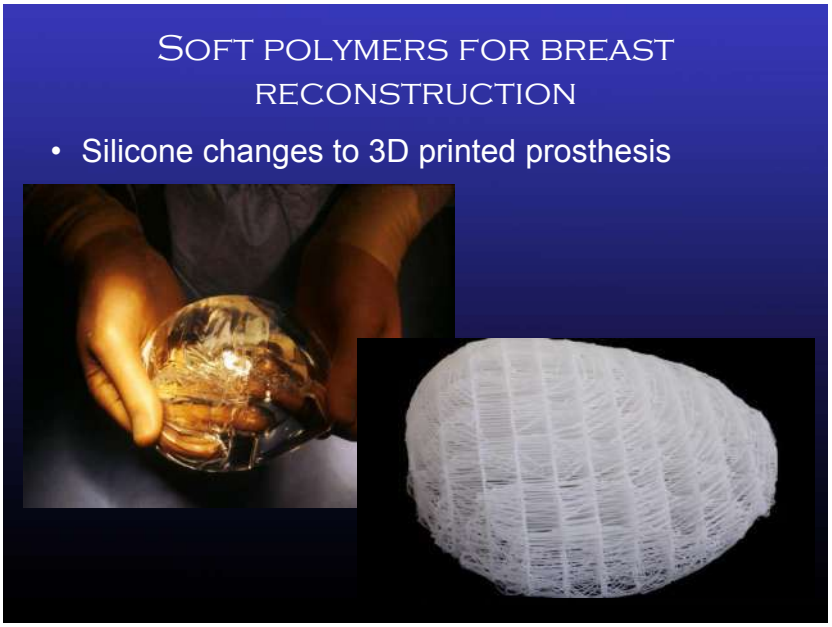
is all polymeric and people don't hurt their feet, if they fall down they don't get injured and they can run a little bit faster and break records and so on.



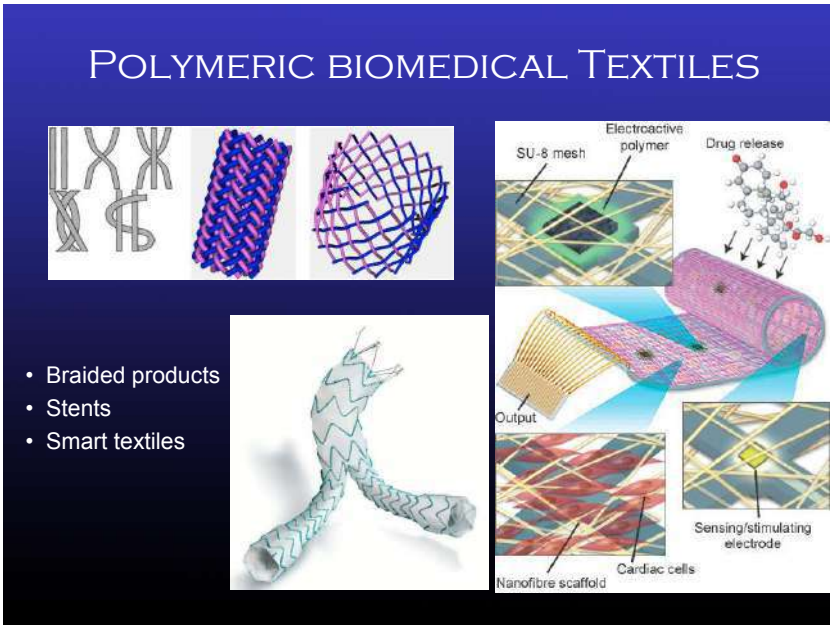
Coming to Medical Applications of Polymers, since polymers have made huge impact, braces or callipers, artificial arms/legs all those which earlier were made of wood and, all have gone. Polymers are used for bone cement, x-ray analysis and treatment devices, heart valve, blood bags, dental applications – those silver fillings and all are passé now, they are all some sort of a polymer which is the knee joint bearings are made of very high molecular weight HDPE because they have good frictional

resistance. One thing about knee joint is that they rub against each other, you don't want any abrasions to that will abrade and form debris can go inside the blood vessels and you don't want that. Hence you have to make really nice materials which will not abrade themselves in applications like the knee joint. Silicon is used for breast reconstruction, this is basically silicone materials and so on which are used by women who sometimes due to cancer and lose their breast and this is the

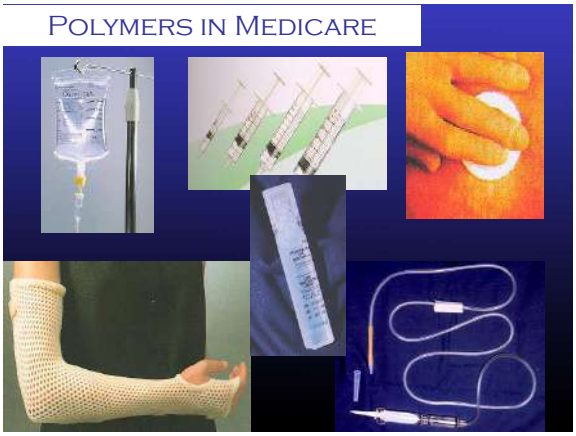


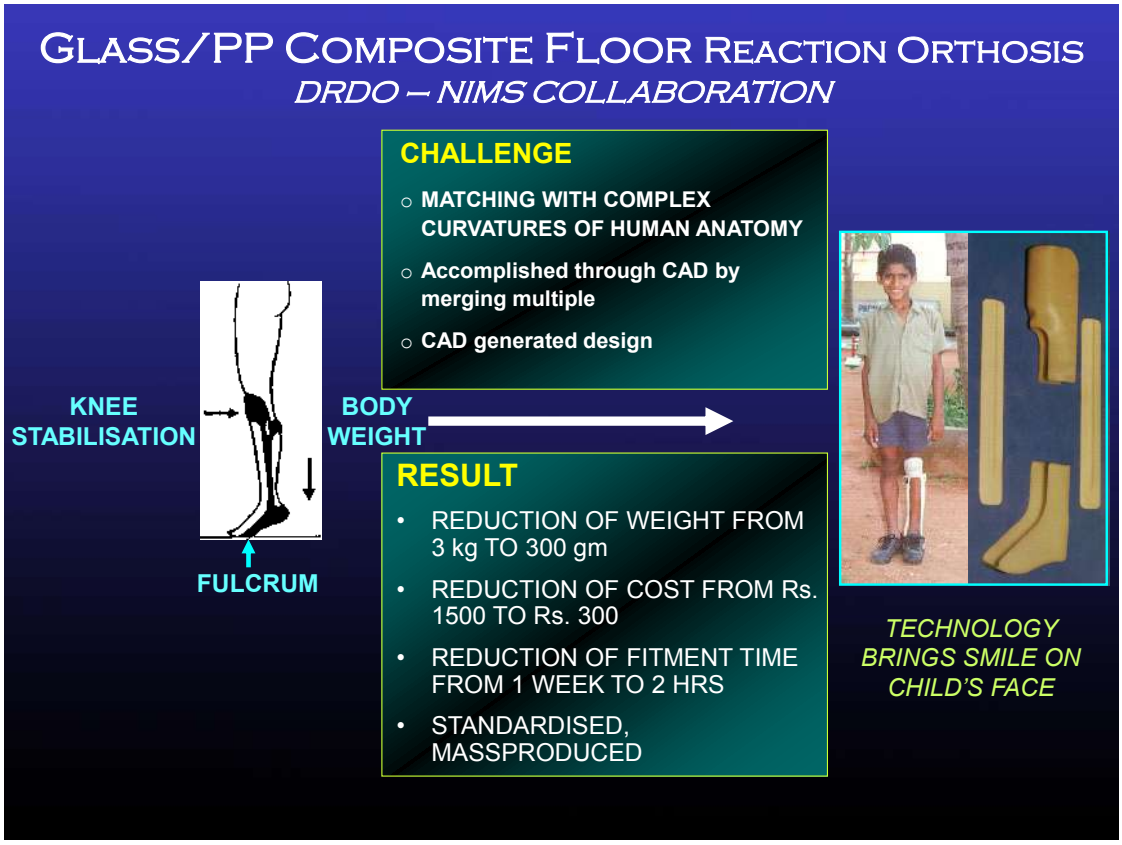


key really used to reconstruct. Then there are polymeric biomedical textiles, all the stents that you are talking about, strengthening materials inside the body, fibres used for sutures that will dissolve after a while – these are all one type or the other polymer. I can go into details of that but due to time constraints I can't do that. Then you have bone replacement, reconstruction of teeth, of course some metal may still be used – people are working on bone replacement by polymeric materials. I recently heard a talk by a company which is on 3D printing and they are making 3D printed skulls of people who have head injuries for replacement by specialized polymers when bone has to be placed in the head. One of the new very nice applications that has come up is the artificial skin, when you have burns you can use these materials put it on the burn till it heals

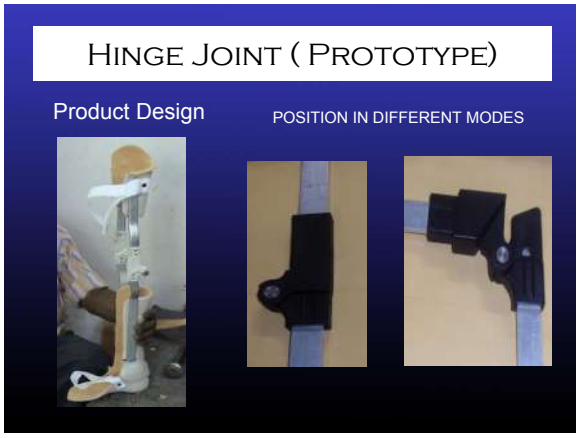


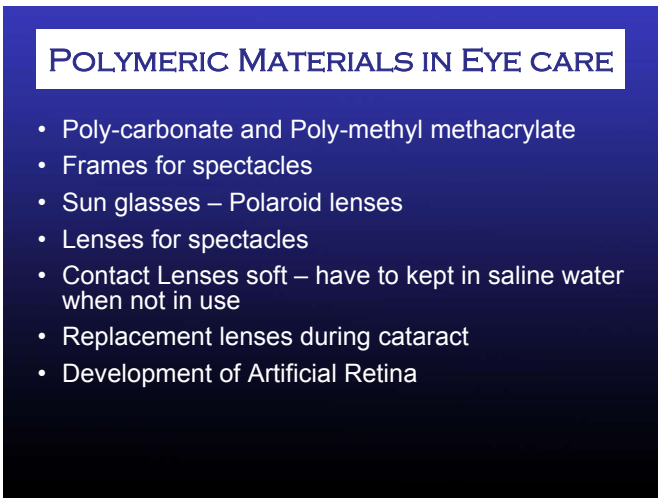
and then it will biodegrade itself and you have a much nicer healing process through this artificial skin. You have arm supports, when you go to the hospital all these bags in which fluids are there which are fed into the body which is made of all special plastics and all the tubing are made of plastics.





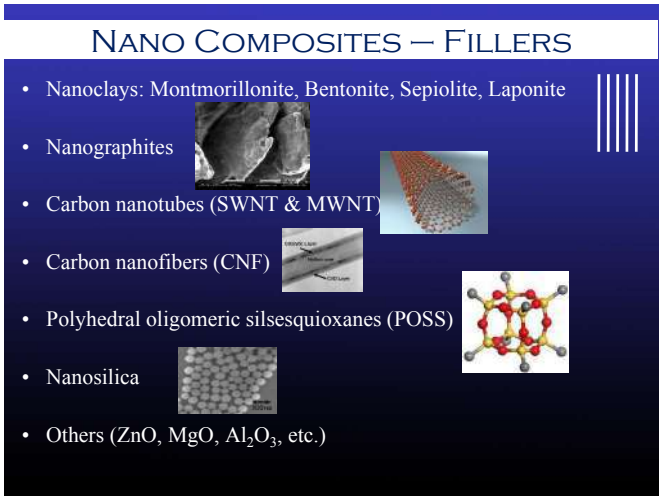
What you see now is basically glass reinforced polypropylene composites which are being developed by DRDO for DRDO use but they used it for the replacement of the old type of callipers which polio patients used and this has been fitted to 40-50 thousand people already – much lighter much cheaper and it brings a smile on the face of the child. Recently IIT Delhi has developed the knee hinge joint for those who needs to have replacement due to polio or accidents, the hinge joint which has been developed so that you can actually walk just like you would walk with a hinge joint of your own original body.



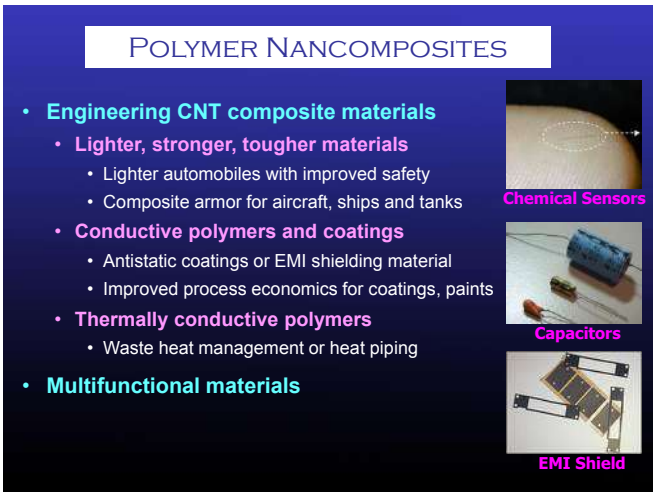


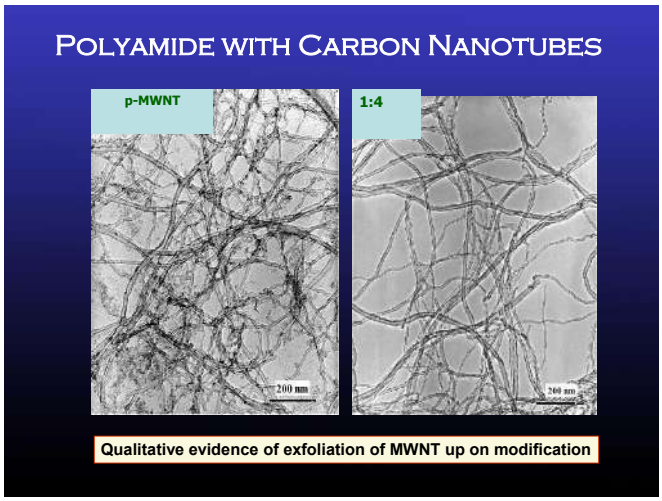
In eye care, if you are using lenses made of polycarbonate or polymethacrylate, polaroid lenses, contact lenses are of polyacrylates and they have to have a special softness to them, so if you don't put them in saline water they will go bad that is why you always put it in saline water and replacement lenses for cataracts. Then we have nano-composites, the fillers can be nano-clays, they could be carbon nanotubes and with nano-fibres all kinds of nano-fillers can be used and they develop materials which have very special properties and so on.

One of the things which I worked on in IIT Bombay was to have carbon nano-tubes which are very thin in a very nano scale exfoliate themselves so that from one end to the other they are touching each other and they are conductive so you can transmit messages or transmit electricity or signals from one end to the other and you can see that this side is the conductivity with very special blending and so on was increased many fold in such materials and this has led to nano



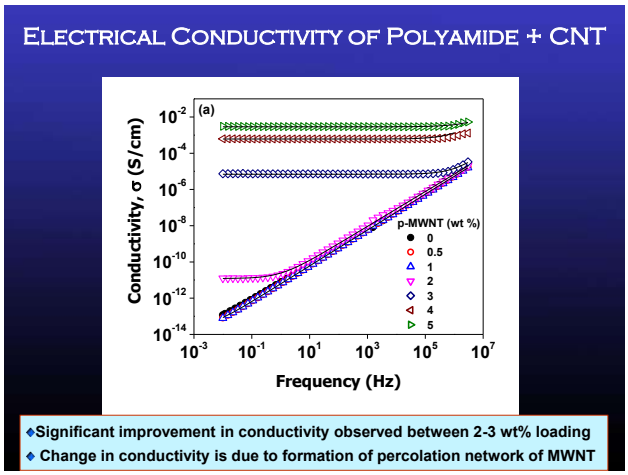
materials towards highly electrically conducting nano composite fibres, I think in the stage of high development of making smart clothing so that the soldiers can wear

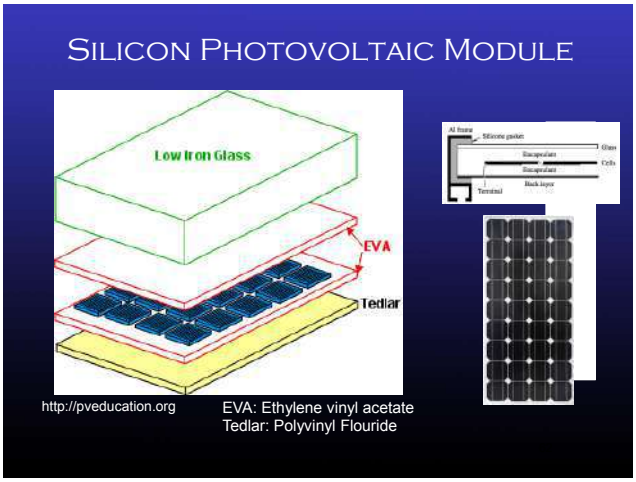


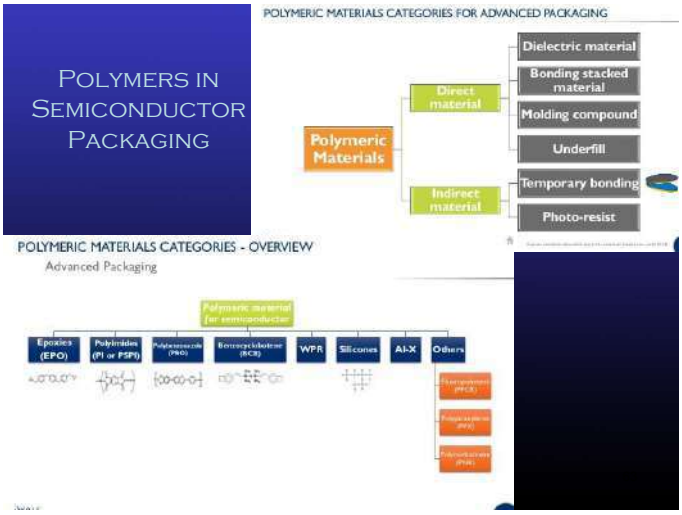


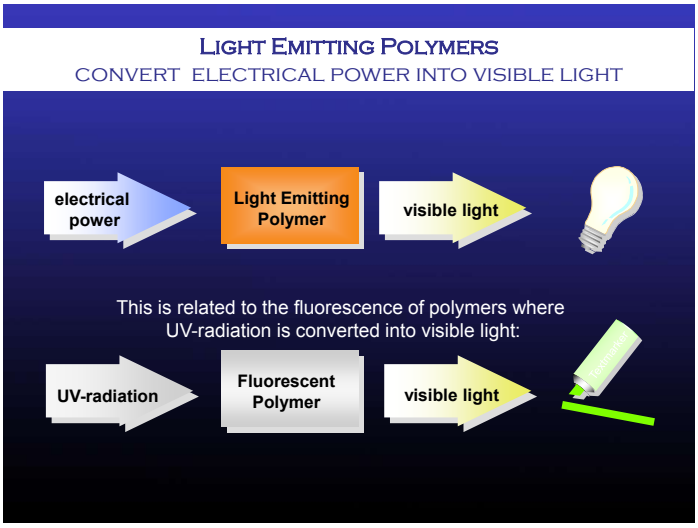
and pass on a signal by touching the sleeve because it can pass signal from their equipment than they have, these are very smart materials.

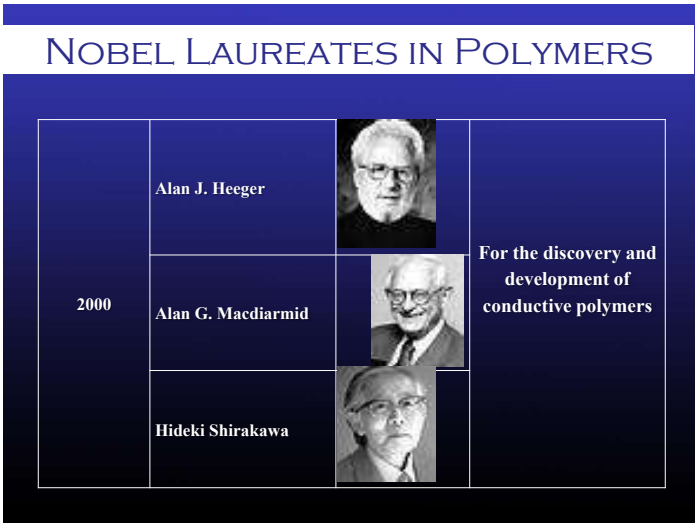
We talk of photovoltaic modules for solar cells. They would not work if you didn't have encapsulating materials and these are polymers and the base which we call the tedlar is another polymer – polyvinyl fluoride. So in every area they are used, in





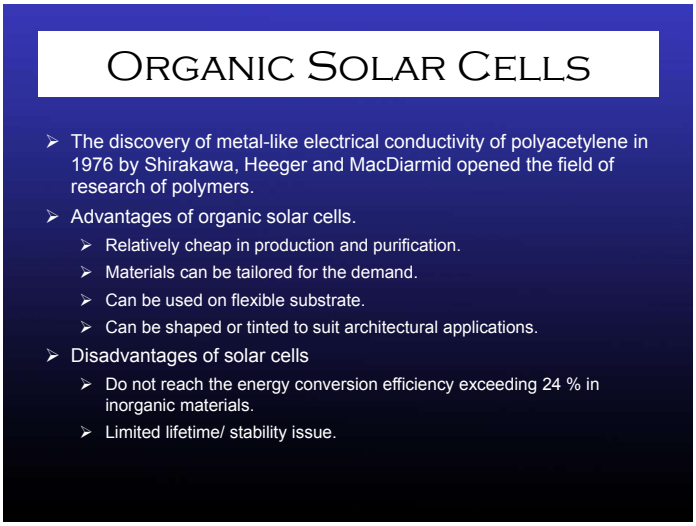




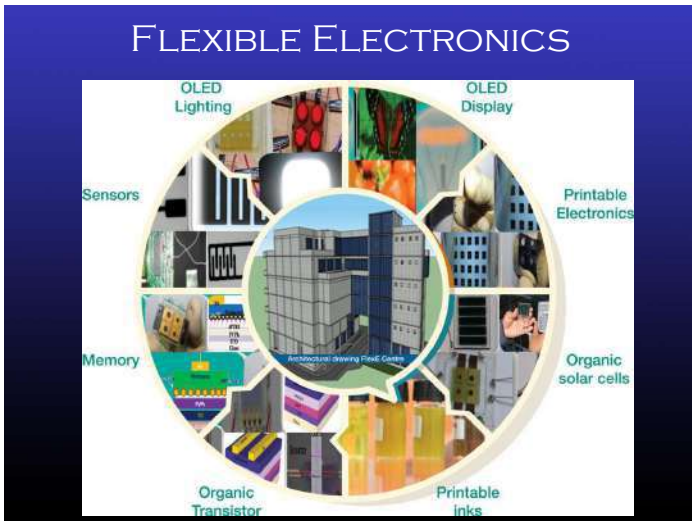


semiconductors and you make semiconductor material then you have several polymeric materials which are used to make the chips which were there in my talk earlier and those chips have to be made with polymer on top of it and then you etch out the circuitry and so on and without polymers they won't go that much farther, so very critical role unseen and quiet role they play in semiconductors. Then there are light emitting polymers, electric powered light emitting polymers and you can see visible light.

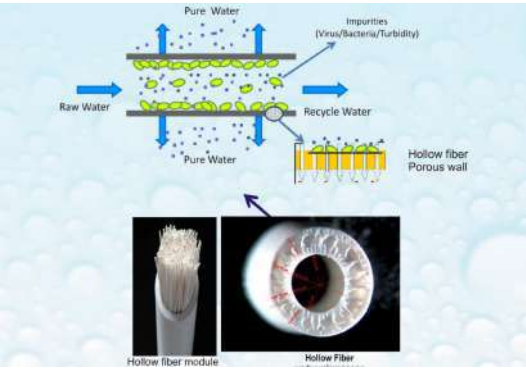
What you now see is three gentlemen, Allan J. Heeger, Alan G. Macdiarmid and Hideki Shirakawa, all Nobel Laureates in Polymers, I had an occasion to meet all three of them and Macdiarmid I got to know a little bit



better, one of the things he said, science is people and I love that phrase because science doesn't come from heaven, only the people develop new science. What they did was that this will lead to organic solar cells because they can transmit electric currents and so on and one can start making organic solar cells. This is in due course in life I think we will see many more organic cells they are relatively inexpensive, easier to make but their efficiency and life may be a slightly lower so all these things are being looked at. Then there are flexible electronics – IIT Kanpur has one of the best four centres of flexible electronics, electronics is the main thing but flexibility comes from the use of polymeric materials as the base and all kinds of things, only lighting sensors, organic solar cell they are working in all these areas. One of the best centres I have seen in the world, not in India, it is Centre for Flexible Electronics and this is an example of variable electrodes as part of the flexible electronics. One of my students (not direct) at IIT Kanpur has developed hollow



Water Purification technology: Hollow Fibre Membranes the Indigenous technology



- Very low maintenance
- No Need of electricity
- Any one can installed and operate
- Works on Gravity pressure
- Higher water flux compare to any membrane available in the world

Our customer

Ref: Technorbital Advance Material Pvt. Ltd.

fibers which are used in Swatch water filter which is developed by Tata for water purification

and it is a very successful way of cleaning water. I will take a little break here and let my friend Ajit take over.

Dr. Ajit Sapre: Prof. Misra, there are lot of questions, quite a number of them are related to actually on environmental pollution and issues related to that, probably you can talk about it in your next session. Two or three questions that have popped up, one is that why no new polymer has been invented in the last so many years. Can you shed a light or what is it we need to do for new polymers.

Prof. Ashok Misra: Several new polymers have been invented. I didn't go to exact polymers but a lot of liquid crystal polymers have come into play. What happens is that when you make a polymer, there are two things which are required that they are to be processable, sometimes they have properties which are good for publishing and so on but if you can't make them into a final product, if their processing is difficult then they won't see light of the day. Secondly, some may be very expensive materials then to replace some other materials which is existing is a little difficult.

Dr. Ajit Sapre: Another question that has come up is that are there any ferromagnetic polymers, or polymer composites with ferromagnetic properties?

Prof. Ashok Misra: Polymers normally would not have ferromagnetic properties but they can be blended with some materials to give you ferromagnetic properties but having said that polymers do give very good electrical properties, in fact I was involved in developing dielectric materials and piezoelectric materials out of PVDF by changing the structure which I showed you earlier so that they could be used for condensers and capacitors and products like that.

Dr. Ajit Sapre: Two other simple questions, one is that you talked about cricket bat, what would take to replace cricket bat with a polymeric material or some composite, any ideas?

Prof. Ashok Misra: It is matter of people getting involved in it and developing a bat which would have the same properties or are very similar to a wooden bat. In a way the cricket bat today is also a polymer, it is wood, it is a natural polymer so the only thing is you have to replace the natural polymer by a synthetic polymer, it should have the durability, it should have the striking power. One of the things in the tennis racquets which I didn't talk about, the wooden tennis racquets are all solid and all the composite racquets that you have, they are hollow inside, so one can make a

cricket bat which could be hollow inside, but it will take somebody to get involved in it and get on with it and then only it will happen.

Dr. Ajit Sapre: I will summarise a few questions which are all related to role of polymers and how ubiquitous it is in our daily life, but the visible impact is pollution you see as trash. The questions they are asking is something about micro and nano-plastics pollution which they don't see, but recently there is a lot of talk about it, so if you could shed some light on it would be appreciated.

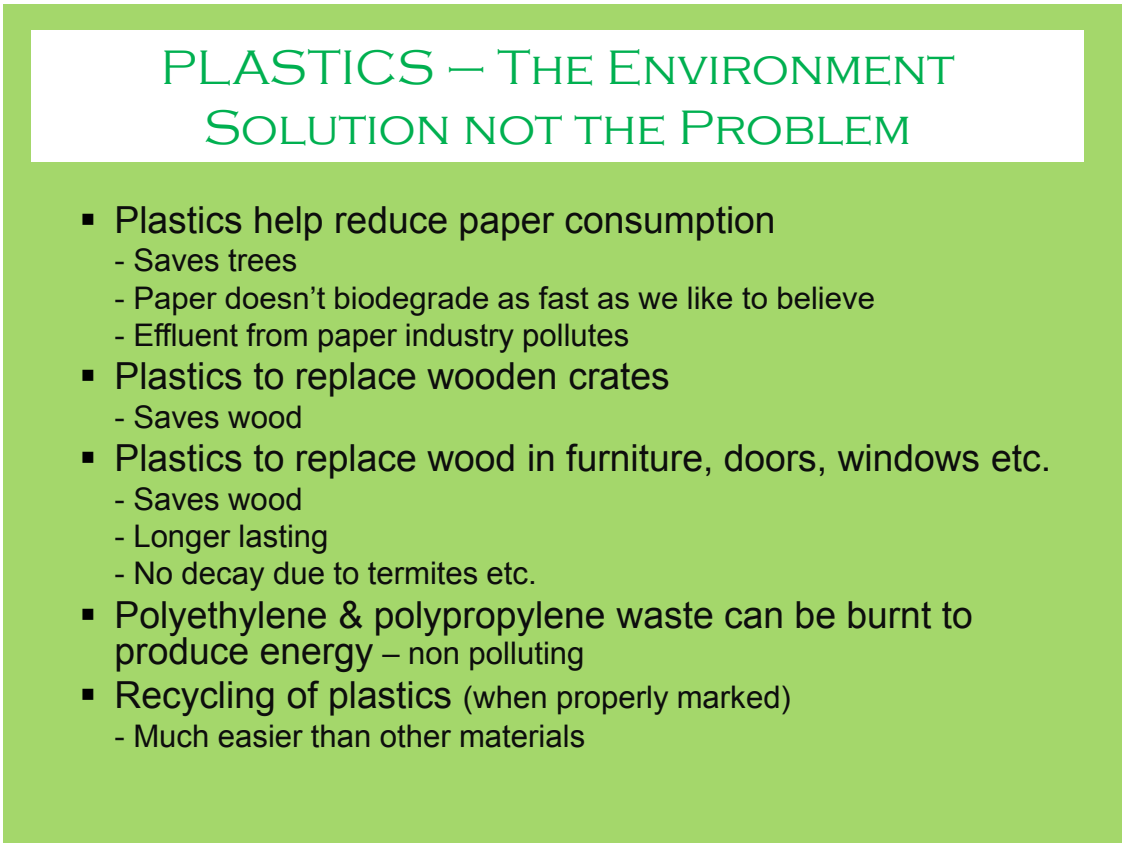
PLASTICS IN PACKAGING VS OTHER MATERIALS

Article	Plastic	Other Materials
Bag to carry 5kgs	4gms	paper – 20-30gms
Bottle (750 cc)	50gms	Glass – 500gms
Milk Pouch (1 lit)	6gms	Glass – 500gms
Cold drink Crate for 24 bottles	1kg	Wood – 2kgs
Apple Crate	300gms	Wood – 600gms
Cement bag	70gms	Jute – 350gms

Prof. Ashok Misra: Let us look at the environmental issues, let us first see what the major pollutants in the plastic world other packaging materials. So first let us see why

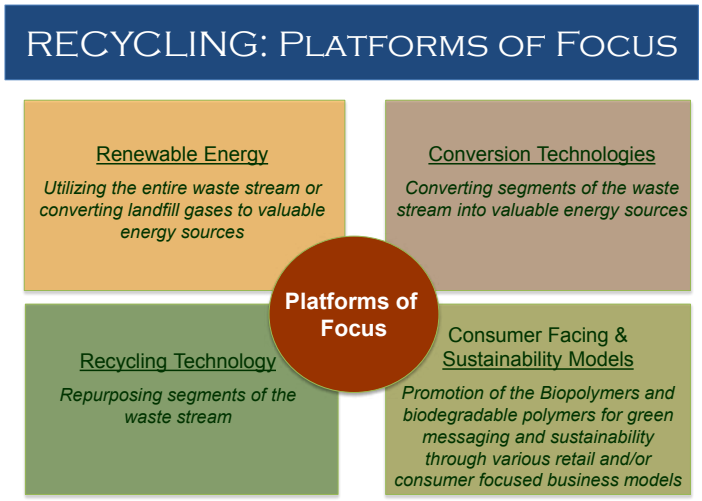
we are using plastics to begin with. Carry bags which will carry about 5 kgs of potatoes or rice or whatever a plastic were could be about 4 grams whereas the paper bag would be about 20 to 30 grams and then if you are carrying sugar, let us say in a paper bag and by chance you slip and falls down, sugar is all over the road. Bottle with same carrying capacity about 750 ml, CCO of

one bottle would be 50 gm as opposed to 500 gm for glass bottle and again a glass bottle can drop and break. Plastic milk pouches of 1 litre are 6 gm but the glass would be about 500 gm for the same 1 litre and so on, crates and hand bag all the same thing. This will give an idea, if you take milk, if you had milk in glass bottles and you take it in a truck, you will be carrying 53% milk and of let us say 50% glass but whereas if it is in a plastic pouch and it will drop and break and so on and you not worry about washing the bottle and recycling it, it will be 93% so the efficiency of transportation goes up.



So it is actually helping the environment and in all these previous examples. So as I said it would help to save trees if you don't use that much wood and paper it would save trees. Paper also doesn't biodegrade as much as people thinks. In landfills in

America, they found papers of 20-30 years old but when they went down, there was no air, oxygen and so they also didn't degrade. The effluent from the paper industry are also quite toxic, so actually you are helping the environment if you are not using these materials and using paper. It saves wood, plastic is longer lasting and polyethylene, polypropylene wastes can be burned to produce energy if you collect it properly and then you can burn it as a fuel, make it a liquid fuel and it becomes a solid fuel and you can recycle plastics much easier than many other materials. People say plastic won't biodegrade for so many years, tell me if you throw a glass bottle it will take that many years and for ever and never degrade so it is not just not plastic material which won't biodegrade. So recycling is there, renewable energy you can do conversions in technologies, recycling technologies and some consumer facing so on and so forth.



Ajit will talk a little bit about that. Now one of the thing is the biodegradable plastics, the sheer volume of plastic waste has been generated over the years is subject of this environmental issue, there are always reports that so many million tons of plastic they found in the sea bed. The question I ask is that plastic bags or water bottles or whatever, they neither have legs, nor they have wings, nor they can swim, so how did they end up there, they ended up there because we as a civilized base of human beings have indiscriminately thrown them here and there and they find

their way into the streams and they end up into the sea. So we have to be careful. Lots of report you would hear about a plastic is bad because it goes into the cow's stomach. If you try to feed cows plastic, will it eat it, it will not but if you put kitchen waste in the plastic and throw the cow wants to eat the kitchen waste and unfortunately, unknowingly the cow eats the plastic bag as well. Is it the cow's problem or is the plastic's problem, no it is the peoples problem, people are not thinking about these things and so you go to a dump and you see basically it looks like a plastic dump but actually if you do an analysis of plastics in a dump, it is only about 7-8% and the rest are so many other things because people put the garbage in a plastic bag so it won't smell and through it indiscriminately on rail lines, roads, streams and so on.

BIO-DEGRADABLE PLASTICS

- The sheer volume of plastics waste that has been generated over recent decades has brought up the subject of plastics disposal as a major environmental issue
- Biodegradable plastics offer a key solution, although there are many factors to consider such as;
  - Toxicity of end-products
  - Degradation mechanism of the polymer
  - Processability of the polymer
- Retention of form and function of the final product throughout its expected lifetime
- Biodegradable polymers are playing critical roles in other areas, like medicine, pharmaceuticals e.g. drug delivery & dentistry

There is possibility of also making biodegradable plastics but throwing plastic waste/waste bags doesn't change then this will not help the problem. There are some plastics which were made are biodegradable, what they do they put starch along with the plastics so the starch is eaten by the bacteria and plastic bag is cut up into small pieces so it becomes micro pieces but it is not going away, it is still there and it is still we who have thrown it indiscriminately so we have to label all the

BIOPOLYMERS

Challenges associated with petroleum based polymers

- Limited resources of petroleum
- Increased environment concern
- Packaging waste: Major environmental problem
  - Non-biodegradability
  - Recycling
  - Shortage of land fill
- Increasing cost of petroleum based polymers

Biobased polymers

- Based on renewable resources
- Compostable and recyclable
- Reduce carbon foot print
- Desired range of performance properties of material (mechanical, barrier, optical)
- Comparable cost with petroleum based polymers
- Easier processing

plastics, collect all the plastics and many societies are doing that. Also there are biopolymers so polymers can be made from biological monomers, so if you do that their base of renewable resources that is one thing, we talked about limited resources the petroleum are there but I don't know if you have an idea that petroleum that is used to which goes into the plastic industry is only about 7-10%. Actually when you run a car for about 2-3 kms, you burn more petrol that is required to make one sari, one sari can be made in about a big mug full of petrol/petroleum equivalent. It is not the resources but if it is based on bio-monomers and they can degrade easily and but people have developed a lots of polymers but they are expensive, would they be as cheap as a polyethylene bag for transportation of things and so on, the so called single use plastic and son on so we have to worry about that. Let us look at the common person, he is amongst us, we are the common person, we use variety of product made of plastic in our everyday life,

The common person is among us

- He/she uses varieties of products made out of plastics in their daily lives
- However, they often understands little about the real value of these materials
- Nor do they understand the harm they do to the environment by careless disposal of plastics
- They also equally get confused with what they hear about this material. *"Plastics are harmful to the environment".*

Please treat plastics with respect

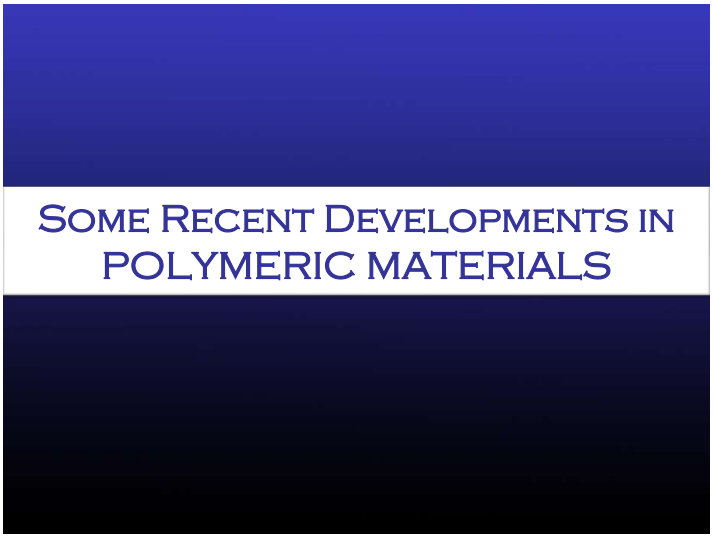
however they often understand little about the real value of these materials nor do they understand the harm they can cause by indiscriminate disposal of these plastics. They are also equally confused with what they hear that plastics are harmful, lot of people who are not knowledgeable they say if you leave plastic in the environment they will leak out gases and so on. Plastics are so stable unfortunately in that sense, they will not give any gases, since they are stable. So what I am saying is treat plastics with respect and that is my speed event idea as Ajit mentioned. So one of the wonders offered each other is nature makes polymers which are at ambient temperature, most polymers synthetic polymers we made at high temperatures, 210 degree centigrade and so on, but all these wood, shellac, terpene resin, cotton, silk, wool, they are made at ambient temperatures, the silk worm is making the plastic at room temperature or outside temperature and so on. What the challenges to us, polymer people is, I am unfortunately not a chemist, but it is to mimic nature and can we make these polymers in ambient temperature with biological monomers and that happens if the human race keeps on discriminately throwing they will biodegrade and also you will probably get some superior properties and so on.

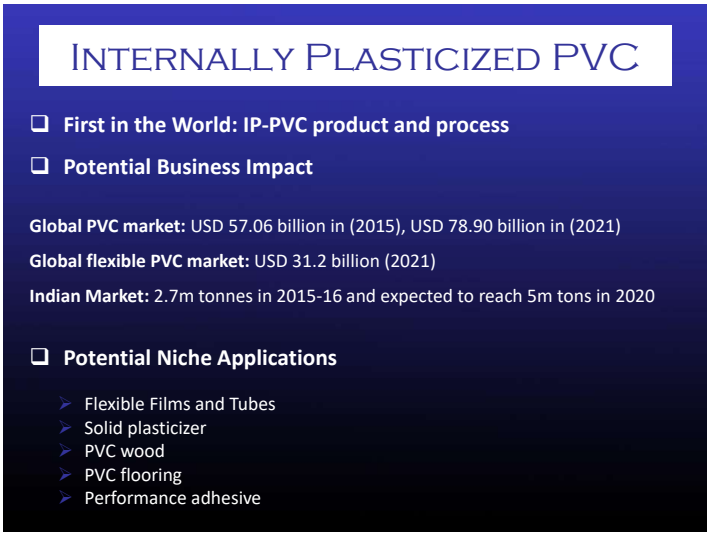
Wonders of Nature – Polymers Made at Ambient Conditions

- Wood – Cellulose
- Natural Rubber
- Shellac
- Terpene Resin
- Cotton
- Silk
- Wool

➢ *Can we mimic nature and make polymers at ambient temperatures*

➢ *Can we make polymers by bio initiators that may also be bio-degradable*





Now I will talk about some new developments in polymeric materials and this will be good for you to see. Recently, myself along with my colleagues at Reliance have developed what we call it Internally Plasticized PVC. This is the first time in the world we have done, through the nature survey it is not there, nobody has done that before, so when you take an ordinary garden hose and leave it in the Sun, the plasticizer goes away and the next season it is hard and brittle. What we have done is to link up the plasticizer onto the backbone chain so it will never come out and also when you get some plasticized PVC bags you can smell the plasticizer all that is gone and this will of course be very useful to make Flexible Films and Tubes, PVC wood, PVC flooring, performance adhesive

and so on. Some of the examples are given here. These are the medical tubing that you have, flexible to bring success to packaging, it will hopefully will revolutionize and change how people look at PVC and plasticized PVC. Then other material we have jointly developed again with Reliance is the Self Healing Halo-Butyl Elastomer for Tire Inner Liner Application. It is a normal material, it is self-healing, there is some technology to do it, it needs no compounding. No curing is needed and we are working on this and it is not final, so if you put a liner of that inside a tubeless tyre today, and if there is a puncture you have to go to the tyre guy and he replaces the puncture and he puts a plug in there. This self-healing material inside it, if the tyre get a puncture and will heal itself and you don't have to worry about a puncture guy any more. Hopefully this will come. We are working on that. Reliance is working on the polypropylene

catalysts and these polypropylene catalysts will make unique polypropylene grades which will have higher strength and unique properties. I can't discuss that in detail but these catalysts are available in the world but they are available at a very high cost that you always get the previous generation catalyst but Reliance is trying to do it themselves and it is not just for Reliance but for India if we do this and we can be the leaders in polyethylene and polypropylene technology in the world. In the time of pandemic you can see this article from Mint newspaper, all kinds of plastics are used for hand gloves, for covering the hair, covering the mouth, whole body suit and so on and so forth and these are all plastics so the so called single use plastic which were bad for us has suddenly become very good and useful for you because nothing else can replace that so easily.

PLASTICS – AT THE TIME OF A PANDEMIC

COVID 19 and polymers

Behavioural shift in COVID19 pandemic

- People working more from home
- Increased expenditure on health
- Preference for online shopping
- Reduced discretionary expenditure

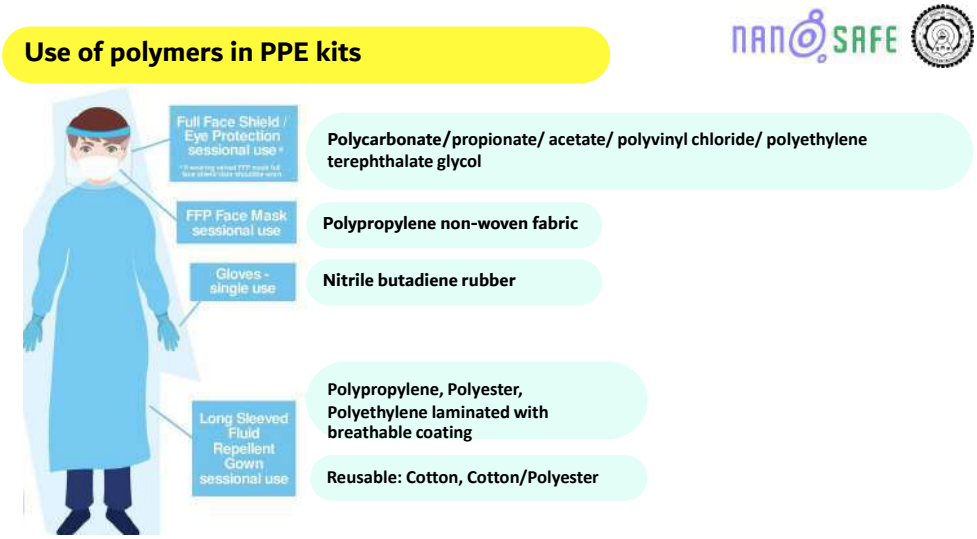
Polymers are in the forefront for combating SARS-CoV-2

"Polymers are like invisible warriors, they are present in every item related to COVID-19 fight, from medical devices housings, diagnostic tools to personal protective equipment"

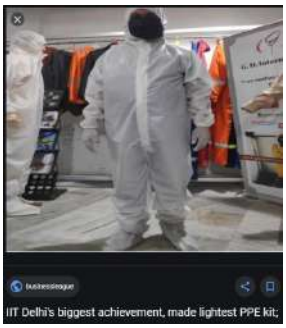
Polycarbonate (PC)	medical devices and equipment, blood oxygenators, hemodialyzers, intravenous connectors, syringes, safety glasses and face shields
Polystyrene (PS)	test tubes, petri dishes, diagnostic components, housings for diagnostics
Polyvinyl chloride (PVC)	flexible fluid bags, tubing, oxygen, masks, surgical gloves

Luxury companies diverting their market to polymers to combat COVID 19
Ferrari : Thermoplastic components needed for respiratory valves
Apple : Face shields from PC

My colleague, Mangala Joshi from IIT Delhi has developed these nano-safe filters which you can put on the mouth which is the mast that you have and it has this antimicrobial coating which is much safer to wear than just ordinary cloth masks and so on. People are working on that and the way it is made as it has different layers of polymers, inner layer: PP spun bound fabric middle layer: PP melt blown fabric, outer layer: PP spun bond fabric and that is how it looks like nano safe mask which is supposed to be much better than the masks that are normally used by people. Then the PPE kits have been made for people who are working with Covid patients, they have to take all this care and it is extremely important. Then all kinds of materials are used and structure of the polymer is such that the corona virus and all that cannot penetrate through these several polypropylene layers.



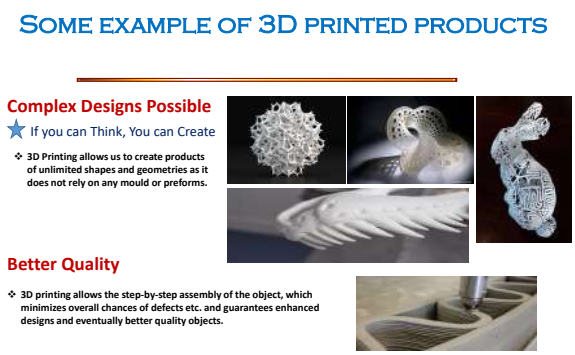
An IIT Delhi startup "Nanosafe Solutions" has launched an antimicrobial and washable face mask "NSafe", which is reusable up to 50 launderings, thus cutting the cost.
The team consists of Dr. Anasuya Roy, an IIT Delhi Alumnus, Founder and CEO of Nanosafe Solutions Pvt. Ltd. and Prof. Mangala Joshi, Department of Textile and Fibre Engineering, IIT Delhi and also Founder and Director of the startup.



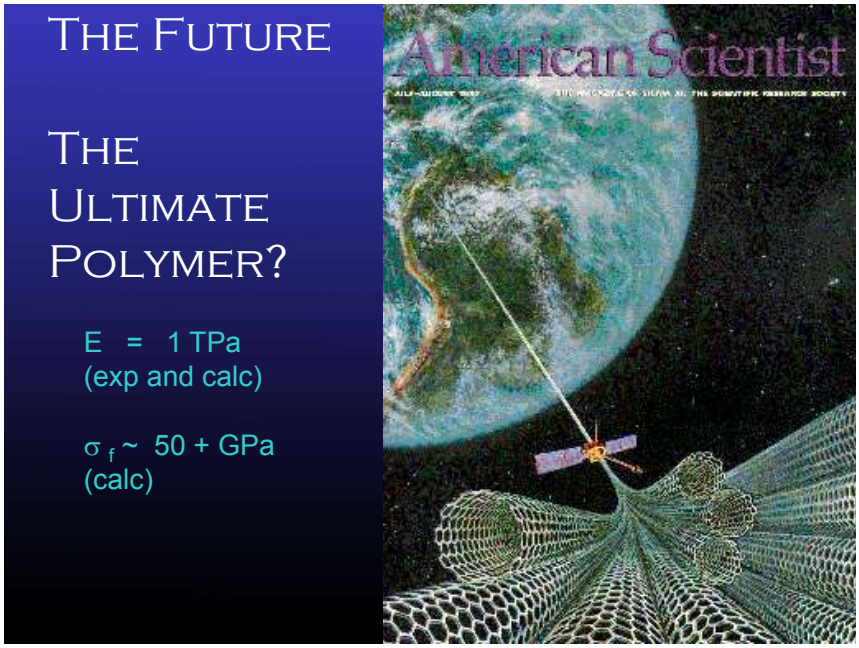
This is different from the existing PPE kit,
Prof. SM Ishtiaq said that this PPE is very different from the existing PPE and has many features provided. Fiber has been used in such a way that the infected particles cannot stay on it. If the water also pours in it, it will spill. It is capable of rescuing doctors and health workers from Kovid-19. It weighs 300 grams, which is much less than the PPE currently available in the market.

My colleague at IIT Delhi, Prof. Ishtiaque has developed breathable body suits made of plastic, which does not sweat inside and make you uncomfortable. He is working on actually making them as light as possible so they can be disposed easily. However, we can see the masks floating in water, we humans don't learn and we indiscriminately throw these things away after single use and so on, single use is helping you and also hurting you.

The last thing I would mention is about this new technique called 3D printing which is basically replacing traditional methods of making articles and they make layer by layer or they stick to each other to make the final product and several application areas are there: you can do this in automobiles, in architecture - 3D printing house, you



can make fire arms made or you can make medical devices, artificial human heart, you can have electronics which are 3D printed and so on, I am not going into further details, but several other areas. somebody was saying, now instead of buying a shoe of size-9 or 10 and so on and so forth, you give your size of your foot and they will 3D print shoe for your foot which is not possible today but with 3D printing in future they may do that. What you see now are some other examples of some complicated shapes, complex designs possible through 3D printing. So polymers are one of the most versatile family of materials at least I like to believe that and I hope I have given you some food for thought for that, they are revolutionizing several application areas but number of technical challenges remain for the future and we need innovative scientists to take care of them. The Ultimate Polymer you see now, this is an American Scientist magazine sometime back published, this is only a concept that if carbon nanotubes can be made into a polymeric manner, they are actually very strong but if you can make fibre out of it



they will have one Terra Pascal strength and from earth you can actually have a satellite like a kite you can control it just by a string and not depend on other things so you can position it and this is how carbon nanotube look like, of course much expanded scale. These are the things we have to look forward to. So I think with this I will end my talk. Thank you so much for listening.

Dr. Ajit Sapre: Actually it is an honour and a pleasure to participate in this webinar. I must thank Prof. Misra and the IITACB for this opportunity Mr. Ashok Kamath mentioned in the intro that I have an extensive experience in polymers; but, to be honest, I started my career in oil and gas and refining and petrochemicals, and polymers is not something I have studied as much as my colleagues in Reliance. It was kind of Prof. Misra to talk about some of the activities that we are doing at Reliance. I was specifically asked to talk more about the plastic waste that seems to be on many peoples mind. I will give you a brief glimpse of what we are doing in Reliance. As you heard from Prof. Misra, it is a wonderful material and in order to tackle the pollution challenge I am going to talk about some of the work we are doing in the broader area of sustainability at Reliance. We typically look at everything from molecules to finished product markets and everything in between from the scientific perspective and we integrate the fundamentals of science, engineering, and economics when we are developing products. We not only consider the use by consumers, but also after life and the whole lifecycle of such products. and this is something I will talk about in this part of the presentation. Outline of my talk is given in the bullets on the right-hand side:

* Sustainability & Circular Economy

* Opportunity

* Polyester Recycling

* Other plastic waste

* Organic waste

* Waste to wealth

So if you look at the plastic paradox, it is high value in use as Prof. Misra explained, but our real challenge is the unmanaged waste that gets created at the consumer end. Therefore, we have to look at how to change the consumer behaviour. We need to make sure that we recycle, we aggregate and we also start introducing biopolymers and biodegradable polymers, minimize the use of single-use plastics as much as we can and also need to organize the waste collection so that it can be recycled. If you look at what McKinsey is projecting, the whole industry of reuse, recycle has impact of close to 40 to 70 billion US$. In fact by one estimate, by recycling plastics alone you have a bigger impact on oil consumption than probably electric cars in the foreseeable future. Anyway Reliance has been actively focusing on how to make sure that the waste is managed and we promote recycling and reusing. So I will give you some examples, we are a founding member of an alliance to end plastic waste and we have made a significant commitments in terms of resources. Our approach has been to innovate, collaborate and educate. Emphasis, on consumer education is just as important, because consumers don't directly work with us. So the way we look at this challenge is that the plastic waste as you are calling is actually a resource. We think of the entire lifecycle and work with various players in the value chain, to ensure that this resource is used to create more value.

Certainly we need to fight pollution and not plastics because it makes our daily life so much more comfortable but we cannot misuse it otherwise it can cause severe environmental damage.

Now let us talk about polyesters. Everybody is familiar with water bottles, they are all made from polyester, and in fact India is probably the most advanced in terms of recycling and reusing polyester. We in India recycle more than 80% of all polyester bottles, which is significantly more than most of the developed countries like Japan, EU, USA. This is primarily because lot of our unskilled manpower, the rag pickers, they collect waste bottles and they bring it back in the recycling value chain, because it gives them income. In Reliance, we are actually processing recycled polyester bottles and upcycling them. I will talk about it later, but essentially we are converting the bottles and converting them into new garments. In this chart we are showing T shirt, in fact we have made more than a billion T shirts. We have branded this fabric as RElan green gold, this material is produced from recycled plastic bottles. So it is an example of how do you convert waste into wealth. From this chart you can see when you replace for example 50% cotton with this green gold polyester made from recycled bottles, carbon footprint and other environmental damage is reduced significantly. Similarly when you replace 30% cotton in jeans there is significant benefit to the environment. You may note that our fabric from recycled bottles are used by some of the brands that you use every day; for example, brands like Wrangler, Van Heusen, Arrow, Allan Solly, Lee, Kappa, Raymond, Tesco, Splash and others use these fabrics regularly. So we are collaborating with many leading global and Indian brands to ensure that this recycled polyester material is actually getting into clothing. In the past, we used to

actually down-recycle bottles to make carpets, whereas here we are actually upgrading it to use it into garments, so this actually adds significantly more value both to the environment but as well as to minimize the use of polyester. Somebody may ask a question now that the recycled polyester has ended up in high end clothing what we plan to do at the end of life for other clothing materials. So we are working on many technologies and couple of them are fairly mature, at least ready for scale up, as shown in this chart. In clothing, which is mostly mixed fibres, the polyester is mixed with either cotton or viscose. So we have now developed technology whereby we can actually get the polyester chips back and then we can convert that polyester as I showed you before to finished products, and remaining cellulose and viscose that is removed from the mixed fibres can be valorised in the paper pulp industry. We are also developing another technology to convert this waste into composites for building construction materials.

Next is about use of plastic waste for road construction. There were lots of questions about use in the road construction. As discussed before, polyester has well established recycling business; however, when it comes to polyethylene, polypropylene and other plastics, including multi-layer plastics – which is a large part of trash that we see along roadsides, a significant amount of it comes from packaging. I will talk about packaging a little bit later. If you look at the waste plastics value chain, the aggregation of the plastic waste and how it can be converted into making roads, is depicted in this slide. In fact we have made more than 50 kms of test roads to perfect the ability to mitigate any unintended consequences, and make sure that the road is properly built and is durable for long –term heavy traffic loads. Please note that for each ton of plastic waste that is used

to make road you are saving about 3MT of CO_2 going into atmosphere because you are essentially taking the carbon in the plastic and you are sequestering it in the road itself, thus helping us reduce global warming. Although the demand for road construction is booming in India, if you look at the total bitumen we use for roads today, and typically we can incorporate only about 10% plastic into the road construction, the amount of plastic waste that can end up in roads is limited. The way this technology works is that plastic is mixed first with gravel and other solid materials and essentially plastic forms a thin layer around the solids, and then it is mixed with bitumen to make the road. In fact Prof. Vasudevan from Madurai is known as the plastic man of India and he has been actually galvanizing this particular effort and this has actually taken traction. Many of the state governments are mandating it that you incorporate 10% of the multilayer plastic waste into road construction. But if you look at the total amount of bitumen consumed for road construction and if you consider only 10% plastics can be incorporated, from a waste plastic disposal perspective, that amounts relative to say waste generation in the top 10 cities in India is not going to consume all the waste plastics, simply because the amount of plastic waste we generate is significantly more than what can be consumed for construction of roads.

So we in Reliance have developed a technology to actually convert the plastic waste to synthetic oil. This technology involves proprietary catalyst and reactor design. Reliance technology is superior than thermal technology employed by many small scale companies. To thermally convert waste plastic to oil they need to clean up and segregate the feed, and the oil that is produced is not that high quality. You can see from the picture on the right, the thermal processing oil yield is not as much and

the quality is not that good either. Whereas because of the use of proprietary catalyst and the type of reactors we use we get significantly higher conversion to oil. This oil is quite stable and can be reused in our refinery and petrochemical plants to make various plastics that Prof. Misra talked about. Certainly this way you can close the loop, so what happens on net basis is you are reducing the oil consumption through recycling and you are also mitigating the environmental damage. So this is one form of chemical recycling if you will. We have done this technology development at a pilot scale and will be scaling it up in the near future. This technology development and large scale deployment is critical to create value from plastic waste and and help solve pollution.

There were many questions about biodegradable plastics. Here I have summarized the work we are doing in Reliance, on biodegradable plastics. It is primarily poly butylene adipate co terphthalate, called as PBAT in short. We have developed proprietary technology for catalyst and reactor design to make this polymer. Today this material is being imported from China and if you go to some of the grocery stores you will see some of these nets at the bottom for packaging fruits and vegetables. Certainly making this India will have a tremendous benefit and you will start seeing material made from our own PBAT in the Reliance stores and obviously at other stores as well in the near future. Our biodegradable PBAT materials meet ASTM standards which are worldwide used by other manufacturers. This is also a compostable material and can be used for agricultural applications as well. We are really excited about this technology development and we will see this in packaging applications very soon, especially with the current emphasis from the consumer of

not using Chinese products. We will see significant demand for Made in India biodegradable plastic materials.

Prof. Misra mentioned about packaging, which is very critical because large amounts of plastics are getting used in packaging and they are the ones who actually create a problem of littering and trash that you see, especially in India we have a lot small pouches for one-time use of shampoos or other materials which are essentially creating a littering problem. It is partly also a challenge of being more disciplined by the consumer for recycling to ensure that they just don't throw it away but it is properly segregated and so we can aggregate it and recycle it in a more responsible way.

Let me talk about alternate way to make bioplastics. If you want to make the same polymers but say make it from, for example oil made from renewable resources, it will qualify for bioplastic. In Reliance, we have a flag ship technology development programme called algae to oil, or A2O, where we convert sunlight to renewable crude oil using on purpose production of algae, or biomass, which is then converted using our proprietary technology called RCAT-HTL. The beauty of this technology is that that it allows us to convert any organic material to renewable oil. So we have done work with food waste agri-residue waste, dairy waste and so on and so forth as shown on the left hand side of this chart. This organic material can be converted to renewable oil using RCAT-HTL, it stands for Catalytic Hydrothermal Liquefaction. In this process water acts as a co-catalyst along with the proprietary catalyst to actually convert these various organic materials including natural polymers and convert them to renewable bio-crude oil. If you notice that today's crude oil is nothing but old biomass that got cooked up in the earth's belly over millions of

years, and as a result, is non-renewable. What we are saying is that today's biomass, which actually is nothing but sunlight that got captured by agriculture very recently and that you readily convert to renewable crude. When you use this renewable crude to make plastics with existing refinery and petrochemicals plants the resulting plastics are bioplastics. So this way, it becomes completely renewable. This chart also shows that the technology we have developed is far more efficient than alternate use of such materials whether it is burning to make electricity, or current emphasis on making ethanol from agri waste and or anaerobic digestion to make biogas. So if you look at the conversion of energy in the feed, to energy in the product, we are at 66% which is shown at the bottom of the chart. On this metric if you look at all the other technologies, they are much less efficient, so what it really means is that you are not fully utilizing the energy content of the feed. We feel pretty good about our proprietary RCAT-HTL technology, in fact this is a great opportunity for India especially when we talk about Swatchh Bharat. For this technology to work, what we need is nicely aggregated feedstock and this expertise belongs to waste management companies. Although we developed a technology for on purpose algae production and conversion to make renewable oil and the technology is applicable to available organic waste, Reliance is not into waste management; therefore we are looking for partners or other start-ups who could utilize this technology. Since waste biomass is a distributed resource, the technology implementation will also be small distributed plants. This has to be done at a village level or for big cities like Mumbai, it has to be done close to where the trash gets aggregated. Obviously we need to segregate the organic material from the rest of the other inorganic material because this technology works only on organic piece. So any entrepreneurs interested in pursuing this as a business opportunity, we

could work together and figure out how do we solve our pollution problem and convert waste into wealth, while we are also contributing to Swach Bharat.

Prof. Ashok Misra: Thank you Ajit for a lovely presentation that blended very well with where I left off more or less. I will address two-three very quick questions when somebody asks, can we replace engine parts by plastics, the answer is no, mainly because in engine when the combustion takes place the temperature goes very high and plastics being organic materials cannot withstand those high temperature, but many other parts within the automobiles around the engine can be replaced but not the engine itself.

Another question was that in railway carriages can you replace some parts, yes you can replace a whole bunch of things by plastics, the benches and the doors and all such things. Can we switch to conventional materials to reverse the trend, the answer is no, the usefulness of plastics is so much that it can't easily reverse it, just as an example, you need clean water and the water bottle is the easiest way to do it but in some case people are preferring cotton shirts and so in some places it is reverse but not fully, the answer is no but we have to make sure that we also preserve our forests, wood and so on. Somebody asked is this PPTs will be available, yes we can send it through email, but the whole lecture will be available on YouTube. Over to you Susheela.

Dr. Susheela Venkataraman: Thanks very much both Ashok and Ajith, all of us agree that this has been a very very fascinating session, obviously Ashok, your passion for

teaching and your passion and love for the subject showed through and through and now I understand really well why all of your students think of you as a teacher par excellence. Thank you very much for taking us through this whole thing. What we saw was polymers are all around us from the electronics we use to satellites that are enabling us this webinar to happen to the tricky chewing gums stuck under the library table to missiles, it is just everywhere and this is where the world is, this is where technology has taken us. As we talk of things like Athmanirbhar Bharath, Make in India and so on, Ashok talked us through all of that as to why the country needs polymers and plastics and what we can do with them. I think this has been an excellent session in informing about what polyesters, plastics and polymers are really about and what a big role they have to play in things like light weighting and things like additive manufacturing, these are all the ways in which India can become a globally competitive economy. We also talked about, heard about things like logistics and in the efficiency of logistics, the efficiency of the manufacturing process itself as well as maintainability and how polymers play and these materials play a big role in all of that. We look forward and talked about bio-polymers and self-healing materials and Ajit took on to say, all of this is actually happening in India and contrary to what we all think the popular impression is that we are not recycling, we are generating so much waste and so on and so forth, we are doing a good job of recycling our plastics and where all of that is leading or something that Ajit took us through. Thank you Ajit, thank you for talking to us about all the exciting thing that is happening in Reliance and how new products and new technologies are emerging from waste. It is absolutely fascinating to see the kind of work that is happening. You also talked about Swatch Bharat and both of you talked about why eventually it is about people being responsible about every one of us being

responsible and Ashok you said that we have to treat plastic with respect and I think that is a very thoughtful message and we will close today remembering that message keeping it with us. Whatever we do at the end of the day, it is not about the technology, it is not about the materials, it is really about the way use those materials and the way we dispose off or we reuse those materials, so it is really in our hands and there is no point of blaming technology and blaming the kind of materials and science that went into all of that. So with this once again thank you both for this absolutely wonder session and many thanks to the audience for your questions and for participating and hope to see your in our webinars on Saturdays.

Thank you very much!

IMPARTING SENTIMENT AND POLITENESS ON COMPUTERS

PROF. PUSHPAK BHATTACHARYYA I JUNE 27, 2020

Prof. Pushpak Bhattacharya is the Director of IIT Patna (since 2015) and Professor of Computer Science and Engineering Department IIT Bombay where he also held the Vijay and Sita Vashi Chair Professorship. He is a Distinguished Alumnus (awarded in 2018) of IIT Kharagpur. Prof. Bhattacharyya's research areas are Natural Language Processing, Machine Learning and AI (NLP-ML-AI).

He has authored the text book 'Machine Translation' and has shed light on all paradigms of machine translation, with abundant examples from Indian Languages. Two recent monographs by him called 'Investigations in Computational Sarcasm' (with Dr. Aditya Joshi) and 'Cognitively Inspired Natural Language Processing - An Investigation Based on Eye Tracking' (with Dr. Abhijit Mishra) describe cutting edge research in NLP and ML.

Prof. Bhattacharyya has been President (2016-17) of Association of Computational Linguistics (ACL), the highest International body defining standards of and propagating Computational Linguistics and is a Fellow of the Indian National Academy of Engineering (FNAE).

Anoop Kunchakuttan is a Researcher, Machine Translation and Multilingual Learning, Microsoft. His research areas are Natural Language Processing, Machine Learning, Information Extraction and Retrieval. He is interested in building tools and resources for Indian language NLP.

Lecture at IIT Alumni Centre, Bengaluru, by Prof. Pushpak Bhattacharyya, Director of IIT Patna, June 27, 2020.

Link to the webinar : https://www.youtube.com/watch?v=tazawAagbbg&list=PL0zMQ-70IHIX-df3u2Tto6dkKHCRC6iFL&index=12

Mr. Ashok Kamath: Good evening, this is our 12th webinar after the lockdown. We had a variety of speakers talk on variety of topics and have had an overwhelming response to the entire series. Today we are excited to have Prof. Pushpak Bhattacharyya, Director, IIT Patna and Professor from IIT Bombay. Prof. Bhattacharyya is best known as the leading expert on linguistics when it comes to natural language processing and besides just being a teacher he has written over 300 papers in various areas of NLP and the topics are quite interesting because it has to do with imparting sentiment and politeness on computers. It is a very novel thought for those of us who grew up with the PC in 1981, politeness was not clearly there in MS-DOS when we first started using it. Prof. Bhattacharyya is a Fellow of the National Academy of Engineering and an alumnus of IIT Kharagpur and got the Distinguished Alumnus from IIT Kharagpur and has many other awards to his name. Moderating for his today we have two people, one is his own student Anoop Kunchakuttan who currently works at Microsoft and it was a coincidence that when Anoop's name came up we realized that he was a student of Prof. Bhattacharyya and I am sure he can read his Professor's mind quite easily and other moderator of course is from IITACB - Dr. Susheela Venkataraman, she will be looking at the Q&A and chat boxes quite regularly.

Prof. Pushpak Bhattacharyya: Thank you very much, thanks to the IIT Alumni Centre at Bengaluru for giving me this opportunity to present our work.

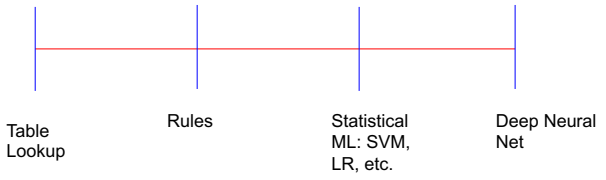
Imparting Sentiment and Politeness on Computers

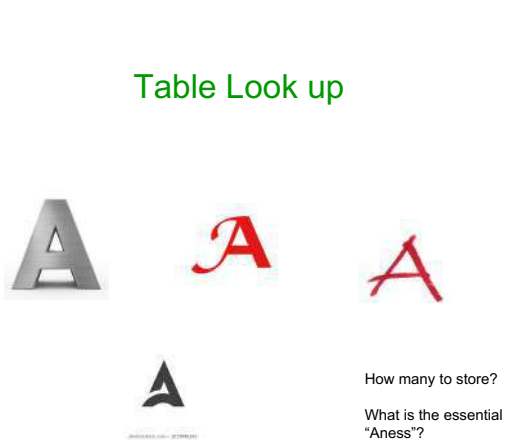
Pushpak Bhattacharyya
Computer Science and Engineering Department
IIT Patna and IIT Bombay
IIT Alumni Center Webinar
27th June, 2020

Acknowledgement: IITP and IITB NLP groups: especially Tulika, Mauzama, Dr. Aditya Joshi, Dr. Asif Ekbal and many more

As Ashok announced, the title of the presentation is Imparting Sentiment and Politeness on Computers and the theme of the session today is making computers human, a fairly dramatic title I would say since the time computers came into the scene our expectation from the machine increased, increased in two fronts, one is speed of the machine, faster and faster computers and other is the expectation to make them more and more intelligent. Now sentiment, politeness, they are human attributes and as we try to bring the machine closer and closer to human beings, we would like to see these properties also. Now I am deeply grateful to the two natural languages processing groups I lead along with my colleagues, other faculty members who are researchers at IIT Patna and IIT Bombay. I will begin with a perspective on machine learning because these problem of sentiment, emotion analysis, making computers human their AI problems (artificial intelligence problems) and the

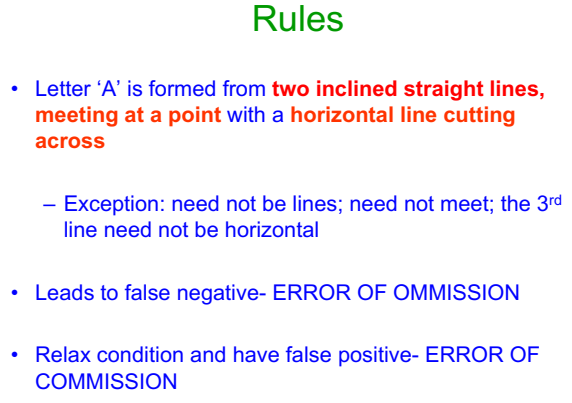
A Perspective on Machine Learning



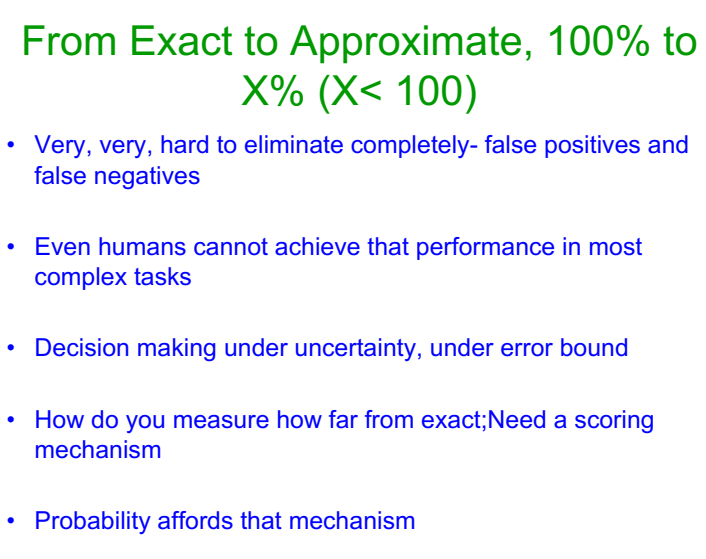


predominant techniques of artificial intelligence today is machine learning. Now if you look at paradigms of machine learning we can put them in four groups and these are the groups which appeared on the screen in this sequence. So we have what is called table look up, then rules, then statistical machine learning and finally today's paradigm deep neural networks. I will give an example, suppose we want to teach the machine recognizing the alphabet A, the alphabet a is written

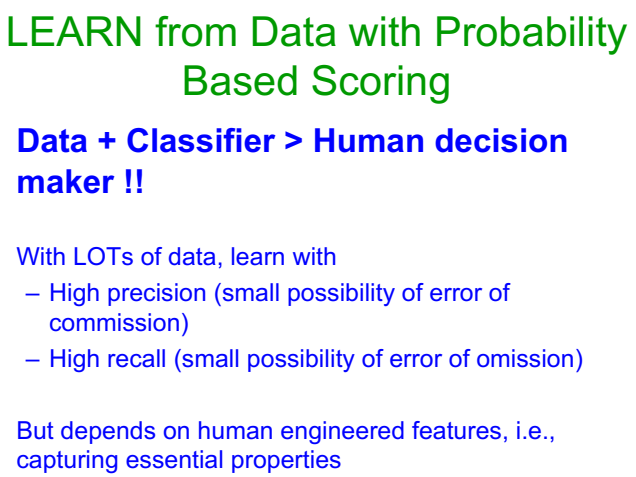
in many different ways, the first a is the classical A, then other different forms a in different shapes - A, A, ... and sizes. The last a is almost a suggestion of A, but we can make out the pattern on the context. Now one method of learning, quote-on-quote learning would be to store these patterns in a table and when we see a new pattern you would like to see the match with these table store patterns and identify the new pattern is an A or not. Now since A can be written in many many different ways, we have to store as many patterns as there are, so that is not intelligent because in spite of all these variations the pattern A has some invariant properties and rule based learning tries to latch on to those invariable properties. So a rule for learning the letter A would



be this statement, letter A is formed from two inclined straight lines meeting at a point with the horizontal line cutting across. The essential features for a pattern to be an A are inclined straight lines meeting at a point and horizontal line cutting across. Now these properties are not really sacrosanct, there can be exceptions, these lines need not be straight lines, they need not meet and the third line need not be horizontal also. So all of these have exceptions, therefore if we are extremely strict about these three features of inclined straight lines meeting at a point and horizontal line cutting across, that may lead to what is called a false negative. This is called an error of omission and if we relax the condition, then we may have the situation of false positivity. This is called an error of commission. So we erroneously commit something, we brand a pattern as A, this is false positive when the pattern is not any and we miss out on patterns as being a when we denote a correct pattern as not A. This is false positive and false negative error of omission and commission. It was realized that the decisions on various situations in that including pattern recognition need not be exact, we can work with approximate decision, approximate correctness so from 100% to X percent where X is less than hundred. So false positives and false negatives to eliminate them completely is a very very hard proposition and may not be worth it. The return on investment to eliminate error 100% false positive or false negative is not justified



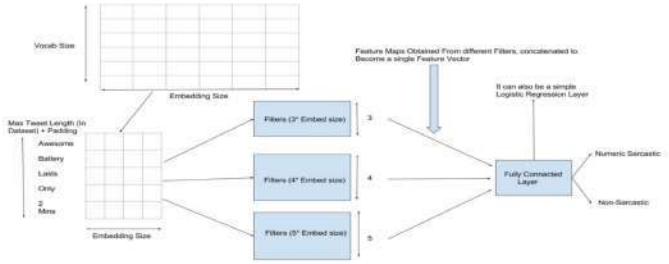
many times. Even humans cannot achieve that kind of performance, so decision making under uncertainty, under error bound is the hallmark of intelligent behaviour. Now the distance from the exact decision, how to measure the distance, we need a scoring mechanism and fortunately for us this very powerful mathematical framework of probability many hundred years of accumulated knowledge in measure theory, statistics, probability comes to our help.



So we go to the data and we learn the pattern from the data based on probabilistic scoring and we have come to see through experiment after experiment, application after application that this combination of data and classifier is very powerful so much so that large volumes of data with a powerful classifier can surpass human decision making ability. So it is lots of data we can learn with high precision and high recall that means small possibility of error or commission and small possibility of error of omission. However, this kind of learning which is now called classical machine learning is based on human engineered features, you would recall two straight lines meeting at the point with a third horizontal line cutting across.

Reduce human dependency: DEEP LEARN

- End to end systems; essential properties learnt at intermediate layers



Theseare human engineered features, human beings look at the data and decide that these are the features based on which learning will take place. So this dependence on human judgement also is a limiting factor and therefore today's paradigm is called deep learning, this is also known as N to N decision making or pattern recognition into machine learning where we present only the data on the input side and make decisions for classification on the output side leaving all the intermediate processing to many layers in between. So this is a typical deep neural network where a convolutional neural network is followed by feed forward, hence the character network with a soft max at the output layer. All these are terminology which is very standard these days and they only emphasize the fact that processing happens in multiple layers with input being given and output received from many neurons at the output layer, so this is the deep learning system where there is ideally no feature engineering but this is really an idealization as we see.

Importance of Natural Language Processing: Start up on **Call-Center-Analytics** (anonymized)

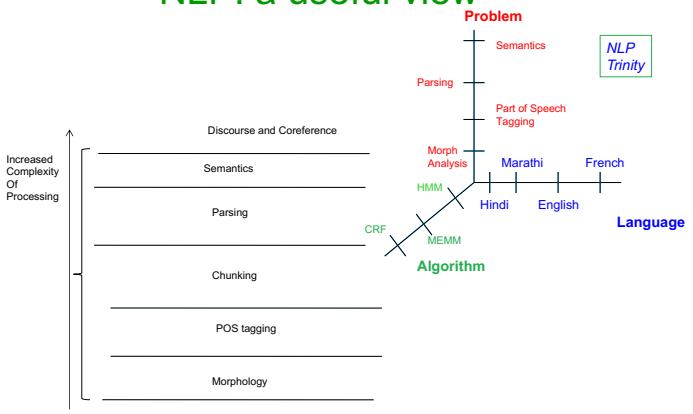
- A property and casualty insurance company has a call center
- Deal with customer complaints; cannot handle volume

- Call center too cannot! !
  - AUTOMATION called for
    - ***Natural Language Understanding-Automatic Speech Recognition-Sentiment***

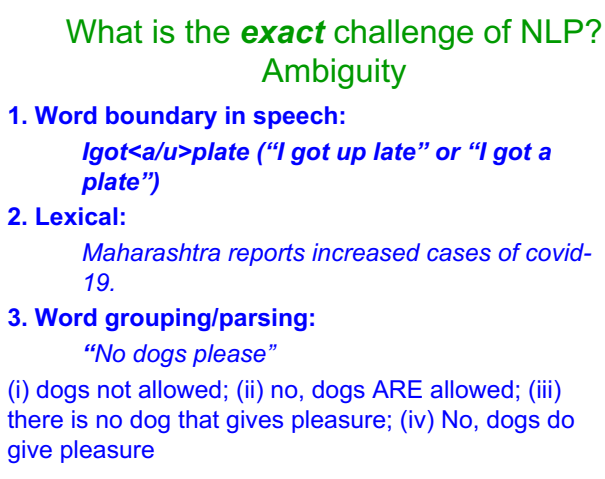
After this very brief overview of machine learning or the essence of machine learning, we come to some remarks on natural language processing. This is illustrated through a practical application in the domain of Call-Centre-Analytics. A property and casualty insurance company has a call centre. This call centre is employed because the company cannot deal with customer complaints, the volume is huge. Even a Call Centre cannot handle the volume. So automation is called for, which requires natural language understanding, automatic speech recognition and very importantly sentiment. So the spoken utterances are converted into text, text is processed into natural language understanding and finally the sentiment is detected, is the customer angry, is the customer happy, those sentiments are detected from the sentiment analysis techniques.

One of the useful use of natural language processing is what is shown on this slide here, natural language processing happens in layers starting with morphology where the word is broken into parts, Jaoonga for example is "Jana" is the stem and "oonga" is

NLP: a useful view



the suffix indicating future terms, first person singular number as the features. Then the word goes through the part of speech tagging layer and nouns, verbs, adjectives are detected, chunking where small phrases are formed, the blue sky, parsing which produces the phrases in the sentence and dependencies, semantics which does these which are various kinds of disambiguation and semantic role identification and finally larger pieces of text are formed from small pieces of text through various resolutions like for reference resolution discourse processing and so on. Natural language processing is also a three dimension problem where we deal with the languages of the world which have their own properties. We solve a particular problem related to language for example boxing and this is done through algorithms which are designed by computational team of having proper expertise in machine learning, linguistics, language properties and also a good sense of the problem. Now we use language every day, we do not think about our capability of using language, this is a very spontaneous capability of intelligent beings. Now what is the exact challenge of natural language processing, a faculty that we use effortlessly what exactly is the challenge of replicating this faculty on machines. So the main challenge or even on the only challenge is ambiguity, there is ambiguity at various levels. So if I utter these words very rapidly, I got<a/u>plate, "I got up late" or "I got a plate", it is not clear what I say. So the translation of these sentences into Hindi



or Marathi will depend on this application. There is this lexical ambiguity which depends on the ambiguity of word meanings, so look at this interesting sentence which recently came in newspapers, "Maharashtra reports increased cases of Covid-19". One meaning would be Maharashtra has reported, has described or brought to the notice of others increased cases of Covid 19 but it is also possible to have another interpretation which is not likely but that interpretation exists. Maharashtra reports, the reports from Maharashtra caused increase in cases of Covid 19. A very unlikely interpretation but it is not wrong if we go word by word. The reason for this ambiguities reports can be nouns as well as forms "Maharashtra reports" process is hard sense, the second sense is noun sense will increase is the main word and in the other sense reports is the main verb. What groupings can lead to ambiguous situations " No dogs please" depending on where you fall where you put the punctuation and also depending on the invidious interpretations you can get four meanings out of the sentence, "dogs are not allowed ; no dogs indeed are allowed; there is no dog that gives pleasure; no dogs do give pleasure. All these four meanings can come from these three words depending on the pause and the meaning of please.

Ambiguity: at every layer

4. Semantic Role:

Flying planes can be dangerous

"flying" dangerous? Or "planes"

Case-1: 'planes' are objects; case-2: planes are subjects

5. Pragmatics

@abc-airlines (sarcasm)

Thank you *for sending my baggage to New York and myself to Chicago at the same time. Brilliant service!*

3. **Discourse co-reference:**

The cat went near the dog, and it bit it (who bit whom?)

Semantic Role ambiguity, this is a very classic sentence, flying planes can be dangerous, what is dangerous is act of flying dangerous or planes dangerous. In

the first case planes are objects of flying, in the second case planes are subjects with predicate as being dangerous. There is what is called pragmatic ambiguity, there is an ABC Airlines for which an irate customer remarks, " thank you for sending my package to New York and myself to Chicago at the same time. Brilliant service." On the surface this looks like a statement of praise but actually the customer is unhappy and the chatbot replies "Thank you", then the customer's irritation will increase. Discourse or core difference ambiguity arises from the noun pronoun binding "the cat went near the dog and it bit it", it is not clear who bit whom, a cat or the dog. So there is ambiguity at every layer and this is the challenge that is posed by natural language processing when we teach machines how to use language and this is not true of only English, all languages have ambiguity. Another sentence which emphasizes the interlayer information transfer, the need for interlayer information transfer is this sentence, "I saw the boy with a telescope" - this is an ambiguous sentence, it is not clear who has the telescope. I saw the boy with a telescope which he dropped accidentally, now it is clear who has the telescope but to process this second part of the sentence, the subordinate clause requires parsing to be done and parsing to be done requires resolving the pronoun references, resolving he to the

Enter deep learning: Inter Layer interplay

Text-1: "*I saw the boy with a telescope which he dropped accidentally*"
Text-2: "*I saw the boy with a telescope which I dropped accidentally*

nsubj(saw-2, I-1)
root(ROOT-0, saw-2)
det(boy-4, the-3)
dobj(saw-2, boy-4)
det(telescope-7, a-6)
prep_with(saw-2, telescope-7)
dobj(dropped-10, telescope-7)
nsubj(dropped-10, I-9)
rcmod(telescope-7, dropped-10)
advmod(dropped-10, accidentally-11)

nsubj(saw-2, I-1)
root(ROOT-0, saw-2)
det(boy-4, the-3)
dobj(saw-2, boy-4)
det(telescope-7, a-6)
prep_with(saw-2, telescope-7)
dobj(dropped-10, telescope-7)
nsubj(dropped-10, he-9)
rcmod(telescope-7, dropped-10)
advmod(dropped-10, accidentally-11)

correct noun and there is a chicken-and-egg problem, a circularity in the problem which can be broken only through the back and forth information transfer between different layers of natural language processing. This is where deep learning comes into play a neural network with multiple layers is a natural matching technique for natural language processing which is also done in multiple layers. Now we have been doing natural language processing in IIT Bombay and recently at IIT Patna, the IIT Bombay lab is in existence since 2000, it is a lab for processing Indian languages and another lab on AI natural language processing machine learning lab in IIT Patna, this is in existence since 2015.

Since 2000

27jun20 webinar:pushpak 13

We tackle many different areas of natural language processing starting with machine language processing and going up to cognitive natural language processing through sentiment analysis, information extraction, lexical semantics and so on. We believe both linguistics and computation are important and use this statement in our lab "linguistics is the eye and computation is the body". So

linguistics gives the insight and computation realizes that insight to build a backdrop practical application.

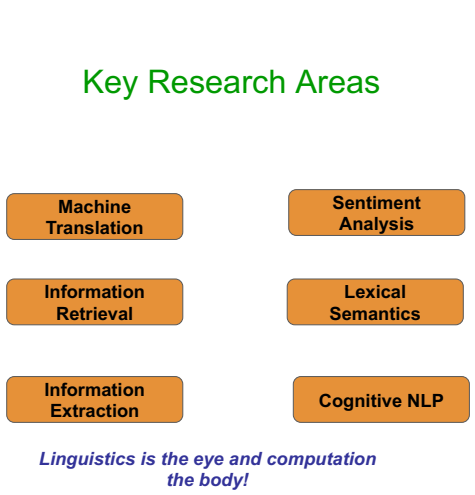
Since 2015

27jun20 webinar:pushpak 14

Now we come to the topic of today namely Sentiment Analysis but here now 20 minutes are over, may be I will take a break and see if there are questions which audience might want to ask.

Mr. Anoop: One question from Mr. Basu. Is it true that the level of ambiguity varies with different languages.

Prof. Pushpak Bhattacharyya: All languages have ambiguity but the variation can come in different layers, so languages for example differ in morphology where there are morphologically strong languages like Hungarian, Turkish and Dravidian



15 languages where a huge amount of information is based on the words. My favourite example is Hindi and English comparison. Now if I look at the two words, will go, optionally verb and main word it is not clear if the number is plural or singular, I will go, We will go, so number is left ambiguous, person is also ambiguous, He will go, I will go. But take the Hindi corresponding string, Jaunga or Jayega so when I see Jaunga there is no ambiguity, it is I first person, singular number and future tense. So because of will the tense is disambiguated but there is no other cue with respect to personal number but for Hindi, the personal number is indicated on the word itself. But does it mean that Hindi has less ambiguity compared to English, no as we move up the layer we go to more and more difficult problems of semantics, question answering sentiment analysis, we see ambiguity appearing whatever with the language and measuring ambiguity is still a distant proposition. There are entropy measures but they really do not indicate ambiguity as precisely as we want to be done.

Mr. Anoop: One related question that seems to be popular with lot of people is, it is said that Sanskrit is unambiguous, it is true.

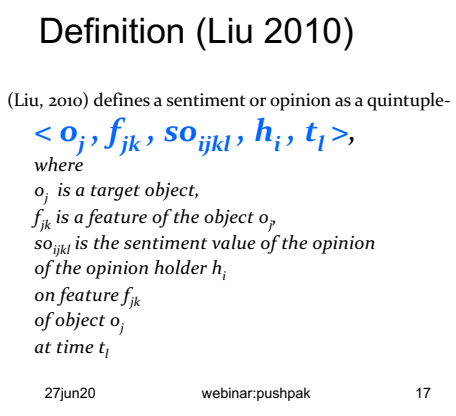
Prof. Pushpak Bhattachryya: Sanskrit enforces a lot of information on the word and that is why there is this feeling that Sanskrit is unambiguous and this is a pretty old notion but that is not true really. Again my favourite example here is "....", three words. Now, one translation of this is the `old friend's house', here vridha meaning old is adjective for mitra which is friend, the other meaning is the old man's friend's house, so here vridha is a noun so here vridha means an old man, the sentence can mean, the old man's friend's house or old friend's house. So this ambiguity is arising because the vridha can be both adjective and noun. So this part of speech ambiguity is in existence for Sanskrit also and therefore higher levels of natural language processing have ambiguity problem even for Sanskrit.

Mr. Anoop: When you initially talked about how machine learning has evolved, you related to these different layers, different approaches where more and more data is being used, this one should be lesser expertise as I see it is required in some areas but may be more expertise on the algorithmic front, less on domain front, so this introduces a challenge of how do you start off with many problems or languages where there is little data. So you combine approaches in certain ways.

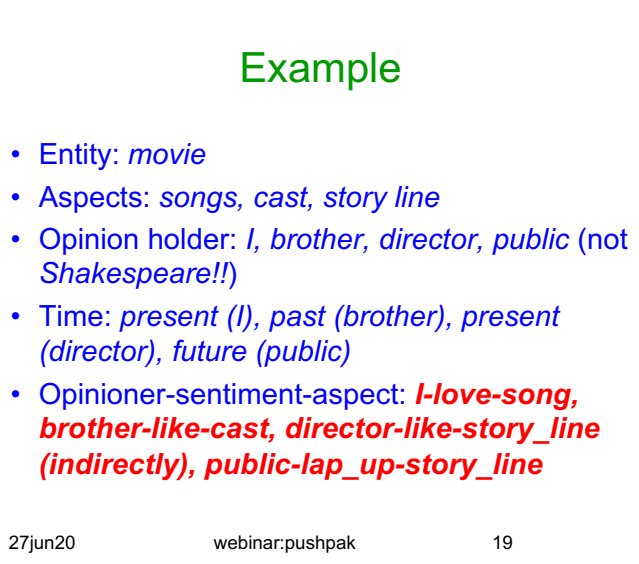
Prof. Pushpak Bhattacharyya: What data scientists and machine learning researchers do is that they try to extract as much as they can from data. Now when data is in short supply, they lean on their insight into the problem, so if I take a problem of language processing, we solve with machine learning and if I see scarcity of data then I appeal to insight into language and who gives me insight into language, the knowledge that gives me insight into language is linguistics. So linguistics studies, chronology, phonetics, morphology, semantics, syntax these are

traditional divisions of linguistics. So the insights from these areas namely the syntactic structure the morphological behaviour of words, they are taken and they are encoded on the data. The data is embellished with this kind of linguistic properties and example is factor based machine statistical machine translation, so people try to make up for data with linguistic insight, a situation which is a reversal of what used to happen before, people used to rely completely on problem insight and going forward would understand that the problem insight is limited by our own understanding so therefore we would like to augment the problem solving situation with this. So data and problem specific insight are synergistic forces to solve a problem.

Mr. Anoop: Now we can continue with the lecture.

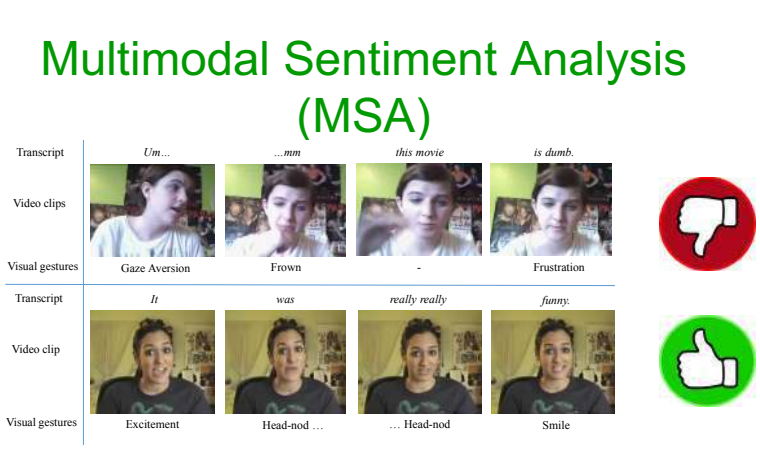


Prof. Pushpak Bhattacharyya: So the topic for today, Sentiment Analysis is the first part of the talk. Sentiment is formally defined by a quintuple where the third entity SO is the most important component of the quintuple which is sentiment on an object for a feature F by an opinion holder h at a time T. So this is a quintuple definition of sentiment analysis and we will see with an example that this quintuple definition is very important, otherwise there can be confusion going forward. So this is a long sentence, "I love the songs in the movie, though only the cast was liked by my brother who said the

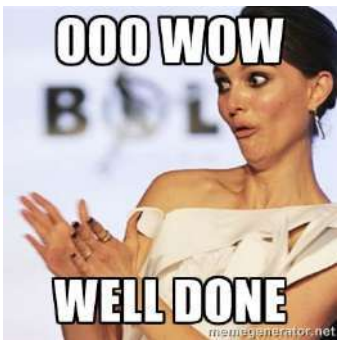


director was of the opinion that the story line which is from a novel by Shakespeare will be lapped up by the public". So this sentence is complex because there are many nouns, many verbs and there is complex interaction of who likes what and when. So this can be organized in the form of what is called dependency parsing and we have these combinations. I love song, brother like case, director like storyline, public lap up storyline. Though Shakespeare appears in the text, Shakespeare is not a participant in the sentiment analysis processing. So now it is important to create this tuples carefully and accurately otherwise the sentiment decision can be wrong. So there is relationship between me and the song, brother and cast, I love the song, there is nothing is said about my opinion about the cast or my brother's opinion about the storyline. So it is important to pair these nouns properly along with their sentiment value. So this is what is ensured in the five double definition that we just now saw. Sentiment analysis is a multi-dimensional problem involving languages, involving the granularity of the sentiment involving the kind of machine learning paradigm we use, the resources, the emotion dictionary for example which is used and so how is the sentiment expressed, for example the ordinal value of 1 2 3 4 5 going 1 being very negative, 5 being very positive and so on. Then features which are used for machine learning are syntactic dependencies, discourse features that is words, phrases and so on. It is a complex

problem involving attention to be given to multiple dimensions and this point about sentiment being sensitive to the language that is used is an important one.



Now, these days multimodality is becoming increasingly important in sentiment analysis. For the problem of sentiment analysis let us remember and see if a computer can detect the sentiment of an utterance or a piece of text, also can it produce sentiment for example a chat bot, can it show emotion in empathy acts etc. when it is interacting with a customer. Now multimodality is important because of facial expressions, tonality - they play an important role in detecting sentiment. So this becomes all the more important when we deal with a very difficult problem for sarcasm, so if we look at the text only, "ooo wow well done" , this looks like a praise but look at the body language of the speaker, this is very negative, so a positive sentiment text with a negative sentiment body language shows that there is something



special about the situation that speciality is the very difficult problem of sarcasm. We have done lot of research into computational sarcasm detection and I will talk about it during the course of the presentation.

Emotion Analysis and Sentiment Analysis

- **SA** : positive/negative/neutral
- **EA:** Finer labels like Anger, Disgust, Happiness, etc.

Emotional analysis is slightly a more difficult problem because in sentiment analysis we only concentrate on neutral affinity and negativity. In emotional analysis we have to deal with multiple emotions which makes it a multi-class machine learning problem, for example you have to deal with finer levels like anger, disgust, happiness and so on. Now there has been a lot of work into emotion, the psychology of emotion and two basic emotions have been identified, happiness and sadness, then the psychologists, Ekman's distribution of emotions is very classical, there are six emotions - anger, disgust, fear, sadness, happiness and surprise. Plutchik, another psychologist introduced two more emotions - anticipation and trust and India also contributed to this research on psychology of emotions through what is called

Basic emotions: multiple frameworks

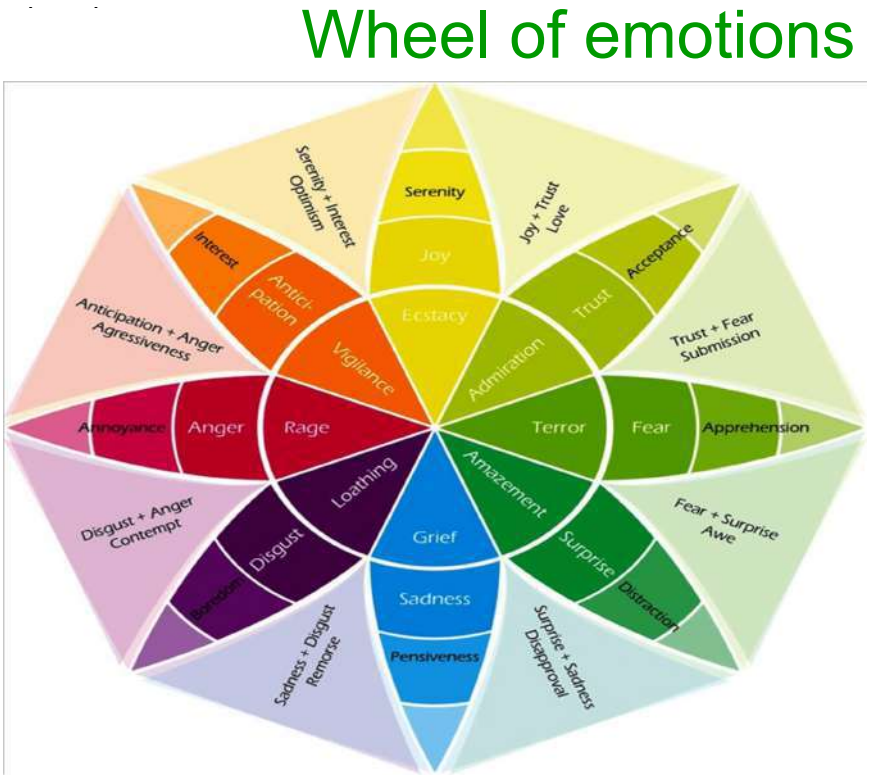
Basic emotions:
Happiness, Sadness

Ekman's emotions:
Anger, Disgust, Fear, Sadness, Happiness, Surprise

Plutchik's emotions:
Anger, Disgust, Fear, Sadness, Happiness, Surprise, Anticipation, trust

Bharat-muni's "nava-rasas":
Love, Mirth, Fury, Compassion, Disgust, Horror, Terror, Heroism, Wonder

"Navarasas", which a dancer must master. If Bharatanatyam dancer or Odissi dancer for example should be able to depict or express these nine emotions which are called Navarasa. Now Plutchik's wheel of emotions which came from the



psychologist Plutchik in 1982 is very important fundamental to computational emotion detection, there are eight basic emotions - anticipation, joy, trust, fear, surprise, sadness, disgust. So this wheel structure is very interesting because as we go from the centre to the periphery the intensity of emotion decreases. So terror is very intense, fear is less intense, apprehension is the least intense and similarly the area between two petals is the combination emotion region for example joy and trust together produce love. So this was a very nice contribution from Plutchik where emotions have been categorized and even combination emotions have been identified with their constituents.

Our work spans multiple areas of SA/EA with multiple techniques

Problem-vs-Technique	Basic Sentiment/Emotion Detection	Thwarting	Sarcasm	Emoji	Cross and Multi-Lingual SA/EA	SA/EA in Dialogues
Rule Based	year 2000 onwards	2012	2013			
Classical ML Based				2016	2015	2018
Deep Learning Based						
Hybrid						

Since 2000

We have been working on sentiment analysis, emotion analysis since 2000 and this matrix shows the techniques we have used over the years from rule based to classical machine learning to deep learning to hybrid base and many different kinds of sentiment analysis problems we have dealt with like basics sentiment motion detection to thwarting, sarcasm, emoji, cross and multi-lingual sentiment analysis/end analysis, sentiment analysis/end analysis in dialogues. So sentiment analysis in dialogue is one of our recent efforts, we have been working on this since 2018 with the application of classical machine learning and deep learning and hybrid based methods. Moving forward, I take up a specific piece of recent work, this is done with our Ph.D. students, Tulika Saha and Aditya Patra at IIT Patna and Sriparna Saha who is my collaborator and faculty member at IIT Patna.

Dialogue Act Classification and Sentiment

Tulika Saha, Aditya Patra, Sriparna Saha and Pushpak Bhattacharyya, *Towards Emotion-aided Multi-modal Dialogue Act Classification*, Association of Computational Linguistics Conference (**ACL 2020**), Seattle USA, 5-10 July, 2020.

Dialogue Act Classification (DAC) and Multimodality

- DAC → Intent
- Each turn primarily *a question, a statement, or a request for action*
- Prior work: Jurafsky et al. (1997), Stolcke et al (2000), Verbree et al (2006), Kalchbrenner and Blunsom (2013), Liu et al. (2017), Ortega et al (2019), Saha et al (2019) etc.

This is towards the emotion aided multimodal dialogue act classification. These proceeds from the observation that dialogue at classification has the objective of identifying the intent, so a dialogue is taking place between two speakers or multiple speakers and each turn is primarily a question, a statement or a request for action with variations on these three basic aspects, question, or statement or request for action. So there has been lot of work in dialogue act classification that means the basic question is to identify is this turn of dialogue a question or a statement or a request for action. So a change of tone and facial expressions for example needs to understand is the input from the user a question or a statement or action and similarly has to understand the response from it, it should be a statement or a request for action or a question. So there has been lot of work from linguists as well as computer scientists and psychologists and we the researchers have understood that nonverbal features like change of tone, facial expression, they provided beneficial use to identify the dialogue act so for example raised eyebrows can show that this start of the dialogue is a question, so to exemplify what I am saying is this statement `haji ha' and in fact emotion also expressed in this dialogue, for example "haji ha" could be a statement denoting agreement or it can be a disagreement in a sarcastic way, "haji

Emotion and Dialogue

- Non-verbal features
  - change of tone, facial expressions
  - provide beneficial cues to identify Das
  - Emotion aided multi-modal DAC
  - "ha ji ha" in Hindi can denote agreement (statement) or disagreement *(sarcasm)*
- Contributions
  - Emotion-aware DA dataset (EMOTyDA)
  - Multi-modal, multi-task DNN for DAs and emotions identification
  - Showed: Multi-modality and multi-tasking DAC better than uni-modal and single task DAC

Example of dialogue and dialogue acts

Fragment of a labeled conversation (from the Switchboard corpus).

Speaker	Dialogue Act	Utterance
A	YES-NO-QUESTION	So do you go to college right now?
A	ABANDONED	Are yo-,
B	YES-ANSWER	*Yeah,*
B	STATEMENT	*it's my last year [laughter].*
A	DECLARATIVE-QUESTION	You're a, so you're a senior now.
B	YES-ANSWER	*Yeah,*
B	STATEMENT	*I'm working on my projects trying to graduate [laughter].*
A	APPRECIATION	Oh, good for you.
B	BACKCHANNEL	*Yeah.*
A	APPRECIATION	That's great,
A	YES-NO-QUESTION	um, is, is N C University is that, uh, State,
B	STATEMENT	*N C State.*
A	SIGNAL-NON-UNDERSTANDING	What did you say?
B	STATEMENT	*N C State.*

ha", where the tone shows that the speaker is not satisfied with the situation and this "haji ha" is actually a negative statement. It is a disagreement. We understood that identifying the turn of the dialogue as question, statement or action also depends on the emotion and the tonality and facial features. This is multi model emotional assisted dialogue. So

Prior Work

- Dating back to late 1990's (Reithinger and Klesen, 1997), (Stolcke et al., 1998) and early 2000's (Stolcke et al., 2000), (Grau et al., 2004)
- DA specification and taxonomy got established
- ***DAC = sequence labelling***
- DL Based:
  - Khanpour et al. (2016)- stacked LSTM
  - Kumar et al (2018)- hierarchical bi-LSTM and CRF
  - Raheja and Tetreault (2019)- contextual self-attention framework fused with hierarchical recurrent units
  - Yu et al (2019)- CNN

our contribution was we created a dataset which other researchers can use, we have trained a model with this data set, this model can be used for new dialogue situations and we have also established that capturing multi-modality that is visual clues and the speech clues is helpful for pacifying the dialogues and detecting emotion alongside helps this task of dialogue and transcription. These tasks help each other. So dialogue classification can be looked up and as a sequence labelling task as the next slide show, there are two persons interacting with each other, they are in a dialogue, there are two persons A and B, so A says, "do you go to the college right now", so if B is a computer, B should identify that this is an Yes or No question and then A starts to say something more, are you then abandon this and then says yes it is my last year and then abandon this because B says Yes it is my last year so this way the dialogue progresses and each of these starts available whether it is a question or abandoned declarative question, appreciation, back channel and so on. So this becomes what is called the sequence levelling problem, there are sequence of turns from which we have to level and if we can identify the emotion for example laughter we see this laughter expressions then this task becomes a little easier. So it is customary to report in this kind of work what was the data, how did the data come along what is the source of the data what is the quality of the data size of the data which is fed into the machine learning technique so there are many different kinds of data I am going to read them but we have taken IEMOCAP and MELD data set these two data sets and these have

Our Dataset: EMOTyDA

- Short videos of dialogue conversations manually annotated with its DA along with its pre-annotated emotions
- Studied existing emotion recognition data sources
  - Youtube (Morency et al 2011), MOUD (P´erez-Rosas et al., 2013), IEMOCAP (Busso et al., 2008), ICT-MMMO (W¨ollmer et al., 2013), CMU-MOSI (Zadeh et al., 2016), CMU-MOSEI (Zadeh et al., 2018) and MELD (Poria et al., 2019)
- Zeroed down on IEMOCAP and MELD datasets
- Manually annotated for DAs

been processed further for creating the data set for our problem. So 12 frequently occurring chosen tags are: Greeting (g), Apology (ap), Command (c), Question (q), Answer (ans), Agreement (ag), Disagreement (dag), Statement-Opinion (o), Statement-Non-Opinion (s), Acknowledge (a), Backchannel (b), and Others (oth) and we have about twenty thousand statements in a dialogue sequence which have been annotated this way , so this becomes a very valuable resource for researchers working on dialogue act and emotional analysis also.

Data Annotation (1/2)

- SWBD-DAMSL tag-set consisting of 42 DAs (Jurafsky, 1997) for task-independent dyadic conversation such as SWBD corpus used
- Out of the 42 DAs of the SWBD-DAMSL tag-set, 12 most commonly occurring tags selected
- 12 frequently occurring chosen tags are
  - Greeting (g), Apology (ap), Command (c),
  - Question (q), Answer (ans), Agreement (ag),
  - Disagreement (dag), Statement-Opinion (o), Statement-Non-Opinion (s),
  - Acknowledge (a), Backchannel (b) and Others (oth).

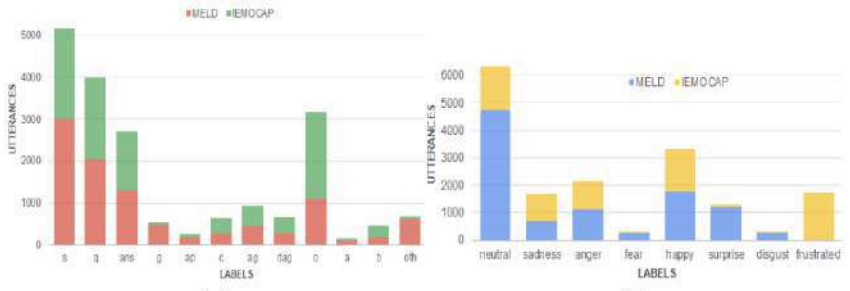
Data Annotation (2/2)

- A subset of 1039 dialogues from MELD amounting to 9989 utterances and the entire IEMOCAP dataset of 302 dialogues amounting to 9376 utterances
- Three annotators graduate in English were assigned to annotate the utterances
- The inter-annotator score with more than 80% was considered as reliable agreement
- Mapped the *joy* tag of MELD to *happy* tag of the IEMOCAP

Here is a graphics which is describing some of the properties of this data set. For example, in this twenty thousand statements in dialogue tags a large number of statements are not opinions, then there are questions, then there are answers, also opinions are quite high in proportion and if we look at the emotion distribution then neutral statements are maximum in number followed by happy followed by frustrated anger, sadness and so on. This is the property of the data showing

Particulars of EMOTyDA

- 1341 dyadic and multi-party conversations resulting in a total of 19,365 utterances or annotated videos with the corresponding DA and emotion tags considering the dialogue history



(a) (b)

Figure 1: Statistics across the datasets : (a) Distribution of DA labels, (b) Distribution of emotion labels

distribution of emotion and showing the distribution of kinds of dialogue terms. Now the case for multi-modality is an apparent problem. These dialogues, for example, if you look at two that is very amusing indeed so if you look at the text along that then it looks like an appreciation, a statement which is happy but actually if we look at the facial expression and the audio, audio a sarcastic tone and video shows slight anger, so these three clues, these three signals should be processed together to understand this dialogue and also to make an appropriate response to this dialogue. Now the technique that we used is a machine learning deep learning based technique which makes use of textual features, the text is

Case for modality

(a) (b)

Figure 2: (a) Incongruent modalities in DAC, (b) Importance of emotion in DAC.

converted to vectors by making use of what is called embeddings. These are deep learning constituents, we capture the audio features, for example emphasis features, voiced segments and their statistics. Also frequency coefficients which comes from ASR, (automatic speech recognition) and these features are put together. Similarly, the visual features are put together obtained through Image_net Rest_net, these are techniques in learning system, finally we get a representation which is shown in this diagram.

Technique: Feature Extraction (1/2)

- **Text**: transcripts of each video; concatenation of pretrained GloVe (Pennington et al., 2014)
- **Audio**: OpenSMILE (Eyben et al., 2010), an open source software used
  - 12 Mel-frequency coefficients, glottal source parameters (Drugman et al., 2011), maxima dispersion quotients (Kane and Gobl, 2013),
  - several low-level descriptors (LLD) such as voice intensity, MFCC, voiced/unvoiced segmented features (Drugman and Alwan, 2011), pitch and their statistics (for example, root quadratic mean, mean etc.), voice quality (for example, jitter and shimmer), etc.

Technique: Feature Extraction (2/2)

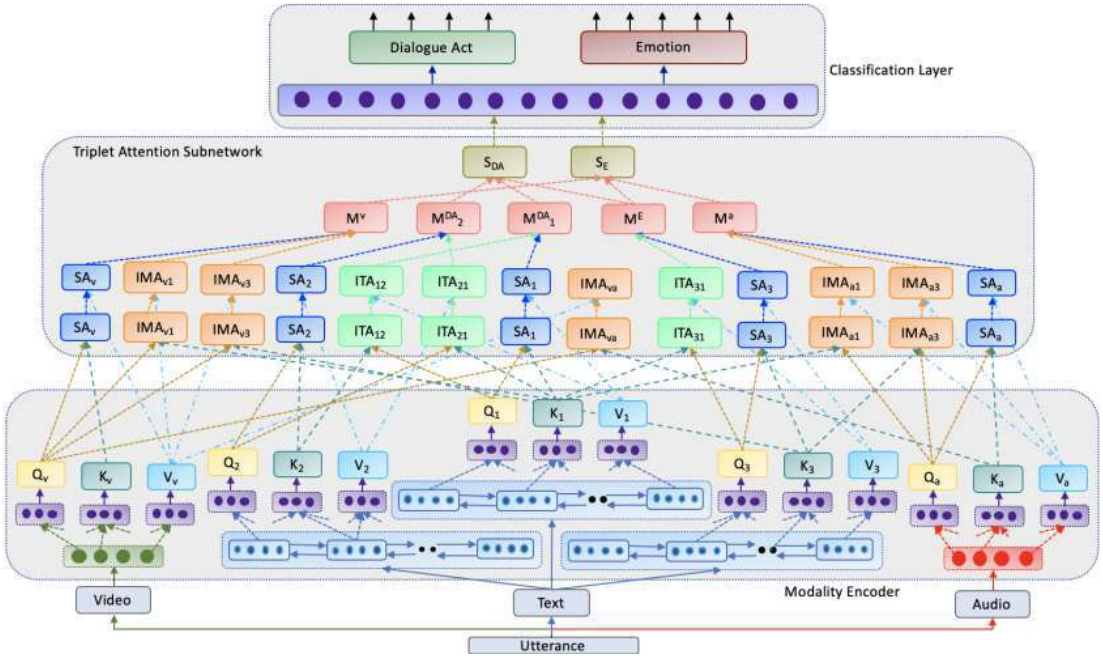
- **Audio (cntd)**:
  - Extracted features concatenated together to form a $d_q = 256$ dimensional representation for each window. The final audio representation of
  - each utterance (A) is obtained by concatenating d_q for every window
- **Video**:
  - ImageNet (Deng et al., 2009) pretrained ResNet-152 (He et al., 2016) used
  - Visual representation of each utterance (F) is obtained by concatenating the obtained $d_f = 4096$ dimensional feature vector for every frame

Network Architecture

- Three main components:
  - (i) Modality Enocoders (ME) which typically takes as input the uni-modal features and outputs the modality encodings,
  - (ii) Triplet Attention Subnetwork (TAS) that encompasses self, inter-modal and inter-task attention and
  - (iii) Classification layer that encompasses outputs of both the tasks (DAC and ER) to be learned jointly conditioned on the output of the TAS

This is a complex picture depicting a deep neural network where, in the input layer we can see the video input, the text input, and the audio input all converted into vectors, they pass through what is called a triplet attention layer that means all these different features of video text and audio are combined. Finally, in the outermost layer we get the dialogue act and the emotion. This is a very typical, very classical deep learning network with multiple layers and multiple compartments doing a particular task so the first compartment

Network Diagram



SA, IMA, ITA represents self, inter-modal and inter-task attentions respectively.

simply processes the input, the second compartment sort of combines the text audio and video features and the final compartment gives the decision on the dialogue act, is it a question or is it a statement or request correction or some kind of variation on that and also the emotion, angered, joy, sadness and so on. Now it is also customary to report the performance of the system by means of numbers and these numbers are in the form of what is called accuracy, F1 score etc. People in the field use these metrics. So, these are the metrics for performance. Now the most important and the most interesting component in this table is this EmotiDA which is a dyadic situation that means it is a two part dialogue and we find that the best accuracy is obtained when we do dialogue at classification and emotion recognition together this DA + ER means dialogue at classification in important emotion recognition are happening together. So we get best accuracy for when we use both text and video.

Results

	Dataset											
	EMOTyDA:dyadic				EMOTyDA:multiparty				EMOTyDA			
	DA		DA + ER		DA		DA + ER		DA		DA + ER	
Modality	Acc.	F1-score	Acc.	F1-score	Acc.	F1-score	Acc.	F1-score	Acc.	F1-score	Acc.	F1-score
Text (T)	63.75	60.67	65.23	62.35	46.20	39.23	48.90	41.10	53.56	49.17	53.02	50.22
Audio (A)	32.06	24.95	35.42	38.92	25.76	19.45	26.58	21.01	27.13	23.09	28.65	24.87
Video (V)	35.94	29.71	36.88	30.34	27.23	20.26	28.12	21.03	30.16	26.85	32.09	27.73
T + A	65.43	60.67	**66.98**	**62.08**	47.17	40.30	**49.42**	**41.69**	54.12	50.00	**56.62**	**51.99**
A + V	38.59	34.98	40.07	36.00	27.91	22.76	28.95	23.89	32.09	28.86	33.76	29.13
T + V	67.12	64.14	**70.55**	**68.12**	49.80	41.90	**51.00**	**44.52**	57.31	53.20	**60.88**	**57.96**
T + A + V	66.35	62.30	**69.45**	**67.00**	49.02	41.00	**50.65**	**44.00**	56.77	52.09	**59.86**	**56.05**
T + V (emotional cue)	65.26	60.20	-	-	46.88	39.70	-	-	54.31	50.02	-	-

Table 1: Results of the various models. Higher the values of accuracy and F1-score, better the performance of the corresponding model. All the reported results are statistically significant

So multimodality is important, multitasking is important, so dialogue act and emotion go together, text and video as input both together. This establishes the fact that a multi task, multi modality approach to dialogue and classification is useful. So the case study that we did was on the friends dataset and here you can see there

are five dialogue turns and then troop levels at the settlement, agreement, opinion and apology. Our system produces the disagreement, agreement and statement and apology whereas a single task system with text and video produces statement, opinion, question and another statement, this is very different from true label, our labelling is closer to the true level. So we report numbers, we report qualitative case study to establish the fact that our system is better than the state-of-the-art and show that emotion and multi-modality in dialogue classification is useful, the data set is contributed to the researchers and they can use this for dialogue, a classification research. The whole system is attention based which combines text with audio and video features and both multi-tasking and multi-mode are useful for doing these tasks.

Case Study

Utterance	True Label	MT(T+V)	ST (T+V)
She is not Larry's girl	dag	dag	s
I know, it was amazing! I mean, we totally nailed it, it was beautiful.	ag	ag	o
Then why is she still single?,New York is full of men.,Why hasn't she married? Probably a hundred people told her she's foolish, but she's waited.	o	s	q
God, I,feel so guilty about Ross.	ap	ap	s

Table 2: Sample utterances with its predicted labels for the best performing multi-task (MT) (T+V) model and its single task (ST) DAC variants; These examples show that ER as an auxiliary task helps DAC for better performance in MT.

Greeting (g), Apology (ap), Command (c),
Question (q), Answer (ans), Agreement (ag),
Disagreement (dag), Statement-Opinion (o), Statement-Non-Opinion (s),
Acknowledge (a), Backchannel (b) and Others (oth).

General SA: accuracy falls in face of sarcastic data

	Precision (Sarc)	Precision (Non-sarc)
Conversation Transcripts		
MeaningCloud[1]	20.14	49.41
NLTK (Bird, 2006)	38.86	81
Tweets		
MeaningCloud[1]	17.58	50.13
NLTK (Bird, 2006)	35.17	69

45

I will quickly finish the next part of the discussion and then hand over again to Anoop for the Q&A part. It is not very big. I must mention that sarcasm detection has been one of our important contributions from our lab, general sarcasm detection is a very difficult problem where the statement is deceptive, it looks like a positive sentiment, appreciation, joy etc. but the underlying sentiment is exactly opposite and we find when we used standard machine learning techniques on benchmark data that the accuracy falls by about half when the input is sarcastic. So non-sarcastic text the accuracy is 50%, 80% by different techniques and this accuracy becomes almost half when the input is sarcastic. So that showed that we need to deal with sarcasm in a special way. When people produce sarcasm, when they resort to sarcastic statements, they also leave clues, for example laughter expressions are quite liberally used; every punctuation use is "protein shake for dinner" to "great"

Clues for Sarcasm

- Use of laughter expression
  - *haha, you are very smart xD*
  - *Your intelligence astounds me. LOL*
- Heavy Punctuation
  - *Protein shake for dinner!! Great!!!*
- Use of emoticons
  - *i LOVE it when people tweet yet ignore my text X-(*
- Interjections
  - *3:00 am work YAY. YAY.*
- Capital Letters
  - *SUPER EXCITED TO WEAR MY UNIFORM TO SCHOOL TOMORROW ! ! :D lol.*

27jun20 webinar:pushpak 46

exclamations, then emoticons are used, interjections are used, capital letters. So these clues are important for detecting a sarcastic situation. So users make use of a very complex instrument, the instrument of sarcasm but also leave behind quite a few clues which are called pragmatic.

Incongruity: at the heart of things!

- *I love being ignored*
- *3:00 am work YAY. YAY.*
- *Up all night coughing. yeah me!*
- *No power, Yes! Yes! Thank you storm!*
- *This phone has an awesome battery back-up of 2 hour (Sarcastic)*

Two kinds of incongruity

- **Explicit incongruity**
  - Overtly expressed through sentiment words of both polarities
  - Contribute to almost 11% of sarcasm instances
    'I love being ignored'
- **Implicit incongruity**
  - Covertly expressed through phrases of implied sentiment
    'I love this paper so much that I made a doggy bag out of it'

27jun20 webinar:pushpak 48

Sarcasm Detection Using Semantic incongruity

Aditya Joshi, Vaibhav Tripathi, Kevin Patel, Pushpak Bhattacharyya and Mark Carman, *Are Word Embedding-based Features Useful for Sarcasm Detection?*, **EMNLP 2016**, Austin, Texas, USA, November 1-5, 2016.

Also covered in: How Vector Space Mathematics Helps Machines Spot Sarcasm, MIT Technology Review, 13th October, 2016.
www.cfilt.iitb.ac.in/sarcasmsuite/

27jun20 webinar:pushpak 49

Our contribution is the following. We understood the sarcasm arises from what is

called incongruity, so "I love being ignored" is a sarcastic statement. "3:00 a.m. work YAY. YAY." is again a sarcastic statement. They are sarcastic because they have incongruity. Love is a positive sentiment, ignore is negative sentiment, YAY YAY is positive sentiment. Somebody working at 3:00 a.m. is a negative situation. So the presence of both positivity and negativity is an incongruous situation and that is exploited for algorithm design. So this the work of my Ph.D. student, Dr. Aditya Joshi and his investigations into all sarcasm was very deep and broad. Now incongruity can be explicit, "I

love being ignored" where positive and negative sentiment bearing words appeared overtly on the surface of the sentence and implicit incongruity is the situation where negative phrase or positive phrase is implicit. "I love this paper so much that I made a doggie bag out of this." This paper refers to research paper, the purpose of research paper is to obtain knowledge not really to make a doggie back so this is implicitly in harmony. Now we latched on to incongruity and we gave different techniques or circles of detection and through the exploitation of incongruity we could devise systems, we could engineer systems whose accuracy is better than anything existing. Now, here we made use of standard natural language to synch features like Unigrams which are words, then pragmatic features which are left behind by users, the writers or the speakers in the text capitalization emoticon, punctuation marks etc. and incongruity both in implicit and explicit form by making use of various kinds of dictionaries and language resources. So, we have used tweet data, discussion data and here the numbers which are in capital show that our

Feature Set

Lexical	
Unigrams	Unigrams in the training corpus
Pragmatic	
Capitalization	Numeric feature indicating presence of capital letters
Emoticons & laughter expressions	Numeric feature indicating presence of emoticons and 'lol's
Punctuation marks	Numeric feature indicating presence of punctuation marks
Implicit Incongruity (Based on Riloff et al	
Implicit Sentiment Phrases	Boolean feature indicating phrases extracted from the implicit phrase extraction step
Explicit Incongruity (Based on Ramteke et al	
#Explicit incongruity	Number of times a word is followed by a word of opposite polarity
Largest positive /negative subsequence	Length of largest series of words with polarity unchanged
#Positive words	Number of positive words
#Negative words	Number of negative words
Lexical Polarity	Polarity of a tweet based on words present

Datasets

Name	Text-form	Method of labeling	Statistics
Tweet-A	Tweets	Using sarcasm-based hashtags as labels	5208 total, 4170 sarcastic
Tweet-B	Tweets	Manually labeled (Given by Riloff et al(2013))	2278 total, 506 sarcastic
Discussion-A	Discussion forum posts (IAC Corpus)	Manually labeled (Given by Walker et al (2012))	1502 total, 752 sarcastic

system in different forms of texts or for much better than state-of-the-art. So the main point here is that we give an algorithmic realization of the linguistic concept of incongruity to detect sarcasm and then came what is called word embedding the deep learning era where we make use of word embeddings in a pretty clever way to detect incongruity.

Results

Features	P	R	F
Original Algorithm by Riloff et al. (2013)			
Ordered	0.774	0.098	0.173
Unordered	0.799	0.337	0.474
Our system			
Lexical (**Baseline**)	0.820	0.867	0.842
Lexical+Implicit	0.822	0.887	0.853
Lexical+Explicit	0.807	0.985	0.8871
All features	0.814	0.976	**0.8876**

Tweet-A

Approach	P	R	F
Riloff et al. (2013) (**best reported**)	0.62	0.44	0.51
Maynard and Greenwood (2014)	0.46	0.38	0.41
Our system (all features)	**0.77**	**0.51**	**0.61**

Tweet-B

Features	P	R	F
Lexical (**Baseline**)	0.645	0.508	0.568
Lexical+Explicit	0.698	0.391	0.488
Lexical+Implicit	0.513	0.762	0.581
All features	0.489	0.924	**0.640**

Discussion-A

So if you take this sentence which appears in the screen, "A man needs a woman like a fish needs bicycle." This is a sarcastic statement because similarity value between man and women is much more

Capturing Incongruity Using Word Vectors

Use Similarity of word embeddings

"A man needs a woman like a fish needs bicycle."

Word2Vec similarity(man,woman) = 0.766
Word2Vec similarity(fish, bicycle) = 0.131

than similarity value between fish and bicycle. Fish is hardly like a bicycle but man and women are very similar to each other being species of human beings. Now they took these two parts of the sentence and linked by a preposition called "like". So this similarity is computed by means of cosine similarity of word embeddings, slightly technical here and this has been exploited to capture incongruity as well as sarcasm.

We again made use of different features of incongruity text and then made use of this cosine similarity based on embeddings, we use them on different data sets which are standard benchmark data and we found again with different kinds of embeddings we could improve upon the reported work wherever we made use of this kind of similarity values of word embeddings. For example, compared to L which is a particular of work due to Liebrecht, we had our accuracy value close to 80 whereas their F score value was close to 76. This was the observation for many different reported work with many different kinds of prior works with four word embeddings. We also tackled a very difficult kind of sarcasm which is called numerical sarcasm, sarcasm itself is difficult but numerical sarcasm is still more

Word embedding-based features 54

Unweighted similarity features (S):
- Maximum score of most similar word pair
- Minimum score of most similar word pair
- Maximum score of most dissimilar word pair
- Minimum score of most dissimilar word pair

Distance-weighted similarity features (WS):
- 4 S features weighted by linear distance between the two words

Both (S+WS): 8 features

difficult because the sarcasm arises from numbers, "3:00 a.m. at work." "3:00 a.m. YAH YAH at work" is not very good, "9.00 a.m. YAH YAH at work" is normal but "3:00 a.m. at work is not normal". So this sarcasm is due to a number and that is a very difficult proposition. So here also we made use of rule based approach, machine based approach and the deep learning approach, neural network based approach gave us an accuracy of about 93% which was better than anything reported at the time, so this was the part of sarcasm and the sub part of numerical sarcasm and this

55

Experiment Setup

- Dataset: 3629 Book snippets (759 sarcastic) downloaded from GoodReads website
- Labelled by users with tags
- Five-fold cross-validation
- Classifier: SVM-Perf optimised for F-score
- Configurations:
  - Four prior works (augmented with our sets of features)
  - Four implementations of word embeddings (Word2Vec, LSA, GloVe, Dependency weights-based)

56

Results

Features	P	R	F
Baseline			
Unigrams	67.2	78.8	72.53
S	64.6	75.2	69.49
WS	67.6	51.2	58.26
Both	67	52.8	59.05

	LSA			GloVe			Dependency Weights			Word2Vec		
	P	R	F	P	R	F	P	R	F	P	R	F
L	73	79	75.8	73	79	75.8	73	79	75.8	73	79	75.8
+S	81.8	78.2	**79.95**	81.8	79.2	**80.47**	81.8	78.8	80.27	80.4	80	**80.2**
+WS	76.2	79.8	77.9	76.2	79.6	77.86	81.4	80.8	81.09	80.8	78.6	79.68
+S+WS	77.6	79.8	78.68	74	79.4	76.60	82	80.4	**81.19**	81.6	78.2	79.86
G	84.8	73.8	78.91	84.8	73.8	78.91	84.8	73.8	**78.91**	84.8	73.8	**78.91**
+S	84.2	74.4	**79**	84	72.6	77.8	84.4	72	77.7	84	72.8	78
+WS	84.4	73.6	78.63	84	75.2	**79.35**	84.4	72.6	78.05	83.8	70.2	76.4
+S+WS	84.2	73.6	78.54	84	74	78.68	84.2	72.2	77.73	84	72.8	78
B	81.6	72.2	76.61	81.6	72.2	76.61	81.6	72.2	76.61	81.6	72.2	76.61
+S	78.2	75.6	**76.87**	80.4	76.2	**78.24**	81.2	74.6	**77.76**	81.4	72.6	76.74
+WS	75.8	77.2	76.49	76.6	77	76.79	76.2	76.4	76.29	81.6	73.4	77.28
+S+WS	74.8	77.4	76.07	76.2	78.2	77.18	75.6	78.8	77.16	81	75.4	**78.09**
J	85.2	74.4	79.43	85.2	74.4	79.43	85.2	74.4	79.43	85.2	74.4	79.43
+S	84.8	73.8	78.91	85.6	74.8	79.83	85.4	74.4	79.52	85.4	74.6	**79.63**
+WS	85.6	75.2	**80.06**	85.4	72.6	78.48	85.4	73.4	78.94	85.6	73.4	79.03
+S+WS	84.8	73.6	78.8	85.8	75.4	**80.26**	85.6	74.4	**79.6**	85.2	73.2	78.74

Table 3: Performance obtained on augmenting word embedding features to features from four prior works, for four word embeddings; L: Liebrecht et al. (2013), G: González-Ibánez et al. (2011a), B: Buschmeier et al. (2014) , J: Joshi et al. (2015)

short description was to say that we found a solution to include additional sarcasm detection.

Numerical Sarcasm (1: sarcastic, 0: non-sarcastic)

Approaches	Precision			Recall			F-score		
	P(1)	P(0)	P(avg)	R(1)	R(0)	R(avg)	F(1)	F(0)	F(avg)
Past Approaches									
Buschmeier et.al.	0.19	0.98	0.84	0.99	0.07	0.24	0.32	0.13	0.16
Liebrecht et.al.	0.19	1.00	0.85	1.00	0.07	0.24	0.32	0.13	0.17
Gonzalez et.al.	0.19	0.96	0.83	0.99	0.06	0.23	0.32	0.12	0.15
Joshi et.al.	0.20	1.00	0.86	1.00	0.13	0.29	0.33	0.23	**0.25**
Rule-Based Approaches									
Approach-1	0.53	0.87	0.81	0.39	0.92	0.83	0.45	0.90	**0.82**
Approach-2	0.44	0.85	0.78	0.28	0.92	0.81	0.34	0.89	0.79
Machine-Learning Based Approaches									
SVM	0.50	0.95	0.87	0.80	0.82	0.82	0.61	0.88	**0.83**
KNN	0.36	0.94	0.84	0.81	0.68	0.70	0.50	0.79	0.74
Random Forest	0.47	0.93	0.85	0.74	0.81	0.80	0.57	0.87	0.82
Deep-Learning Based Approaches									
CNN-FF	**0.88**	**0.94**	**0.93**	**0.71**	**0.98**	**0.93**	**0.79**	**0.96**	**0.93**
CNN-LSTM-FF	0.82	0.94	0.92	0.72	0.96	0.92	0.77	0.95	0.92
LSTM-FF	0.76	0.93	0.90	0.68	0.95	0.90	0.72	0.94	0.90

back

Now at this point of time I will again take a break for question answering and I will move to Politeness after that.

Mr. Anoop: Lot of questions are there but I picked up a few in the interest of time, so one interesting question: So your work shows that with dialogue classification that getting multiple modalities helps to improve the systems probably because of ambiguity resolution. One question to pore over from deeper is whether ambiguities can also be introduced by different modalities, so for instance body

languages can have different interpretations in different cultures or if you are using emojis than that they can have different meanings in different contexts.

Prof. Pushpak Bhattacharyya: Very good question. There is one observation that in Bengal we say `bishey bishop' that means poison can cure poison. It is a frequent observation in especially language processing that two ambiguous entities can disambiguate each other. So a very classic example of that is relational semantics. The coordinate is created based on that principle. So words can be ambiguous but when we put synonymous words together, many times the unique meaning emerges. So the word "her" in Hindi is ambiguous with many front meanings, but if we create a set called a sin set with "her" and "parivaar" together, then the meaning that emerges is family. So "parivaar" can be ambiguous, "her" can be ambiguous but their combination is not ambiguous. Now it is true that the body language or the body signals are ambiguous, that can be and the text also is ambiguous but when we put them together we hope that the ambiguity gets either attenuated or completely eliminated. This is a good question we need to study this point whether additional ambiguity can arise from multi-modality.

Mr. Anoop: You mentioned about prediction analysis of basic emotions and the way they can be combined into other emotions, so a couple of questions, one when we look at the translation etc. we always see that the neural network can give you representations of language similarity, differences etc. So is there work that kind of shows whether neural network representations can find out, validate Plutchik's analysis to say that these basic emotions are the basic emotions and then these are combinations of emotions.

Prof. Pushpak Bhattacharyya: We actually have started investigating a specific problem, that problem is combination emotion analysis using machine learning suffers from data sparsity. It is not easy to create emotion animated data and even when we get the annotation done, the inter-annotated agreement that means agreement between the annotators many times is low. It is quite easy to confuse joy with surprise, disgust with anger, disgust with anger is a very very common situation of confusion. So data sparsity is definitely hurting this kind of analysis. So your question related to data sparsity and also validate the kind of analysis that Plutchik has done. One piece of work that we started with a few students is that love is said to be a combination emotion, so it is joy and trust, that is what Plutchik's document says emotion as. Similarly there are other combination emotions. Now what we embarked on, is we take embeddings of these words: love, joy and surprise and their synonyms and then we try to see if this embedding of love or associated and synonymous words can be obtained by some kind of combination linear or polynomial combination of joy and trust or they are synonymous. So we have started investigating this question and if this really holds then it will reduce the data requirement quite a lot that means you will not have to annotate for example the emotion of love on the data because it can be generated from the constituent emotions of joy and trust, so this needs investigation and this needs validity.

Mr. Anoop: Now you may continue the lecture.

Prof. Pushpak Bhattacharyya: In the third part of the presentation I take a very important problem which is important for all organisation which employ chat box

Inducing courteous behavior in Customer Care Responses

Hitesh Golchha*, Mauajama Firdaus*, Asif Ekbal, Pushpak Bhattacharyya; ***Courteously Yours: Inducing courteous behavior in Customer Care responses using Reinforced Pointer Generator Network*****; NAACL-HLT 2019**

(slides courtesy: Mauajama)

58

An Actual Example (empathy and assurance)

Generic Conversation	Courteous Conversation
User: y'all just came to my house like last week and I'm having problems with my internet again smh	*User:* y'all just came to my house like last week and I'm having problems with my internet again smh
System: What is happening with your internet?	*System:* **Oh no that's not good. I can help!** What is happening with your internet?
User: I think there's an outage	*User:* I think there's an outage
System: There may be maintenance work in your area. Please DM your info.	*System:* There may be maintenance work in your area. Please DM your info. **Thanks for using our services.**

What is Courtesy

- A courtesy is a **polite remark or respectful act.**
- For example,
  - complain about a bad meal, and usually get an **apology** from the manager and, if you're lucky, a free dinner.

Problem Definition

Domain: Customer Care on Twitter

Input: generic chatbot reply

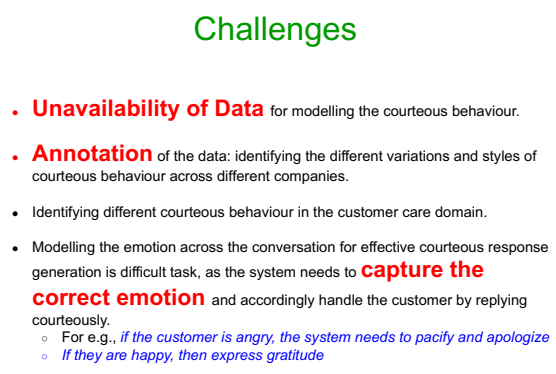
Output: polite reply (*output*) that:

- Is emotionally aware, Uses courteous phrases and emoticons to display appreciation, empathy, apology, assurance.

for customer interaction. This is the work primarily of our Ph.D. students, , Mauajama Firdaus at IIT Patna, her B.Tech. associate Hitesh Golchha and Asif Ekbal who is my collaborator and researcher at IIT Patna. Now courteous behaviour is very important for business for industry. If we complain about a bad meal in a restaurant we usually get an apology from the manager and may get a free dinner also and a courteous expression is a polite remark or a respectful act. Now our problem statement is the following, our domain is Customer Care in Twitter. The input to our module is the output of a chatbot, it is a generic chatbot reply and the output from our model is a polite form of reply. The information content is same which is technically called adequacy compliance but the output is more polite than the output of the chat box that is the task we are addressing. So we want the output to be emotionally aware, it should use courteous phrases and emoticons to

display appreciation, empathy, apology and assurance. So let me give an example, this is an example of a generic conversation. The user says, "you all just came to my house like last week and I am having problems with my internet again smh." System responds: "what is happening with your internet? " User: "I think there is an outage." System responds: "There may be maintenance work in your area, please DM your info." So this is alright as far as dialogue is concerned, it is already making sense and the system's responses are adequate. However, a courteous conversation which could be expected is this, system response instead of just saying what is happening with her internet, system response "oh no that is not good. I can help! What is happening with your internet." User: "I think there is an outage." System says: "There may be maintenance work in your area. Please DM your info. Thanks for using our services." That is the finishing line and this shows more empathy on the part of the chat bot or the system and it gives a little more comfort for the user in using the system and this is a very practical problem, very live problem, also organization indeed is interested in chatbots that display empathy and emotion.

Now the challenge here is that we want to use machine learning. It will be a very very complex task to produce a rule based system here because a human being will have to sit down and give rules for producing polite expression and that will require understanding first of all what is politeness and to our surprise we found that there is lot of work on politeness, the linguistic of psychology of politeness, philosophy of politeness, cognitive aspects of politeness and so on. But turning all these knowledge which is



accumulated over many many years into an algorithm or a data structure or a set of precise rules which a machine can process is a very homogenous task. So we will resort to machine learning hoping that the deep neural network or a classical machine learning system will absorb the patterns in the data and capture the clues from the data and produce polite expressions or will detect absence of presence of politeness. However, data itself is also a challenge because politeness mark data, annotated data is in short supply. In fact we have contributed data in this area.

Contributions

- **Novel research** direction of inducing courteous behavior in the natural language responses for the customer care domain whilst being contextually consistent.
- Creation of a high quality and a large conversational **dataset,** Courteously Yours Customer Care Dataset (CYCCD) prepared from the actual conversations on Twitter. We provide both forms of agent responses: generic and courteous.
- Strong **benchmark model** based on a context and emotionally aware reinforced pointer-generator approach which demonstrates very strong performance (both on quantitative and qualitative analyses) on established and task-specific metrics, both automatic and human evaluation based.
- Accompaniment to any **standalone NLG** system to enhance its acceptability, usefulness and user-friendliness.

The annotation of the data is fought with a lot of subjectivity and capturing the correct emotion which related point is not easy and annotators differ there. Judgement about what is the politeness level or politeness presence. So it is a novel piece of research and I believe pioneers in this investigation, the data set is conversational data set with politeness embedded, the politeness part is our contribution, we have created a strong benchmark model which other researchers can use and since we produce the politeness expression as output, when we looked up on as a stand-alone natural language generation system, it produces natural language sentences where the sentences are polite.

Resource Creation: Data Source and Description

- Twitter data from Kaggle.
- Segment the tweet repository (3 annotators, kappa score: 85%)
  - Purely courteous (and non-informative) sentences must be removed,
  - Purely informative sentences must be retained,
  - Informative sentences with courteous expressions must be transformed (to remove only the courteous part from the sentence).

Now again as customary we report on the source of the data, size of the data, this is Twitter data from what is called Kaggle, it is tweet repository, 3 annotators with kappa score 85%.That is an indication of the level of the agreement. They annotated the data, we only got courteous expressions to remove because we want each part from the sentence, purely informative sentences were retained and sentences which have had politeness, they were transformed into purely informative sentences. So we established a correspondence between informative sentences and the corresponding polite sentences to learn this correspondence. So the input would be a neutral statement and output would be a polite corresponding expression.

Again following the convention, we report the quantity of the data, total number of conversations are about 2 lakhs, total utterances are about 4.5 lakhs, training conversations are about 1.4 lakhs, this is the data which is used to train a machine. The machine parameters are further tuned using about 20,000 expressions and the unseen data

Dataset Details

- **Dataset Statistics**
  - Total conversations: 200300
  - Total Utterances: 455914
  - Training Conversations: 140203
  - Validation Conversations: 20032
  - Test Conversations: 40065

amounts to about 40,000 expressions. So it is customary and conventional to report the data that is used for machine learning. Now the methodology is copying the informative part and inserting the politeness part, this is the methodology. So if we have an output from the chatbot, "how can we help", a courteous expression: "Help has arrived! We are sorry to see that you are having trouble (politeness text), how can we help? (informative part)." This is a kind of apologetic expression. So the

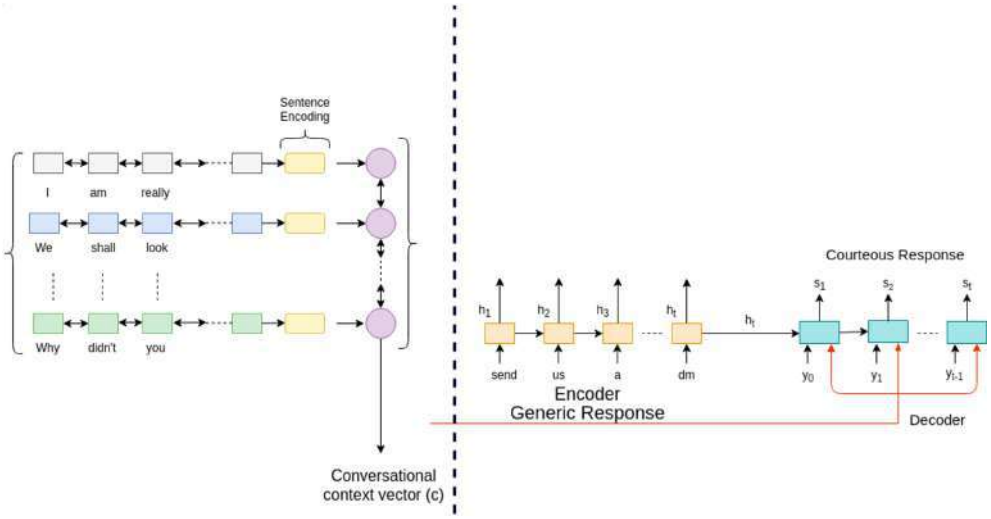
Methodology: Copy (black text)-Insert (blue text)

Generic	Courteous	Behaviour
How can we help?	*Help has arrived! We are sorry to see that you are having trouble, how can we help?*	*Apology*
Can you send us a screenshot of what you're seeing?	*Hey Craig, help's here! Can you send us a screenshot of what you're seeing?*	*Greet*
Let's discuss it in DM.	*We want to help. Let's discuss it in DM.*	*Assurance*
What is happening with your internet?	*Oh no that's not good. I can help! What is happening with your internet?*	*Empathy*
Enjoy your show while flying!	*Thanks for your kind words and enjoy your show while flying!*	*Appreciation*

blue part is the politeness text and black part is the informative part which is passed forward as such. So the first suggestion for technique would be a sequence to sequence transformer - this is a hierarchical encoder, hierarchical because each part of the encoder is processing one sentence and this combination is processing a full part of the dialogue and this transforms an input informative sentence to a

courteous response. The research team of students found out that these responses lack in diversity. The chatbot may always respond as "thank you, it is a pleasure" whereas the human user desires little more variety. So that could be arranged for by making use of little more sophisticated structure, the sequence to sequence transformer although of course exists as the fundamental module but augmented to it there is a reinforcement leaning based module which ensures diversity and as is the convention again in machine learning situations the loss function which measures the departure from the target or expected behaviour is

Baseline (Generic Sentence Input-Courteous Sentence Output)

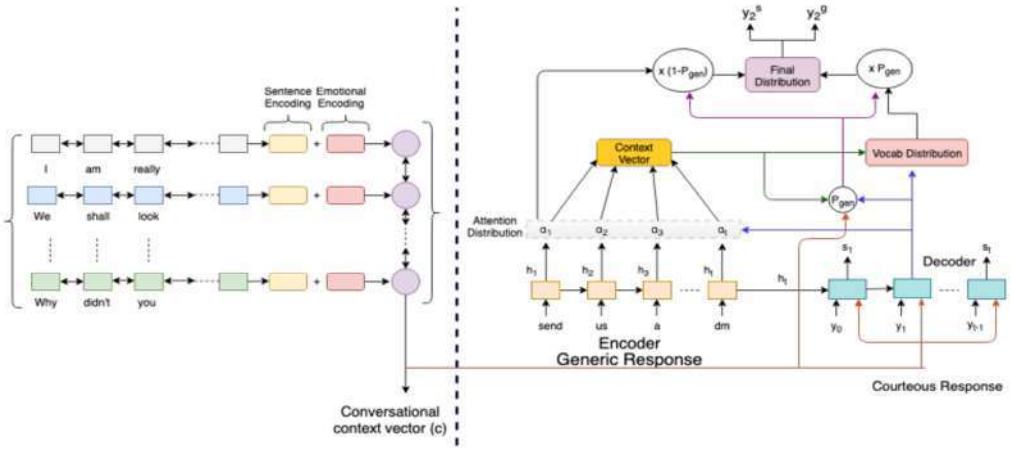


Architecture of the Baseline Model; Input to the Model: Generice Response and Conversational History, Output: Courteous Response

carefully designed. The students came up with a pretty novel idea namely combining maximum likelihood estimate technique and reinforcement learning to create two part loss function. So maximum likelihood estimate is based on what is called language modelling, we predict the next piece of text from previously appearing phrases and words. It is maximising the probability of the next piece of

text. So this is mainly dealing with the authenticity of information transfer, the main information content should be faithfully transfer. Help has arrived, the factors help has arrived is a piece of information, this should be faithfully reproduced, so a component of the loss function which is based on reinforcement learning, it introduces diversity in the response and in this case it is a natural language generation system because an input informative content is transformed into a polite expression. This is like a machine translation situation. So here in machine translation situation the departure from the target behaviour or consistency with the target behaviour is measured by words of blue score. The blue score is like a

Context aware model: copy and/or insert



Inputs to the model: Conversation History (left), Generic Response (centre) Output: Courteous Response (right). The Conversation History is encoded by hierarchical Bi-LSTM to a Conversational Context vector *c*. The encoder encodes the Generic Response into hidden states h_i . Response tokens are decoded one at a time. Attention α_i, and vocabulary distributions (p_{vocab}) are computed, and combined using p_{gen} to produce output distribution. Sampling it yields y^s_i and taking its argmax yields y^g_i

Model Training: MLE

- MLE for most frequent patterns, Reinforcement Learning for diversity

$$L_{MLE} = -\sum_{t=1}^{n'} \log p(\tilde{y}_t | \tilde{y}_1, \ldots, \tilde{y}_{t-1}, x_1, x_2)$$

Where, y_i are the output tokens, x_1 is the generic response, x_2 is the conversational history, n' is the number of tokens in the sequence.

Model Training: RL

$$L_{RL} = (r(y^g) - r(y^s)) \sum_{t=1}^{n'} \log p(y_t^s | y_1^s, \ldots, y_{t-1}^s, x_1, x_2)$$

Where, y_i are the output tokens, x_1 is the generic response, x_2 is the conversational history.

- Reward function r_y, used for evaluating y against the gold standard output is the weighted mean of the two terms:
  - BLEU metric (m_1): Ensures the content matching between the reference and the decoded outputs.
  - Emotional accuracy (m_2): Measured by the cosine similarity of the emoji distributions of the gold and generated responses (using pretrained DeepMoji). It ensures that the emotional states of the generated courteous behavior is consistent with the gold.

Model Training: Explanation for using RL

- Our reward function r(y), used for evaluating y against the gold standard output is:

$$r(y, \tilde{y}) = \lambda_1 \cdot m1(y, \tilde{y}) + \lambda_2 \cdot m2(y, \tilde{y})$$

Where, m1 : BLEU metric, m2: Emotion accuracy, λ1 and λ2 are 0.75 and 0.25, respectively.

- If Reward difference = positive, i.e., the BLEU score of $r(y^g) > r(y^s)$
  Then, the log probability of the generated response by random sampling will be decreased.
- If Reward difference = positive, i.e., the BLEU score of $r(y^g) < r(y^s)$
  Then, the log probability of the generated response by random sampling will be increased.

$$L_{mixed} = \eta L_{RL} + (1 - \eta) L_{MLE}$$

- We first pre-train using the maximum likelihood (MLE) objective , and then using a mixed objective function with a reduced learning rate (η):

feedback, it is distance from the target behaviour which is used as reward or punishment in a reinforcement learning situation. This maximum likelihood estimate and reinforcement learning based expression they are combined together with different weightages. So L_{MLE} is based on reinforcement learning, these two are combined together to produce a loss function which produces faithful content along with politeness. So we again did exhaustive evaluation on benchmark data starting from sequence to sequence transformer which is our baseline model then we snapped on pointer generator model, emotional fading model and finally the

proposed model which is a combination of reinforcement learning and maximum likelihood estimate on a hierarchical encoder with reinforcement learning module. The matrix are matrix for natural language generation namely BLEU score, ROUGE score from summarization literature, perplexity score, then content reservation

Evaluation Results I (Automatic)

	Model	BLEU	ROUGE			PPL	CP	EA
			1	2	L			
1	***Seq2Seq***	56.80	63.8	59.06	64.52	58.21	68.34	82.43
2	***Seq2Seq + P***	66.11	69.92	64.85	66.40	**42.91**	**77.67**	81.98
3	***Seq2Seq + P + EE***	68.16	72.18	67.92	71.17	43.52	76.05	85.75
4	***Proposed Model***	**69.22**	**73.56**	**69.92**	**72.37**	43.77	77.56	**86.87**

Results of various Models; P: Pointer Generator Model; EE: Emotional embedding;
PPL: Perplexity;
CP: Content Preservation; EA: Emotion Accuracy

which is like adequacy and emotion accuracy. So there are many technical words but all it means is that we were trying to see how faithful the output of our system for us to the initial input, let us remember what of a chatbot is it faithful in terms of information transplant and EA which is the emotional accuracy that shows the correctness of the politeness part of the output. So looking at the numbers, we find that emotional accuracy our model is achieving an accuracy of 86% compared to the baseline model which are close to 82. So we are able to improve on the state of the art through our model. Similarly BLEU score is a good measure of faithful transfer of information. So here again our score is much much better than basic vanilla model which is sequence transformer that is 56 to 69. Similarly, perplexity decreased from 58 to 42 but our model could not surpass this score, the perplexity

value for our model is 43 but much much better than a vanilla baseline model. This was

automatic evaluation, mechanical evaluation. Human beings are also evaluated, human evaluation also was done where the courtesy appropriateness is the most interesting parameter. So 1 is very appropriate 0 is somewhat appropriate, -1 is

Evaluation Results II (Human)

Model	F			CA			CoA		
	0	1	2	0	1	2	-1	0	1
Seq2Seq	15.70	42.50	41.80	16.21	41.69	42.10	23.71	51.08	25.21
Seq2Seq + P	14.23	42.77	43.00	15.62	39.65	44.73	22.05	39.43	38.52
Seq2Seq + P + EE	11.15	44.10	44.75	13.66	41.12	45.22	15.23	41.22	43.55
Proposed Model	10.05	44.90	44.60	13.85	38.48	47.67	14.11	41.11	44.78

Human evaluation results for F: Fluency, CA: Content Adequacy and CoA: Courtesy Appropriateness
(All values are in percentages)
(F:- 0: incorrect or incomplete, 1: moderately correct, 2: correct)
(CA:- 0: incorrect or incomplete, 1: moderately correct, 2: correct)
(CoA: -1: inappropriate, 0: non-courteous, 1: appropriate)

completely inappropriate so 0 is non courteous, 1 is an out with appropriate level of courteousness and -1 is not courteous at all. So we can see that our proposed model scores very well on courtesy appropriateness because about 44% of the outputs are in 1 category 41% is 0 category that means it is transferring information and also achieving courteousness in the output expression.

Examples of Courteous Responses Generated by the Different Models

Generic Input	Model 1	Model 2	Model 3	Our Model
dm us more info and well take a look into it for you	we'll look into it	im sorry to hear this please dm us more info and we'll take a look into it for you	were here to help please dm us more info and well take a look into it for you	were here to help please dm us more info and well take a look into it for you at the earliest
adjust the brightness via your display settings on your device	whos the brightness via your display settings on your device	were here to help adjust the brightness via your display settings on your device	we have several ways to change the display brightness on your device and were happy to help	thanks for reaching out we have several ways to change the display brightness on your device and were happy to help
we'll follow up with the store	we'd like to help well follow up	were here to help well follow up with the store	sorry to hear that well follow up with the store	thats disappointing to hear, we'll follow up with the store
can you confirm which platform you are using for video access ? what is the error ?	what is the error ?	I am sorry for the frustration ! can you confirm which platform you are using for video access ? what is the error ?	I am sorry to hear this can you confirm which platform you are using for video access? what is the error?	I am sorry for any frustration, can you please confirm which platform you are using for video access? Please tell us what is the error.
fill this form <url>	please fill this form <url>	were here to help fill this form <url>and I'll contact you at the earliest a	apologies for the hassle, please fill this form <url>and we'll contact you thank you for reaching out to us we will follow up with the store	i am sorry for the hassle, please fill this form <url> and ill contact you at the earliest

Here are few examples of courteous response and some of them are very interesting. The generic output from the chatbot is DMS, direct messages more information and would take a look into it for you. The first module which is in the sequence - it is almost output only the essence of the information present in the input. The second model is little more polite and "I am sorry to hear this please DMS more info and we will take a look into it for you." The third model which is emotional embedding, "we are here to help please rate message as more info and we will take a look into it for you" and our model which combines reinforced learning and maximum learning likelihood say "we are here to help please DMS more info and we will take look into it for you at the earliest.". So at the earliest was an insertion proactively by our system, it almost behaved more human, exceeded the expectation by being more polite and other models. So at the earliest is a very reassuring phrase. So it is not only polite, it is also giving reassurance.

Summary

- Need of NLP and NLP Perspective: ambiguity challenge
- Role of Machine Learning in Ambiguity Resolution
- Sentiment and Emotion Analysis perspective
- Computational Approach to Sentiment Analysis
- Multimodal, Multitasking Dialogue Act Classification
- The challenge of Sarcasm
- Computational Politeness

So I would like to summarize the presentation with a background by giving a machine learning perspective namely four kinds of machine learning starting from table lookup going up to deep learning where no human intervention is required at the end, but that is only an idealization. then the natural language perspective was built different layers of NLP, dimensions of NLP and the main problem was identified as ambiguity, at every layer of natural language processing there is ambiguity. Machine learning and natural language processing have come closer to each other because we cannot really produce exact decision, we have to live with approximate decision but that is often very good and good enough and that is where the goodness is measured. So machine learning uses probability and classifier or solving natural language processing tasks. For us the main problem is sentiment and emotional analysis, perspective on sentiment and emotion through side work on psychology, Plutchik's emotion will, Ekman's emotion , our investigation into dialogue act classifications to show that capturing multi-modality makes the classification of dialogue more accurate and on top of that if you make that task multitasking that is if we detect emotion and dialogue together then we achieve accuracy on both

fronts. So this is an important contribution of the work namely capture tonality, capture body language and capture the text to detect emotion as well as dialogue act. The very challenging problem of sarcasm for that we gave a solution, we exploited incongruity and algorithmised the notion of incongruity. Computation politeness is one of the frontiers we have investigated into and I think we have advanced in this part. So all these problems namely dialogue at classification sarcasm politeness are really in the frontier of natural language processing and machine learning. Our conclusions from this work are we draw some insights that making computers human is really becoming a reality. That time is really not far where chatbots will have lot of empathy, will display a lot of emotion, understanding and producing sentiment and emotion is a highly interesting and practical problem as I mentioned many times. I interact with many organizations and I consult with many organizations. So there is a huge need, you may have immediate need for emotional AI systems. Deep learning with the data with huge amount of data is the key methodology for solving these very challenging problems but where do you find so much data, therefore you have to make use of insight from the problem, make use of insight from linguistics, chronology, psychology, cognitive science and so on. The other problem is explainability, the chatbot is producing a kind of response which may be not appropriate then we have to investigate it from the machine learning system what exactly has gone wrong. This becomes an extremely challenging problem for deep learning systems because they have many many layers of processing, many parameters, huge number of neurons, it really becomes an inscrutable proposition, inscrutable system. New research directions like deep learning with receptor cross dominant, cross lingual assistance, hence are becoming important. A sentiment analysis system built for English can be used for

Conclusions

- Making computers human- becoming a reality
- Understanding and producing sentiment and emotion- a highly interesting and practical problem
- Deep learning with data is the key methodology
- Challenge of DL
  - Data
  - Explainability

Hindi, Marathi or Hungarian for itself. This is cross domain and cross lingual sentiment and emotion analysis and an important mathematical question is right loss function for right problems. And, the third problem that combining reinforcement learning with maximum likelihood was good for producing polite outputs with diversity. Everything I have said is linked as research papers from my homepage (https://www.cse.iitb.ac.in/~pb/) and from our lab (https://www.cfilt.iitb.ac.in) at IIT Bombay we have contributed many tools, resources and datasets, researchers can use. I will end my presentation with a final message, we have found again and again that `NLP (Natural Language Processing) is a task in Trade Off'. We cannot have too much of information because that leads to misleading signals and we can have a topic drift, we can have what is called drift, we drift away from the right path and if we have too little data then there is data sparsity problem. One of the questions was on ambiguity instruction, this is true intext

Research Directions

- Deep Learning with less data
- Cross domain and Cross Lingual Assistance
- Right loss functions for right problems

Final Message

"NLP is a task in Trade Off"

e.g., Not too much of subwords or cooperation

(beware of *'ambiguity insertion'*), not too little

(beware of 'sparsity') !!

for example if we have too many, too long a context then the words in the context can introduce their own FPT. So we have to take a middle path and this was propagated 2000 years back by Lord Buddha who said "The Middle Path is the Golden One".

I would like to thank all and thank you very much for your attention.

"The middle path is the golden one"- Buddha

Mr. Anoop: Thank you. I think we can now go for questions. So you ended with ambiguity and I think that question has covered everyone's queries, since you focused on it during your talk. Couple of questions on that regarding whether there is ambiguity in scientific text, in scientific papers etc. and as languages are evolving, are they were evolving to a situation where there is less and less ambiguity in languages or what is the situation.

Prof. Pushpak Bhattacharyya: Less and less ambiguity I won't agree, we depart more and more from grammar, one of the rules of grammar syntax is to constrain us to keep us moving in the right direction on a narrow straight path. That is the role of grammar, so give an example, agreement in grammar for example, "he laughs" is alright but "he laugh" is not alright, you do see this kind of ungrammatical text, this is very common and when we stray away from grammar it can introduce uncertainty noise and ambiguity in the text so language is not becoming less and less ambiguous, in fact it is becoming more and more uncontrolled and more and more noise introducing ability. Scientific texts have definitely less ambiguity. So every scientific domain has its own parlance, own style of writing and this is very strictly controlled, if you depart from that, then the domain experts raise their eyebrows. The other point was that once the domain is fixed many of the words have very unique meaning so again my favourite example is back if the text is from financial domain I know it is financial bank not a river bank, so scientific text definitely has less and ambiguity.

Mr. Anoop: Another interesting question, you talked about generating responses from chatbots and these are finally machine learning systems so they may go wrong

at times, so are there any costs associated with systems making such erroneous responses; how can we account for that there have been cases where chatbots have come up with really offensive responses which have caused cost bad publicity for companies.

Prof. Pushpak Bhattacharyya: Yes, there can be biased responses, gender biased and so on. The output is polite and appropriateness has been an important concern for us - the human evaluators especially look at the appropriateness of the response and what if the question is on what is the solution, we really don't know so the maximum likelihood is the estimate part of the loss function ensures adequacy, ensures faithful information transfer but I would say that if the reward function is refined and designed appropriately maybe we will have a kind of safety net.

Mr. Anoop: We end with one final question: Since that is the topic I think you work on and very interested in, you talked about a lot of work which deals with emotional analysis, sentimental analysis in English, now it is a difficult problem compared to formal takes when you are dealing with emotion, it already becomes very difficult to process it, now if you also have to do crossing well applications or the kind that you mentioned towards the end, then what do you think is the future in terms of being crossing well learning for these kind of sentiment emotion, kind of problems.

Prof. Pushpak Bhattacharyya: I will first talk about the obstacle, the obstacle is that my favourite example again, may be as a student you have heard that: East Asian countries have a very interesting culture, they do not use strong adjectives even if the emotion is intense, adjectives used are very moderate, very controlled

adjectives, whereas as you proceed towards the West, the intensity of adjective increases and in fact regions like California it is customary to use very strong adjectives, amazing performance for example. It is quite intensive, quite strong. So emotional and sentiment analysis is very much culture and language specific and crossing well sentiment analysis, emotion analysis where the data is from one language and the applications is in another language that has this challenge to negotiate but that said machine translation along with sentiment analysis technique available for one language can really facilitate sentiment analysis in another language and also we would think that you have been working on zero shot learning, one shot learning and so on. Deep learning systems which are trained for sentiment analysis in one language, after training the wait parameters can serve as initialization for sentiment analysis. This would be some kind of transfer learning I would say. So this assistance is available from machine learning literature.

Mr. Anoop: Thank you Sir, we are running out of time, we have had a lot of questions, there are many more but I think now we close the session and hand it back to Dr. Susheela.

Dr. Susheela Venkataraman: Thank you very much, clearly this session has been a very interesting one you took us right from the fundamental to what is happening and I want to look at what things are going to be happening in future. It was lovely to hear what is happening here in India and the kind of exciting things happening in India and really nice to hear about all of that. I am sure any youngster who is looking at his or her areas of research would certainly find it very interesting and something that they would look forward to. I think you also highlighted the fact that

some of these courses of study and work are going to require not just computation but also some social sciences also have a bearing on what is required to make something like this actually happen to realize the potential of something like this and the one other thing that you did mention was there are things that a machine can do and there are things that a machine can't do and where you still need human experts. It is important to kind of understand where those lines need to be drawn. Thank you very much, this is obviously a topic like this needs much more than a one and a half hour webinar and some day we hope we can run a workshop with you on this topic. So thank you Anoop very much for having taken this on so readily and running the questions through and the discussion through in such a nice way, thank you to all our audience for being part of our webinars and for being here today, you can look for all of these recordings on our YouTube channel and with this once again thank you and Namaste.

EDUCATIONAL INNOVATION FOR A POST-COVID-19 WORLD

PROF. SUDHIR JAIN | JULY 4, 2020

Prof. Sudhir Jain is an internationally reputed scholar of Earthquake Engineering and a passionate academic administrator. He holds a Bachelor of Engineering from the University of Roorkee, and Masters and Doctoral degrees from the California Institute of Technology, Pasadena. He was elected Fellow of the Indian National Academy of Engineering in 2003, and conferred Life Membership by the New Zealand Society for Earthquake Engineering (NZSEE) in 2013.

Prof. Jain established the National Information Centre of Earthquake Engineering (NICEE) at IIT Kanpur and developed the National Programme on Earthquake Engineering Education (NPEEE), supported by the Government of India. He was awarded the Padma Shri in January 2020.

P. D. Jose is a Professor in the Strategy Area and the Chair of the MOOCS Initiative at IIM Bangalore. Professor Jose teaches core courses on strategy and electives on Corporate Environmental Management, Sustainable Enterprises and Understanding Corporate Failures. More about him at https://www.iimb.ac.in/user/81/p-d-jose

Lecture at IIT Alumni Centre, Bengaluru, by Prof. Sudhir Jain, Director IIT Gandhinagar, July 4, 2020.

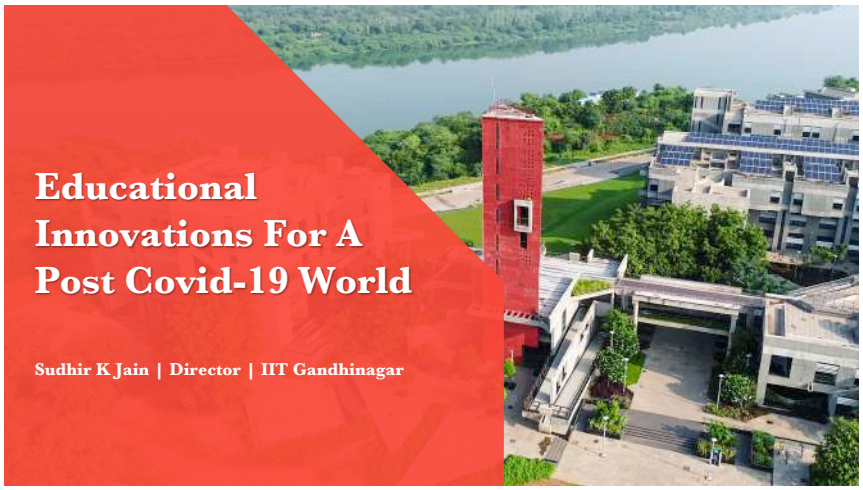
Link to the webinar : https://www.youtube.com/watch?v=_ZAJZ4wXBMI&list=PL0zMQ-70IHlX-df3u2Tto6dkKHCRC6iFL&index=13

Mr. Ashok Kamath: Good evening, this is our 13th webinar after the lockdown. We have had a variety of speakers talk on variety of topics and some of them on Covid-19 which we are experiencing to setting up of the IITs and today is an exceptional topic as well. The first few IITs are clearly over 50 years old, the first five, and they have all celebrated their Golden and Platinum Jubilees. After that I think it is IIT Guwahati that is 25 years old and subsequent to that we had multiple IITs were set approximately 10 to 12 years ago. Most notable one among them is IIT Gandhinagar. The Founder Director of IIT Gandhinagar is our speaker today. It takes a lot to build a new IIT. It is not about setting up a campus, it is about setting up a compete vision for the campus and for the IIT and knowing fully well that the brand IIT out there has got a lot of value and you have to uphold the value of brand IIT as well simultaneously. Sudhir Jain did his Masters and Ph.D. from Caltech, was on the faculty of IIT Kanpur for a very long time, I think 30 years before he became the Founder Director of IIT Gandhinagar, probably one of the only one who has been given a third term as Director of IIT Gandhinagar. Academically he is an internationally well known scholar on earthquake engineering but I think at heart he is a very passionate academic administrator and that is what it has made IIT Gandhinagar what it is today. For all his accomplishments and contributions, he was awarded the Padma Shri by the Government of India this year in 2020. Moderating this conversation today is Prof. P.D. Jose, Professor of Strategy and Chairperson of the Strategy area at, IIM Bangalore. Interestingly Prof. Jose also chairs IIMBX that is IIM Bangalore's digital learning initiative, the MOOCS that you all know. He is a fellow of the IIM Ahmedabad, worked at ASCI in Hyderabad, he was Fulbright Fellow at MIT and also taught at the Cardiff Business School in England and is on the visiting faculty at Gothenbeurg Business School in Sweden. The topic today is Educational Innovation for a Post Covid-19 World. We all know

from primary school to higher education everyone is studying to find answers as to how education can be run, in a post-Covid world with all its constraints specifically with this issue of distancing and not being allowed to be in the same classroom in the same strength. It is going to put a dampener on lot of the efforts and we need innovations coming here. With that I am going to hand over to Prof. Sudhir Jain to talk to us about Educational Innovation for a post-Covid 19 World. I would also like to introduce Dr. Susheela Vankataraman, my colleague at the IIT Alumni Centre who will also join the moderating team for this day. Over to you, Prof. Jain.

Prof. Sudhir Jain: Thank you Ashok, good evening ladies and gentlemen, first I would like to thank IIT Alumni Centre, Bangalore for organizing this opportunity for me to share my thoughts particularly thankful to Ashok Kamath, Susheela Venkataraman, Prof. P.D. Jose for organizing this webinar.

When I was asked to think about a topic for speaking on this webinar, I thought it would be interesting to share about IIT Gandhinagar how it has emerged how it has functioned, how it handled Covid-19 and where does it go, where do we see the future, where are the opportunities that we see as Ashok said we are a new IIT started in 2008 and we said to ourselves that it will be a unfair use of the taxpayers money if we were to try to become like an older IIT. We felt that just as any father wishes the



son to be better, we felt that older IITs would like newer IITs to do better to learn from their mistakes to learn from their successes to use their resources and to do things that would be difficult to do in older IITs things that will be difficult to do in a bigger institution. So that is how we tried to configure IIT Gandhinagar that is how we tried to build the vision and the culture of IIT Gandhinagar and I will give you some glimpse and sense of that and from there will emerge how we handled the Covid-19 and from there will emerge what we see as future of the educational innovations in the years ahead. Let me just share with you my screen. Basically there will be three parts in my talk, (1) Foundation Blocks of Excellence, what we are, who we are, we might take question answers from Prof. Jose and we will continue on (2) Rising to the Crisis, and then discussion about how we handled the crisis (3) New Educational Paradigm.

1 **Foundation Blocks of Excellence**

2 **Rising to the Crisis**

3 **New Educational Paradigm**

IIT GANDHINAGAR

IIT GANDHINAGAR

Foundation Blocks of Excellence

Established: 2008 with 90 students
2019: 1700 Students UG: 44% PG: 56% (PhD: 25%)

Undergraduate Programs

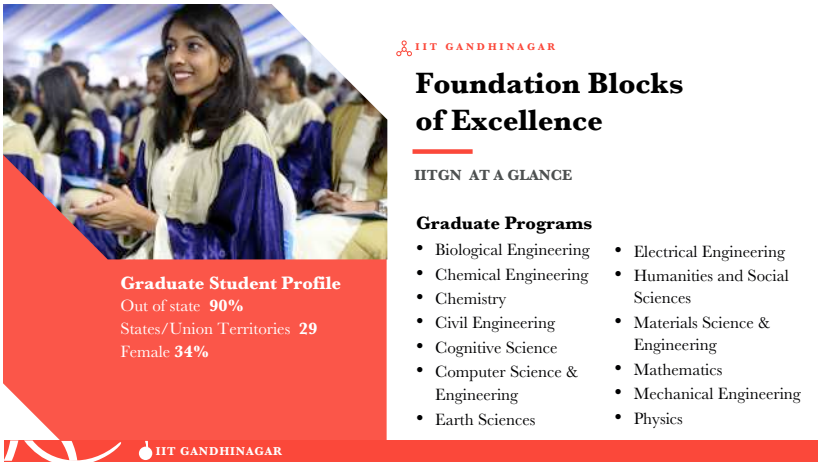
- Chemical Engineering
- Civil Engineering
- Computer Science & Engineering
- Electrical Engineering
- Materials Science & Engineering
- Mechanical Engineering

Interdisciplinary Centres

- Centre for Safety Engineering
- Design and Innovation Centre
- Centre for Biomedical Engineering
- Archaeological Sciences Centre
- Centre for Cognitive Science
- Dr Kiran C Patel Centre for Sustainable Development
- Centre for Creative Learning

IIT GANDHINAGAR

We started in 2008 with 90 students, we have about 1700 students now, 44% are undergraduates and 56% are postgraduates out of 1700 students 25% are Ph.D. students, the standard undergraduate



programmes, chemical, civil, computer science, electrical, mechanical, we created seven interdisciplinary centres and these are quite unique in some sense, you know Centre for Safety Engineering hardly any IIT would have serious centres, perhaps the Archaeological Sciences Centre, Centre for Cognitive Sciences, things like that. So we tried to do something interesting in the interdisciplinary areas, I will come back to that a bit more. We have the Masters and Ph.D. programmes in many more areas than what I showed to you for undergraduate programme. For our postgraduate student body, 90% of them are from outside the State, we have students from 29 States and almost one third of our Masters and Ph.D. students are women. We started to think about building the Institute on certain premises and these are listed here:

- Students First, that is the slogan that my colleages, my students hear from me very often and I think that this is something that our students very proudly say that IIT Gandhinagar believes in students first, every decision we take must look into how it affects the students, how it benefit the students.

- Quality Faculty, we were very slow in recruiting faculty, we still are very slow in recruiting faculty because we think that faculty has to be the backbone of an institution and therefore we cannot compromise with the quality of the faculty.

- Interdisciplinarity, is something again I will talk to you a little bit more in detail later.

- Critical Thinking/Liberal Arts, is a very important agenda for us in our educational programme.

- Project Oriented Learning

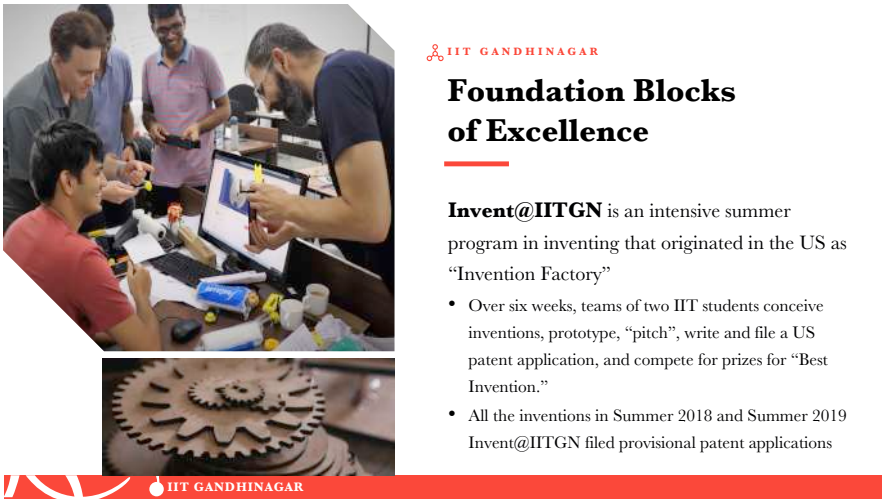
- Internationalization

I will again talk about a little bit and social engagement and I will expand on that as we go along. So when we were designing our curriculum, we said that there is a constant that the students get burned out with the JEE coaching before they come to the IITs and we said that that is not a satisfactory situation, we need to de-stress them, we need to detoxify them from JEE coaching type of environment where they have stopped reading any non-curricular books where they have stopped playing chess or reading novels or playing badminton. So we started this new curriculum

in 2011, there we said that the new UG students will go to five weeks of foundation programme a full day activity starting from 6.30 a.m. in the morning at the playground going upto 10 o'clock in the night. We run a five week foundation programme which focuses on five pillars, creativity, ethics, physical fitness, communication skills, social engagements and the idea was to detoxify the students make them realize that life is much more than getting grades and marks and show them that there is a lot more to life than studies. This has been a very transformative experience for the students and after a few years several of the IITs started to adopt it, many IITs now do a three week foundation programme equivalent, many engineering colleges do it, in fact AICTE issued an advisory to engineering colleges that they should do something similar. So we are very proud of this programme, it has gone extremely well and our students are really very very upbeat about what this programme does to them.

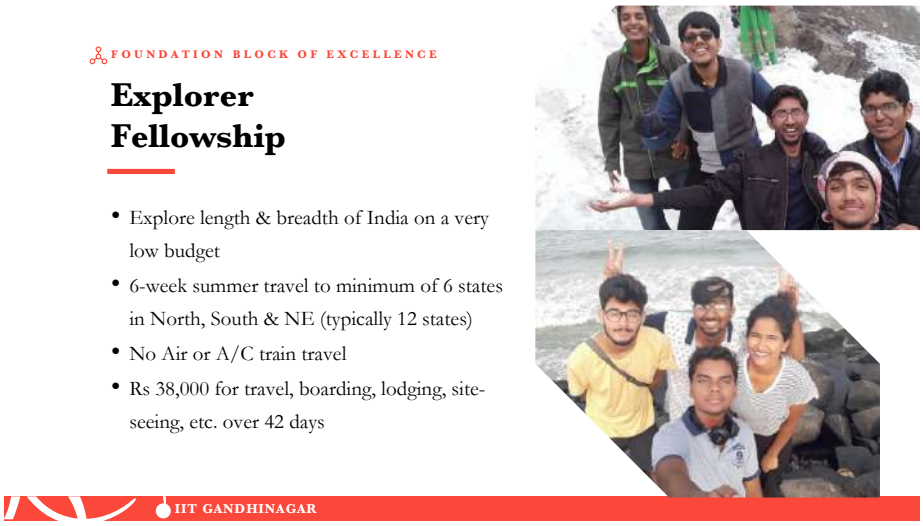
In terms of pedagogy we are very upbeat on humanities and social sciences in the engineering curriculum to encourage critical thinking, creativity.

We were the first IIT to start a compulsory course in design innovation in a B.Tech. programme, we were the first IIT to start a life sciences course as a compulsory one in B.Tech. programme and we thought these are the things that will give a special advantage to our graduates. We are also very strongly commit ourselves to globalization and diversity almost 40% of our undergraduate B.Tech. students would travel outside India at least once during the four years before they graduate from us. They do summer research internships in universities aboard or attend meetings and conferences. Thirty percent of our Ph.D. students spend at least a semester outside India in a laboratory or a university outside, almost 75% of our students would have travelled overseas with some conference assignment and things like that. The idea is that our students must get a sense of where the world is and how we in India must compete with the rest of the world



and learn from diverse sources, diverse environments. As I said earlier, 90% of our students are from outside Gujarat, 35% of our students are women, we are proud of that. Some three years back we started this programme, invented by IIT Gandhinagar which is open to student of all IITs and over six weeks' time team of two students develop an innovation prototype, "pitch", write it and file for a US patent application and compete for prizes for best invention. This is a programme that started originally in the United States and the picture here you see is two Professors from a University in New York, Cooper Union and they brought this programme to us. they taught this programme for two summers here and this year of course we had to cancel the programme because of the Covid-19. We expect that this programme will continue which makes a big difference to the students.

Some years back we started a fellowship we called it explorer fellowship where we said that our students must travel the length and breadth of India on a very very low budget like a very very ordinary Indian would travel, eat or sleep. We give them Rs.38000/- over 42 days, on an average Rs.900/- a day to cover their train ticket, their food, their stay in the dharmashala or lodging, their sightseeing, no air travel, no air conditioned train allowed, they must travel at least North India, South India, North East India, typically they cover 12 States, 13/14 States in the summer months when it is very hot. The idea is that our students must

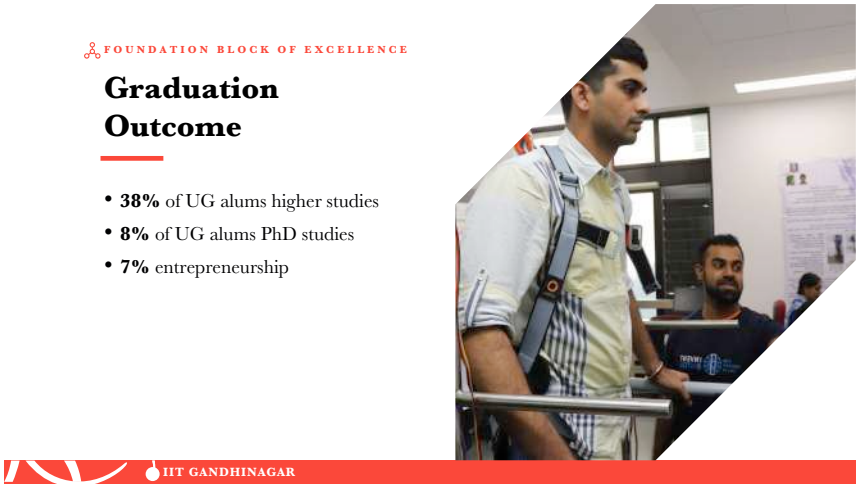


rub shoulders with the common Indians and understand what India is about, this has been a very transformative experience. This is entirely voluntary, almost 40% of our students, undergraduates do this programme after first year summer, during the first year summer and we have been getting very very good feedback in terms of how transformative it has been, how maturing experience it has been and how sobering experience for the students to understand how privileged they have been, how tax payers money has really been instrumental in their education. Interdisciplinary is one of the central pillars of IIT Gandhinagar's continuous thinking and we decided that rather than paying a lip service to interdisciplinarity, we would hardwire it into our academic infrastructure. We would design our buildings, we would design our laboratories and things which are not around disciplines so there is no Mechanical Engineering building, there is no Physics building, there is no floor for Mechanical Engineering, so a Professor of Mechanical Engineering could be sitting next to somebody who teaches English literature, somebody who teaches Mathematics and same things happens with the Ph.D. students, same thing happens with the laboratories, the Chemical Engineering laboratory could be next to the Electrical Engineering laboratory and so on and so forth. We also started two very successful interdisciplinary programme - one in cognitive science and one a Master of Arts in society and culture where any graduate in any discipline can apply. We have had medical doctors doing Master

of Science and Cognitive Science. You could be a graduate of any discipline to be able to apply to any of these two programmes.

Just to give a sense to the outcome of our strong commitment to interdisciplinary, 10% of our faculty members have appointments in more than one discipline - what it means is that somebody who is an Assistant Professor in Electrical Engineering is also an Assistant Professor in Mechanical Engineering. Fourteen percent of our Ph.D. students have adviser/thesis supervisor outside the discipline, what it means is that the student of Mechanical Engineering who is going to get a Ph.D. degree in Mechanical Engineering has his supervisor from Electrical Engineering and no supervisor from Mechanical Engineering. Thirteen percent of our publications would have multi-disciplinary authors, 16% of projects with multi-disciplinary investigators which shows the outcome of our strong commitment to interdisciplinary programmes. We believe that a lot more innovations will emerge when people start to work across the disciplines and this is the focus area for that.

We, as I said earlier, that the faculty is the backbone of any university and we were very very cautious in recruiting faculty, just to give a sense of the quality, we have 60% of faculty with a Ph.D. from overseas, we have the graduates of the best universities, you can think about - Cambridge, Harvard, MIT, Urbana Champaign, Cornell, Georgia Tech and so on and so forth. Eighty-five percent of our faculty have experience aboard, so even if they have done Ph.D. in India, they would have travelled abroad for post doctoral work and so on and so forth, 15% of our faculty would be visiting faculty



from India, from abroad and 5% of our faculty are full time international non-Indian origin faculty. We are trying to build that number further. We think that we should have at any given time about 15% at least of our faculty who are not of Indian origin. So that is how we think that we would like to be a fairly global in our outlook. The result of all of these is that 38% of our undergraduate students go for higher studies, of these 8% are our undergraduates do Ph.Ds and 7% of our undergraduates would have done entrepreneurship for a substantial amount of time, some of them succeed, some of them fail after trying two three years, then they go into a job with another company but they would have learned very very valuable lessons as entrepreneurship experience.

The social engagement has been a very important agenda for us for two reasons, one is that it is the right thing to do, we are paid by the tax

payers and we must show sensitivity towards the most underprivileged sections of the society and I think more important is that our students must become sensitive graduates wherever they go they must not forget their responsibilities towards the society and therefore in 2011 we had a policy on community outreach approved by our Board of Governors. We provide very strong commitment to construction workers welfare, we have very strong clauses in our contracts to make sure that all construction workers are living in a very healthy and satisfactory environment. This is for example the type of housing that our construction workers are provided, this is a picture when the piped gas was not yet provided and these houses would have the piped gas connection for the workers to cook food.

There are several schemes we have developed for the contract staff whether it is the house keeping staff, security staff, the mess workers, we have Nyasa education programme, a student initiative that works for education of the children of construction workers. They run a little school, an informal school that is run right in the middle of the academic area, right in the centre of the class rooms of IIT Gandhinagar where the construction workers children are taught and this lady teacher, she is hired and her

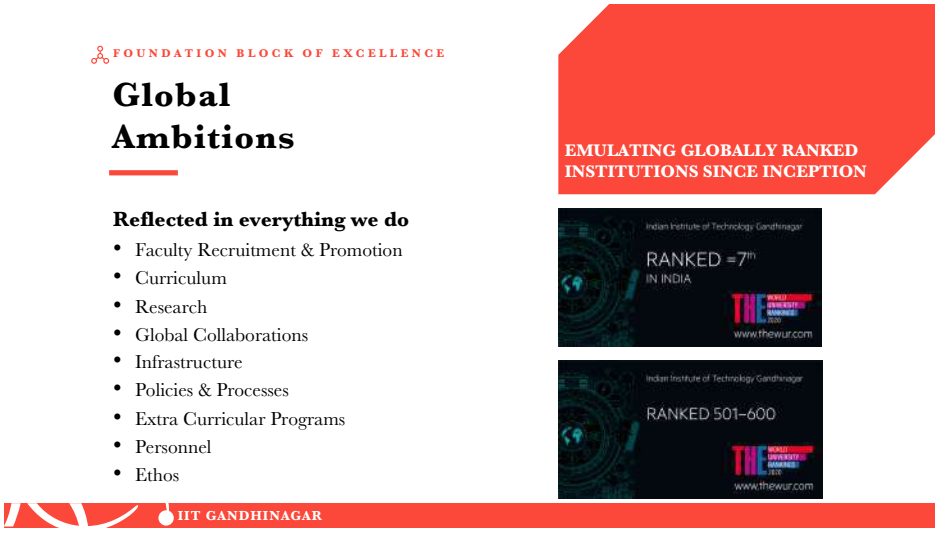
service conditions are managed by undergraduate students. This whole initiative is run by undergraduate students, they take great ownership, they take great pride in working with these kids develop a lot of affection for them, in fact this is a picture of the annual birthday celebration that the undergraduate students do with the kids of the construction workers, what you see here, there are our students and the idea here is that these kids don't know when their birthday is and once in a year lot of celebration happens and it is assumed that everybody's birthday is on that day. That is how the undergraduates engage with them.

There is another initiative NEEV which is to provide entrepreneurship training at grass root level, the idea is that in the neighbouring villages, they must feel certain prosperity as a result of the existence of IIT Gandhinagar and this initiative is about

giving them skills, giving them entrepreneurship training so that the people in the village at the bottom of the pyramid they could start to earn some money, as I mentioned to you the foundation programme of five week duration, that we run for our undergraduates is having five pillars, one of those is social engagement, we have courses on related areas. This is for example the training for stitching, in fact we had trained fairly large number of women in stitching in neighbouring villages and when the lock down happened they actually gave out lot of work to these women for making cloth masks at their own home. So these women in the villages, they could work as per their own convenience of 3 hours, 4 hours, 5 hours a day and make face masks which community would buy in fact in some case the corporates have bought the face masks made by these women, so this generates some sort of employment, some sort of income for these women and the community served well because they are able to get a high quality mask prepared as per our specifications.

This is a training programme for the young boys from the neighbouring villages happening inside our laboratories in summer months when the laboratories are available and we run this programme where they may go through electrician course or a plumber's course or a carpenter's course and gets some skills, we don't give them certificates, we don't certify them, the idea is to given them some really good skills and given them some entrepreneurship mind sets so that they can become self employed or possibly get a good job somewhere else.

Basically, we have had global ambitions and our idea is to do things as if we are a globally ranked, top-ranked university, so build a culture, build a system for everything that we do whether it is curriculum, whether it is faculty, whether it is faculty recruitment, whether it is

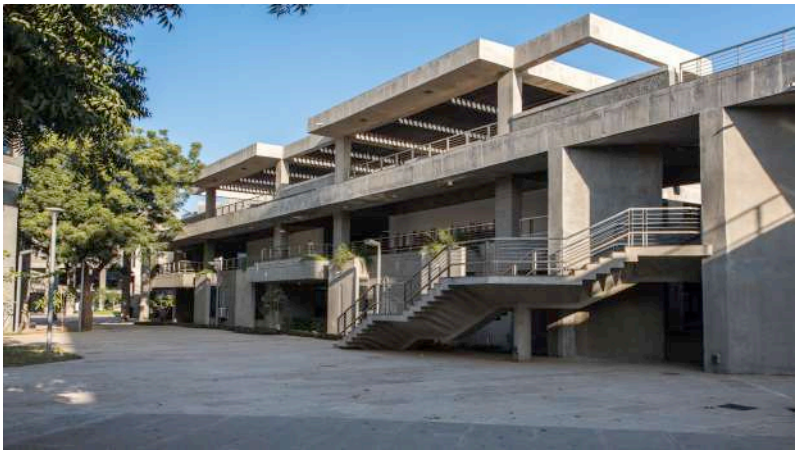


infrastructure policies, personnel, ethos and culture, we have been ranked well over the years although that has not been our high priority. The entire thing at IIT Gandhinagar works on the principle that the Government of India has been very generous in giving grants and those grants are good for paying the bills, paying the electricity, paying the salaries but for excellence we must seek philanthropic money and we are very proud of the fact that even though we are a new Institute, even though our alumni are very very young and don't have much capacity to give money, we have been able to generate a fairly high amount of philanthropic money. For example, in 2019-20 we closed with raising about 20% of the annual operating budget. What I mean is the money that we raised is about 20% of the budget not that, that money is spent on operating expenses as I said operating expenses are run with the government money, most of the 20% money would be perhaps in the endowment whose interest will be used and this money is used really for driving the excellence, this money is used for hiring the best faculty giving them extra-ordinary support, giving our students extra-ordinary support, that is how we are able to send so many students overseas, that is how we are able to run these explorer fellowships and so many other things. While we raise this money from various well wishers, we are also conscious that typically the universities raise money from their alumni and although our alumni are not in a position to give significant amount of money but we are trying to build that as a base for future 2019-20, 50% of our alumni,

undergraduates, postgraduates all the alumni if you take the total number, more than 50% of them made a financial contribution to IIT Gandhinagar as a gift and that I would say is a record of some sort I would not imagine any institution in India would have or perhaps even worldwide would have that kind of a ratio so easily. In fact some of the young alumni as I said we have very young alumni, the first batch of students that graduated was in 2012, so these young students have started to endow scholarship in the name of their parents and the grandparents and we think we are building a good pipeline for the alumni to scale up their contributions and their engagement with the institution in the years ahead.

We have built a campus, we have a 400 acre land with three kms of river front of Sabarmati, we have received many many awards for building this campus, we are just about 30 minutes from the Ahmedabad airport, what you see on the right side is the Sabarmati river and the water you see in river is the real water not the "photoshop" water, what you see in this slide is the

academic area on the left and the farther end you see the hostel area, if I show you the other picture, you can see the academic area, the hostels area and faculty and staff housing. Let me just show you a little bit you now see are the academic buildings, see the natural light, we designed it to minimize the energy consumption, these are the sources for the natural light and these shafts so that when on the ground floor during day time you don't need artificial light. We are also very conscious that every element in the campus is designed in an interesting way if you see this staircase and you see bottom side of it, it is some beautiful geometry and the idea is that people walk around the campus, they see these staircases, bottom of these staircases is always something that people don't pay much attention to and we thought even that should be very interesting as we design. One of the key ideas in designing our campus was that while we focus on the buildings we should focus even more on what



happens outside of it, the area outside the building, how it will be landscaped, how to be used and is there a use for the space because this is a very precious space and we must account for that and for example, this is the academic area, this is the social space for example there is a gathering you can see lot of sitting spaces here, people are sitting across informally talking to each other and whatever. This is a little structure to celebrate the Gujarat's culture of kite flying but it also acts as a shading device, provides some shade during the hot season, then the temperature reduces a little bit because of the shading that the structure does. You can see the auditorium the kind of furniture of this auditorium, we have done numerous iterations of prototyping and designing of this furniture just to make it very very comfortable for somebody

to sit the whole. So we paid lot of attention to details when we designed and built our campus.

This is the hostel area, one of the things we worked with architects was that all our buildings, all our facilities whether it is the hostels, the housing, the academic area, they must encourage interaction between people, they must make people meet each other, greet each other and that is how the academic area is designed and that is how the hostels are designed. Here you see in this picture, in the hostel, this area is called Panchayat Chauk, that is where 500 students can get together, they can hold a meeting, there have been times when our Dean or I will go there, stand here with a microphone and there will be hundreds of students who will sit around here and we will talk, we will discuss things that are concern to them. What you see in front here is a street, we said we want to create old Indian town rather than creating a modern city which is very impersonal where neighbours don't know each other. We wanted to create old Indian city, old Indian

type environment, so what you see at the end of this street is a dining hall, that is where the food is and these are the hostels where the students live and as they walk on the street four times a day for four meals they bump into each other, they meet each other and as they walk there are little shops here, some tea shops there, some juice shops here, something like that.

Next is the housing area, again what I said earlier about the hostel, same thing holds for the housing, again designed to keep interactions possible and keep track of the open areas, the spaces that are outside the building should be utilized, the green campus, the landscaping, this is for example open area, this is a picture that I will talk to you later, again this is a social space that somebody could use for whatever purposes they like, it is a semi-formal, informal type of a space that has been created. There is a festival here, there is a party going on during Dussehra that is a

well know time for celebrations in Gujarat. This is what we call as a gel mandap, in Gujarat there is a tradition of rain water harvesting for hundreds of years and we thought we must do that in this campus, so all the rooftop water comes in the underground water tank here, from here it gets pumped into the water service station where it is processed and used for drinking but to celebrate water we thought we will create a little recreational area here where the kids can run around, you will see in the evenings the elderly sitting here, the women and the children are relaxing here. So there are several of these German ducts that we have designed just to create social spaces in the campus.

The next slide shows the amphitheatre that we built, we have a very undulating topography and we had a natural topography to take advantage of in building an amphitheatre, this is our entrance gate, this a boundary wall. We are very proud of this boundary wall because we said to ourselves that any visitor gets introduced to the Institute, first thing they see is the boundary wall before even enter into the

campus they see the boundary and what is the boundary wall speaking to a visitor and we said to ourselves that we want a boundary wall that is also very transparent that shows that you are open to business that shows that you are welcome to come inside, that is welcoming you. So this is for example and we said boundary wall will be built later, we were not in a hurry to build the boundary wall because we wanted to design it very very carefully.

The next slide shows our research park, 2 lakh sq. ft. of area that would have been commissioned by now but for the Covid we are almost there, needs a few months of work, when the labour comes back this will be finished. We already have some 8-10 companies that we have given temporary space in the academic area but when this 2 lakh sq. ft. buildings are ready we would have very active research park spaces for example the NASCOMM has a centre in IIT Gandhinagar and we have given them temporary space on the floor right below the floor on which my Office is and once this building is commissioned the NASCOM will move into this building. So this is the campus life, I would take a little break here and have Prof. Jose come in and see if you would like to ask some clarifications, some questions, before I move on to the next part of my presentation. Thank you.

Prof. Jose: Prof. Jain, thank you for this part of this presentation and I know you are not watching the chats, people are very effusive in their compliments on the campus, it is a beautiful campus, it is innovative and I wish I could live there, any way, may be something that we can do. Given that some of our participants are interested in moving on to the post-Covid scenario, I want to limit this to two or three questions only. One question that really intrigues me is the fact that you mentioned about the philanthropy and alumni who give you, it is quite interesting that you have 20% of your annual operating budget coming from philanthropy and student giving, this never really happen in most of the institutions, certainly not in Indian institutions, so what is the magic that you wave that people are so willing to open their bank accounts and donate to the Institute.

Prof. Sudhir Jain: See what is happening is that there are lot of people who would like Indian universities to do that and many of them understand that Indian universities will do well only with engagement of everybody, it cannot happen in isolation. My slogan that I take on in IIT Gandhinagar is that nobody owns IIT Gandhinagar, everybody owns IIT Gandhinagar, so people like to contribute, people would like to step and say ok, can I come and contribute to your college, may be with time, may be with money, may be with ideas and most of our universities tend to close themselves, they don't welcome outsiders, because they think outsiders are headaches, they ask uncomfortable questions, they interrupt things, they raise unnecessary issues and we said no that is not good, we need to engage with the society, we need to engage with it and very early in 2009 I was able to persuade some well wishers that we at IIT Gandhinagar would create a totally new paradigm of educational governance and I need your help and they started to

put in some money using which we were able to attract good faculty, we started to support our students and that started that pumped the prime that primed the pump that is how we actually started and slowly more and more people came forward and started to contribute and found that we were very responsive, we were very transparent in terms of money utilization in terms of giving the accounts, maintaining the accounts and so on and so forth. As our students started to graduate, while they were benefitting from these donations, they were also primed automatically, they knew, the student knows that if he is going to Caltech and doing summer internship somebody is paying for it.

Prof. Jose: I am just curious just to speed up this discussion, did you ever have the need to reject some philanthropic giving because of the values of the Institute and the giver or the organization did not match.

Prof. Sudhir Jain: We had situations where we had to negotiate very hard because somebody was giving us money with certain conditions and we knew that those conditions will not achieve the objectives for which the money is being given and we said this is not going to work and the gentleman was very unhappy with us, he said other institutions are willing to accept these conditions, why not you. I said you give it to those institutions, we don't want your money to be with us and we fail. Eventually he came and gave us the money and today he is one of our strongest supporters, so whenever we have a situation where somebody wants to give us money which doesn't meet our values, we would not accept it, but before we reject it we will try to work with the donor and explain to them why we need certain adjustment in their way of giving money.

Prof. Jose: The other thing I wanted to ask you is about the great social engagement you seem to have built up with the community around and also the Explorer programme that you created which sends students out and these are very fascinating models and of course the third element was the innovation that you promote within students, so very briefly if you could tell us how these ideas originated and more importantly what can other institutions do to have similar policies.

Prof. Sudhir Jain: The way I see it is a typical faculty member in a typical institution, university in India doesn't think that social engagement is the university's responsibility. They think it is your private business to worry about the poor people. I disagree, I think that the universities are the place where our students learn the values and they would only learn the values about social engagement if the university has a strong commitment to those, if the university is practising those values and therefore what became very important for us was to practice these social issues in a very very aggressive manner and some of those things I will discuss in the second part of my presentation. The idea is that if the guy who is serving food or making food in the mess, even if he or she is working for the contractor, if I cannot look after him if he has a medical emergency, if he has a child who is not able to go to school, there is some problem. I must look after that person even if that person is working through the contract and we started from there very early, in 2010 we created funds for educational reimbursement for all contractors workers, anybody who is working at the tea shop inside the campus. If the child is going to school we will give them Rs.10000/- per child per year as a scholarship money, whether you are working for the housekeeping agency or working for security agency, for mess workers, for a little tea shop, anybody, anybody working or associating with the

Institute, we will give them money for the children's education. Similarly if this guy working in the mess or the security, if goes through a medical emergency, we have all the legal provisions, we have ESI and we have everything but when the chips are down this person will go to the next available nursing home and spend 10000 rupees or 20000 rupees bill and he may really go under debt, so we created special funds in IIT Gandhinagar Endowment and we said whenever there are emergencies we will look after out people.

Prof. Jose: This is really interesting, I am sorry to interrupt because I know you have a long agenda ahead of this, but this is really interesting to mention this because I think there is a lot of impression that IITs are ivory towers, IIMs are ivory towers and we are completely disconnected from the rest of India and I think what you have demonstrated both on the campus in engaging with the community as well as sending your students out is that they can be very tightly integrated and we can have a set of students who are aware of the real problems of India, one of which is innovation really and that is the question that was also raised and may be that is the last question I will ask you before we move on to the next part. There is a question from one of the attendees today about how do you encourage innovation within the student community as well as among the faculty, you did mention about one of those policies but anything else you would like to share.

Prof. Sudhir Jain: We do innovation in two ways, one is we would firstly have an innovative mindset to solve problems, we will never tell nobody in IIT Gandhinagar has ever heard administration say that this is not allowed as per government rules, this is not allowed for IITs, this not allowed by this or that, we don't do that, we will say if there is merit in it we will find a way to do it, if something is needed, something

is good for the institution we will do it, if the student needs help we will never say no to him. So I think it starts from there, people see that we find solutions to the problems and we engage students into the faculty, it is a very very participative culture that we have built, for example when the students come on day one, I tell them and their parents that I will treat you as adults and I will hold you accountable, I will give you all the freedom but I will hold you accountable and I tell student leaders that all this freedom that you have, autonomy you have and they know that this autonomy is much more than they see with their counterparts elsewhere. I say this autonomy is there with you as long as you are responsibly handling it and because if you start to become like union leaders, jindabad/murdabad type netas this autonomy will reduce and as a result I see more and more commitment of the student leadership or the faculty in finding solutions, what is innovation, innovation is about finding solutions.

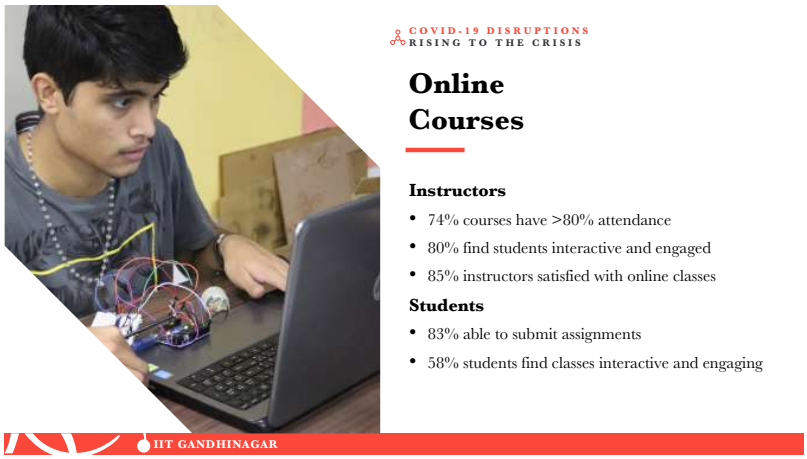
Prof. Jose: There are many questions but you have to cover the next part of the webinar, I will come back to you after we do the next part.

Prof. Sudhir Jain: Come March and we have the crisis that is clear that we have a big problem and one of the first things we did was we gave the students option to stay in the campus or to leave and that was somewhat an unusual decision but that was done after very careful thought after careful discussion with the faculty leadership, student leadership and we addressed

the students and we said look if you want to stay in the campus you are welcome to stay if you want to leave for home welcome to leave, we will facilitate both ways and 25% of our students chose to stay in the campus and we organized that, all the mess workers we provided extra incentives for them to move into the campus, all the essential staff of the water, sewage, electrical supply people, we moved them into the campus with extra financial incentives with proper accommodation to make sure that the campus would run appropriately. Our thought was that students are adults, that is our motto, so we said the students should decide where they want to be and that was I think one the very key, very important decisions that we took at that time which we are very happy about. One it became clear the students who will be away from classes, we created project `Isaac', Isaac for Isaac Newton, there was a story that came in a newspaper which said that Isaac Newton also had to stay home for more than a year during a plague in London and therefore he did a lot of creative work while he was quarantine at home and we created a number of initiatives for the students to engage with depending on their interests, there is a leadership challenge, there is a programming challenge, there is a Sanskrit contest, there is a visual story challenge, innovation awards, a number of things. The idea was that we want students minds to be diverted into creative activities rather than worrying about the health crisis.

We had to decide about academic programmes unlike many other institutions which said to their faculty to start online classes in March, we said no that may not work because universities are not very good with jerky motions, the faculty and the students they don't feel comfortable when you throw surprises at them, so we said it will be a tough task to start online classes, let us not do that, we advanced the summer vacation, so April-May was our summer vacation and we said let us experiment with eight online courses, let us just eight faculty members teach online courses in the summer elective courses and let them gain some experience, let the students get a feel and we use those eight faculty members to do training for the rest of the faculty during the summer for the online teaching we beefed up the hardware, the software, the infrastructure and we started our remaining part of the spring semester, the second half of the spring semester on June 8 in online mode. So the idea was that the remaining classes will be done but they will be done from June 8 and by the time we would be better prepared, our faculty will be better prepared. In the meantime, we were able to also reach out to the students

understand how many of them have challenges with the internet or with devices, we also did something very very interesting at the time when the crisis happened we quickly provided a new provision that students can credit certain MOOCS courses the courses that are there on NPTEL or Coursera, we said if they learn those courses up to so many credits will be transferred and counted in their graduation requirement. We curated 180 MOOCS courses about half of them undergraduate courses, have them postpartum courses and we assign them equivalent IITGN credits so that it is transparent, we told the students, here is the list of 180 courses, here is the equivalent credit for IITGN system, if you learn this course, pass this course, bring a certificate, we will transfer those credits to your credit card and we are excited to see the results, as of today, 64% of our entire undergraduate body has done one or more MOOCS courses, 35% of our Masters students have done one or more MOOCS courses, 1750 MOOCS have been completed by our students and the feedback that we are seeing from our students, very very high level because these are very high quality courses that eminent teachers around the world have created and our students are learning from them and they are learning by themselves and that was a very very successful initiative and we are very happy about that. We are also concerned about online courses that we started from June 8, and we have been keeping a close watch, we did a survey recently to ask the instructors what is the level of attendance and 74% courses have more than 80% attendance in the class room which is very very interesting which is very good. 80% of the instructors found that the students are interactive and engaged in online classes. 85% of our teachers said that they are satisfied with the online classes. When we did the same survey with the students, 83% of the students said they are able to submit the assignments, again not bad considering they are sitting in remote areas all over the place and 58% of students found that the classes were interactive



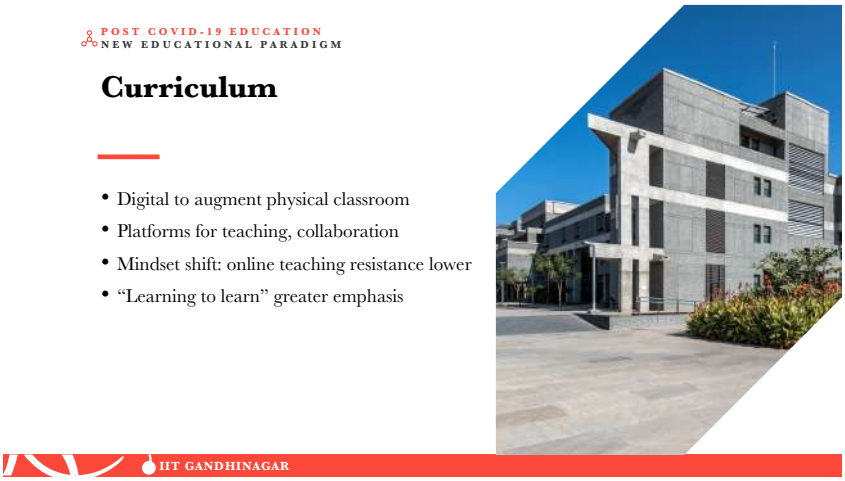
and engaging and so we believe that our faculty have been able to do a decent job of the online courses, thanks to the preparation that they had time for and think than will be a very valuable lesson for us as we go forward. We also realized that the graduating students would have challenges with their admissions, with their jobs, the companies might delay their joining, the American Universities, the European Universities where they are going for higher studies or even in Indian Universities, they might delay their admissions and therefore we created a programme where we said our own graduates we will give a direct admission to a one year postgraduate diploma so that they can be comfortable studying here for one full year and decide future course of action if they decide to do further study at IITGN, we will transfer those credits, otherwise we will give them a diploma and they can go wherever. We created a Research Fellowship for our own students, somebody who is research oriented and can work with the faculty of the Institute and earn some stipend but doing some high quality research and those students who would have gone to corporate jobs we created a junior fellowship

in leadership where they could help our leadership team, the Deans, the Heads in running the Institute and learning leadership qualities in the process.

We were very conscious that the safety and well being in these times is going to be the main agenda, in fact when I addressed the students in March, they were surprised when I started saying that I used to always tell you students first and today I am changing that and they were anticipating what am I going to say and I said from today for the time being student first is replaced by safety first, safety is the most important thing as far as I am concerned. We created a crisis management group consisting of three faculty members, two staff members and we gave them the task of looking at all the possibilities of issues and solutions and work with various units of the Institute. We created a control room in the hostels, so this is the picture of a control room in the hostel where a 24/7 control room was managed entirely by the students. So anybody has any issues can just call control room, ask for any help, for example we would receive calls from the construction workers colony if there is a problem, because we publicized these numbers very widely. We also created a special volunteer force under the leadership of a young Assistant Professor, somebody who was less than one year in IIT Gandhinagar, we challenged him to lead a special volunteer force and that idea of assigning this to a young Assistant Professor of less than one year old was to give a message that this is truly a volunteer effort, this is

not top heavy, top seasoned administrators who are doing and we unleash a lot of volunteering activity in the campus, as a result the spouses, the faculty, the staff, the students, they were able to engage in volunteering activity. What we see here is a picture that I showed you earlier as well, this is the picture of a D-mart, a supermarket, they were able to negotiate with D-mart to say that you bring your groceries, you bring the entire groceries to the campus from morning till evening and people will be able to replenish their requirements for rations, for toiletries, whatever. They did it twice a week, this is how volunteerism can actually unleash tremendous energy. We also have these volunteers bring the vegetable vendors from the city, fruit vendors from the city and make sure that the community is comfortable, as we were one day looking at the vegetable situation and we realized how important vegetables are which we don't think of during peace times, our organic farm group said it would be nice if lot more people start to do kitchen garden and they send out an email to the residents saying that if you want to grow vegetables in your kitchen garden, we will support you, we will help you and 100 families signed up for kitchen garden during the lock down period and I am very proud to say today that many many of them are eating the vegetables coming out of their kitchen garden. Once in a while I see a message where somebody saying I have too much of this vegetable in my kitchen garden, anybody wants just send me a private message and collect some vegetables from my house. These are something that really came out very well during the lock down period, we also created a Shramik Kalyan Samiti and I gave them a

budget and I said you will work with the construction workers. We had about 900 construction workers during lock down in six labour colonies. The actual numbers were much higher but because of the Holi vacation many of them gone home but 900 were still in the six colonies and they are the weakest link in the whole community and our concern was that if something goes wrong because they were not able to work during the time their anxieties, they were away from the families and they were also having certain other resource problems and these group of volunteers of faculty, staff and students, they were charged to work with the construction workers to make sure that they are comfortable, provide them whatever relief was needed and they did a fantastic job. Similarly, we had two neighbouring villages, Basan and Palaj and we thought there may be some underprivileged families which will need help because the bread earner would have lost his daily wages and would not be able to earn money, we created a Padosi Gram Sahyog Samiti, gave them a budget and they went around, distributing the rations, the rice, the aatta, oil, face mask and things like that and the idea was to be good neighbours to show to the two neighbouring villages that we are with you in difficult times.



These are some of the things we did and they reflect from what I explained to you earlier about what IITGN did and what we are and what I am going to now share with you is how I see the future of education as far as IITGN is concerned.

To my mind the curriculum should go through a change, we cannot be living in the same times that we used to live, the digital has to augment now the physical class, we now have learned a very important platform of digital for teaching and collaboration, we have huge mindset shift where faculty and students are quite accepting the online teaching. This wasn't possible under peace times and this is a great benefit I would say out of the crisis that has come and we all educationists have been preaching learning to learn as the key attribute of any university but it is always very hard to practice and I think when students start to do MOOCS courses, they start to do online courses, I think learning to learn will get more emphasis.

The academic programmes have a lot of potential, for example I am imagining IITGN giving admission letter to a student and saying before you come to IITGN,

you are encouraged to do these MOOCS courses and if you do these MOOCS courses successfully we will let you study higher level of the course here, so suppose we are talking about computer programming, imagine now a student comes to us the first day says I have already done this MOOCS courses, we can now put them in a higher level of programming class rather than the ordinary programming class. We think that the universities will be able to give lot more variety, lot more depth lot more threads to their curriculum using MOOCS, the regular classes will have certain elements of online classes and even the students can create content, they can start to contribute to creating the content through online discussions and various other things. We think that there is a huge potential

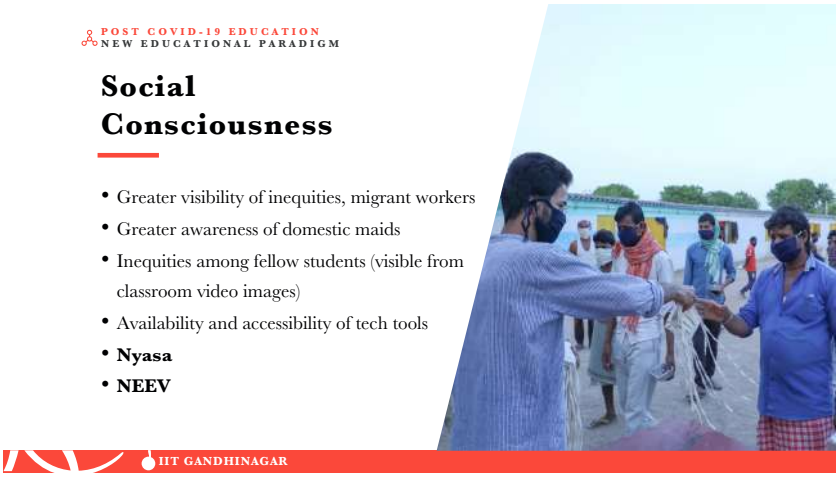
now to use remote faculty, we at IITGN get a lot of visiting faculty from America, from Europe, from elsewhere, some of them comes for 3 weeks, 4 weeks, 5 weeks, 6 weeks, now imaging somebody coming and teaching two weeks, three weeks physically and remaining semester teaching online, I think the range of courses

that we will be able to teach to our students is significantly going to be better tomorrow than what it was yesterday that is something the range, the expertise, the diversity that we will be able to teach our students will be much much more not only that we will be able to perhaps have a Professor of IITGN, a Professor of a University overseas or in India and students of the two sides all learning together, teaching together and the new workspace is going to be complicated, the world is getting complex, challenging and leadership communication, life skills are going to be the most important attribute in the new work force and we believe that the programmes like foundation programme, explorer fellowship, those will really help young people to adapt to the new environment that the world will have.

The placement is another interesting opportunity we feel, we are a very small school, we are very very tiny school compared to our older IITs and therefore many employers would find it very hard to travel to Ahmedabad to meet our students, recruit them but now that everybody has learned that online can be a very powerful tool for everything we are imagining now that these same

employers would be very very happy to look at our students online, recruit them online and it will really open more opportunities for recruitment.

I think the biggest opportunity that IIT Gandhinagar and perhaps for other institutions is to recruit outstanding faculty, as you know that in American universities, there is a financial crisis, there is a pretty tightening of the faculty recruitment so the opportunities are declining in U.S., so some of our best Indians who were potentially looking for a position in American universities, they could become available to us for faculty positions and we are now much more comfortable with online interviews, online processes and I think there is an opportunity here.



The other thing as I mentioned is the social consciousness, I think this is one of the crisis and the benefits of this crisis has been the extreme sensitivity that the country has developed about migrant workers, about underprivileged people, have learned how important the domestic maids are to their living which otherwise they were taking for granted. I think society is going to be lot more humane, a lot more empathetic and I think programmes like Nyasa and NEEV that IITGN has lot more place in the universities to sensitize their students to the societal needs and this my final slide.

I think there is a huge competitive advantage to the IIT system as a result of this crisis. We don't depend on the tuition fee as much as the American universities do, tuition fee is not as much a part of our budget as in the private universities in India and this is a great advantage to us in today's time because I know, I read a lot of stuff that American institutes are worried about the loss of revenue from tuition. We don't have that problem as much. The online has allowed us to realize that lot more collaboration is possible, lot more global exchanges are possible. So far we were constrained about somebody flying for 10 hours or 20 hours to come to visit us and now we can literally have them participate with us online. I think this will also expand our global footprint because we could be streaming our lectures or seminars for the global audiences, so far we were pretty confined to our campuses. So these are some of the thoughts that I have about how this post-Covid situation will change the universities or the IITs. Thank you very much ladies and gentlemen, we will be happy to provide any clarifications or answer any questions.

Prof. Jose: Thank you Prof. Jain, there are lot of questions, so we are going to pick them up one by one. The main point that you made is really fascinating, while most people see Covid as a challenge and probably a big crisis to be dealt with, you turn that into quite an opportunity in terms of recruiting students, even changing this mindset about all education being face to face and so on. You also mentioned something very interesting, that 83% of your students were able to submit the

assignments on time and one of the questions that has come up, that is what we always talk about, the IT infrastructure in non-urban areas is not so good and so are you doing anything to facilitate these students who are in remote areas.

Prof. Sudhir Jain: Our survey showed that about seven and half percent of our students have severe handicap of either the data or the device, we have engaged with these students, I think engagement is the first step that really make the difference because it boosts the morale of the students. Right now what my team is doing is reaching out to the students who need financial help and our intent is that next semester is most likely to be an online semester and we intent to provide certain financial help to those students who are needing financial help to be able to cope with the online education.

Prof. Jose: But what if you can't access the net?

Prof. Sudhir Jain: There will be a very small fraction of students who would have that disadvantage and I believe that we have mechanisms to help those students who will be very few and we must find other ways to help them to do the extra classes, do the extra courses, float the course for them and things like that. There could be ways to support such students.

Prof. Jose: One of the other questions that came up, everybody is asking this, post-covid, when you open up, you have a plan for opening up and how will that happen.

Prof. Sudhir Jain: Prof Jose, as I speak to you, we have about 25% students already in the hostels, we every day are receiving emails from our Ph.D. students and finally

our Masters saying that look my work is suffering because of no laboratory access, it is laboratory dependent and always so, on a case by case basis we let certain students come back and we give them 14 days of quarantine in one of the hostels and after that they are allowed to work in the neighbourhood. So in a very controlled manner we are letting a few students come back for research work.

Prof. Jose: How do you also control this connection between the students and the community, I am not referring to the community on your campus but Ahmedabad of course is not doing so well on this counter here. How do you manage that.

Prof. Sudhir Jain: This is where student leadership comes in picture. As I am very fond of saying that my student leaders have never let me down because the trust that we place on them, they are young people, one of my favourite statements in IITGN is that we older generation always underestimate the younger generation, as parents we always worry about our kids but the fact is that the younger generation always does better than the older generations and therefore our basic premise is that younger faculty, younger students should trusted much more than we typically do and I have never had short of student leadership, if there is a problem in the hostels, if there is a problem in the student body either I or the Dean of Students or appropriate persons would talk to the student leaders and say this is a problem, would you solve it, they say yes we will solve it because they if they don't solve it, we will solve it and if we solve it, that is not a nice way, they don't want to lose their autonomy. Some years back we had a lot of motorcycles in the hostels and we thought that it is creating a lot of problem. We called the student leadership and we said look we don't want students holding motorcycles, a lot of argument, we let that argument continue for months together and once they were convinced we gave

them again many many months, we said you do it your way because they know how to do things their way and we had no education, we had no unhappiness and all the motor cycles disappeared.

Prof. Jose: But now you have a whole range of problems, isn't it, student evaluation, parity and students must be very concerned as there is already a stress of being in a Covid situation, then there is this stress of online learning and there is a stress of how are you going to be evaluated, your place is very competitive, how do you deal with that.

Prof. Sudhir Jain: For example, the faculty is new to online teaching, student is neutral right, so that is one thing, so what we decided was that for the spring semester, the semester that was supposed to finish in April-May, we said all the courses will be only passable, actually it is not failable; it is pass or it is fail/incomplete because somebody doesn't have device so it is incomplete or somebody fails it is fail and we don't know the distribution that you just fail or incomplete and whenever the student is able to come physically they can pass the course by taking the exam, so now we have removed the anxiety about failing, everybody is going to have an opportunity to either pass the course online or later. Now in the process the faculty and students with no stress on top of their mind, they are able to experiment with evaluation. Now they are able to work on quizzes, lot of times things don't work because we are worried, we have some bug in our mind, we think that it is unfair to me, we thing that something will go wrong. Now the moment you remove that fear and we give them freedom I think they do much better. The fact that we give a lot of autonomy to our faculty, we say to faculty, you do evaluation as you deem appropriate, you can do the viva, you can do the

homework, you can do the term paper, you can do a combination of thereof, you can do quizzes, exams, anything you do we will honour it. We give lot of trust and lot of autonomy.

Prof. Jose: One of the challenges of giving autonomy and freedom, I think that is really required in this context and you de-stress the students and faculty quite a bit but one of the challenges coming back to the normal, at the end of the day IITs are respected for the very high level of rigor in the evaluation and just my question to you is do you have some challenges in kind of reversing the clock a little bit, going back to a conventional evaluation system.

Prof. Sudhir Jain: I will say that such things are best done by individual faculty members. If you can maintain a very high level of ethical environment, some years back I asked a gentleman, would you come and teach here for a semester, he said I can teach but I have one condition, I will not conduct an exam and we are talking about control theory course, you know it is a Mechanical Engineering hardcore course. So I said how would you evaluate the student, he said I will go to the student's room in the hostel, I will interview him for 15-20 minutes, half an hour and I will tell him you get a C grade or a B grade and if the student wants to further improve his knowledge I will go again to his hostel room and I will keep going to him till he says I cannot learn anymore and I will give him the full grade. I said fine, we are game for it, now the point is that if you can trust the faculty, if the students trust the faculty, I think all of that can be taken care of. I think what is really very important, what Indian academy doesn't talk much about is the culture, we quite often talk about the quality of faculty, we talk about funding, we talk about equipment, we don't talk about culture. To my mind the culture is the most

important element if you want to be a good university and I believe that in IITGN we have been able to create that trust, faculty versus administration, staff versus faculty, student versus faculty and that trust is the basic underpinning of what we do.

Prof. Jose: I guess in a crisis situation that trust really drives, you know good action and great success. I was just wondering, you know, you actually talked about several innovations in the learning space by way of introduction of MOOCS by changing the evaluation by changing the way classes are structured, by enabling students and faculty and all of these are I think very valuable in the post-covid world. Do you have any other advice that you would give for people who are struggling. I think we have to accept that most institutions in this country don't have the credibility that IITs have, don't have the resources that IITs have, not even the faculty strength, so it is a different world out there, so what may be, a lot of community that is listening to you is the IIT crowd but you know there is a whole world out there, what advice do you give for say mid-range school that doesn't have a lot of the resources and advantages that you have.

Prof. Sudhir Jain: I would say that the faculty and students if they know that administration cares, I think that is important. If I were to tell my faculty go and do it and if you have any problem that is your problem and not my problem that doesn't work but if I tell them look I want you to teach online, please tell me what are your problem is and we will help resolve them, so my Deans for example used April and May to spend a lot of time preparing different types of hardware, different type of software, they procured iPads for example for faculty who wanted to use iPad for teaching, things like that. I think if Administration shows that they care, I think faculty and students would really embrace change much more easily

Prof. Jose: Sorry to interrupt. I was just talking to someone who is connected with a very well know university, quite a big university in Bangalore and they are a private university, you know private universities depend on student fees, they said the applications reduced by an astounding 90%, of course I am sure that must be a temporary blip, but it is true that revenues are going to fall, not for institutions such as IITs or the top institutions but it is going to fall for others and how do you suggest that they manage these challenges.

Prof. Sudhir Jain: Tuition fee based revenue is going to be a big problem for many many universities in India and outside. You come from a business school and I am sure that people are talking all the time that companies that have strong balance sheet even if the profit and loss statement is bad they will survive because of strong balance sheet that they don't have debt, they have cash. I would say same thing happens with university. I think the model that Indian universities have has to change, we have to have a balance sheet, we have to have an endowment, we have to have reserves, cash reserves, in the absence of this cash reserve, they are going to go through similar crisis as many companies would because they have lot of loans and debt and the sales will go down, the production will go down, it is the same problem with the universities. The models that Americans have perfected where private universities are able to raise a lot of endowment funds and they are pretty cash rich and I think that model our private universities have to have where their alumni, their well wisher, have to put in money which is available not only for operating expenses but which is also very critical for difficult and surprising times like this.

Prof. Jose: I think you have been very successful in doing that and so may be many people would be interested in what you specifically did to actually motivate people. You know, Indians are very good in philanthropy but not so much in giving back to the academic institutions. I think that is generally the reality unfortunately, but you know that brings me to another thing which is all these innovations and now people are getting used to a new way of learning and a new way of teaching and so there were some questions, this is the new normal and people get used to it. Then will the relevance of the university or this large campus, big infrastructure, will all that be challenged, do we need such infrastructure to provide excellent education, let us not limit to the infrastructure, if classes can go online, then can we have a less capital intensive model of higher education.

Prof. Sudhir Jain: I don't think so. I think the students don't learn only physics, they don't learn only finance, they learn lot of values, they learn lot of skills, people skills, life skills by interacting with each other by working with their professors. I meet my students whom I have taught 25 years, 30-35 years back, they don't remember the civil engineering I taught but they remember the story I told in the class room. They will come and meet me and say you know you told that story in the class room one day and that I remember it has benefitted me. So I think people learn lot more than just physics or electrical engineering when they come to college and therefore the campuses like us will remain very very relevant, especially if you want to produce leadership if you really want to do a skill development, you just want to create a programmer who will just be able to program, perhaps somebody can learn programming on MOOCS but if you want this programmer to be able to deal with clients, to be able to deal with the team, to be able to negotiate the deal, I think he needs lot more skills than just programming.

Prof. Jose: I completely agree with you because one of the things that we always talk about is learning is social and if you remove students and the learning happens in the physical space, social part despite having all these social media around I think this really reassure a lot of faculty who think that digital is out to replace them and their institutions. So thank you so much for reinforcing that. This is again a question that came up is the post-Covid rules of the game change, for instance social distancing. Now classrooms cannot really be physically structured the way they are and so on, so how do you propose to deal with that because you will have these students and you have the class rooms set up to accommodate a certain number and how do you manage all these additionalities.

Prof. Sudhir Jain: There are two types of things here, one is that the class room that was accommodating 120 students is now going to accommodate only 40 students or 30 students, that is one problem. My guess is that we will have to spend extra effort in scheduling the classes in breaking large classes into smaller classes and all of that will have to be done by the universities and if your faculty is aligned with you, if faculty is part of the decision making they will do it much more easily. If it is going to come from the top and somebody will tell the faculty do it, it doesn't work. So my guess is that this is a problem that students and faculty have to sit together solve and I believe that this is something that can be solved, it will take extra effort, nothing will come free, there will be some extra effort that will be needed, maybe people may have to teach more, maybe there will be parallel classes that have to be done, maybe the classes will have to be done early in the morning or late in the evening, there will be some adjustments that people will have but in the interest of safety I think those things will lead to it.

Prof. Jose: That is interesting because one of the models that we discuss often is if it is a fully residential campus, some students can be sitting in the class and some in the class room we can swap those into groups back and forth so everybody gets at least 50% of face to face time that may be one model to look at. The other question that came and I think it is a very relevant question, these are trying times and everybody is under stress and people do tend to get de-motivated especially graduating students because they are looking at new opportunities and so on. I know you mentioned about providing opportunities within the campus but they might want to look at opportunities outside. These are also trying time for faculty so as a Director, as the head of this Institution, how do you keep the people motivated.

Prof. Sudhir Jain: It is all about communication, if somebody feels that somebody cares, I think that is what is important to know. Recently for example, we have no Covid cases inside the campus, we have thousand family members in the housing area, we have 500 students in the hostel area and fortunately we have so far no Covid cases, but we said we can get into that situation, so we created for example, a 16-bed facility with oxygen, with all the medical supplies so that we can handle too moderate cases inside the campus. We signed up with an arrangement with the top three hospitals in Ahmedabad with the Ahmedabad Municipal Corporation so that we can send our serious cases there. We created the whole infrastructure well before the crisis happens, so today I have an officer in IITGN who knows how many beds are available in each of these three hospitals, how many ventilators are available in each of these three hospitals, he knows it every day and that data come to him. Now when people see that as an administration you care for them and you

are engaged in finding solutions to the unknown problems that might come, I think they feel more comfortable and they are also happy to contribute to the solution. During lock down period, we were able to get them vegetables, fruits, groceries, everything inside the campus, our students volunteers said to everybody, anybody who has a problem, senior citizens, others, you tells us we will bring the groceries to your home, we will bring medicines to your home, a lot of young students, young staff, young faculty, young spouses, all are volunteering to help the campus residents. The trick in this whole things is to trust your people, empower them.

Prof. Jose: I like the way you put it, trust, empower and communicate extensively, but the one part that you are explicitly saying is meticulous planning at the back end and implementation which you have done actually by connecting with the hospitals and mapping availability and having a protocol for dealing with an actual crisis, if it arises. That is really fascinating, I want to shift this conversation a little bit away because only a few minutes left and there were some broader questions that people have asked that is not directly connected to Covid, but I think it is useful to look at this. One is, could you tell us which specific areas are the differentiators of IITGN in the research space and especially does the city connection with the heritage and culture.

Prof. Sudhir Jain: We have several interesting areas that we have done well. Culture and heritage for example. We are very passionate about archaeological sciences, so we have a Centre for Archaeological Sciences and similarly we have courses on Indian knowledge systems, we have people who will talk about classical Indian literature and things like that, so we teach Sanskrit, we teach Urdu, ancient history things like that. I think we have a very strong commitment to those areas, we also

do very good quality work in several areas including cognitive science for example. We were the first IIT to start a formal academic programme in cognitive science, now a couple of other IITs have started it. Our students from cognitive science have gone on to do extremely well and there could be many other. Safety engineering, fire safety, we are the only Institution or the laboratory in the country to have a three-story full-scale first test facility, we put the whole building on fire so you can literally test your solutions to know the building facades, building fire suppression system, any other facility, you can literally come to IITGN and install those things in our three-storey full scale test facility and we will put the building to fire and after some time the fire brigade will actually douse the fire and then the building will look pretty bad, all burnt out and then we will again restore it for the next experiment, so we have dome some very good work in many areas.

Prof. Jose: One final question, it is a summary of many questions people have asked, if you were to look into the crystal ball what would be your top three or four predictions for educational sector in the post-Covid world.

Prof. Sudhir Jain: I would say that more than post-Covid world, India has a crisis of education, right from primary education to university education or micromanaging our education and we need to loosen that control, we need to let people work on the education and empower them and I think if we do that then post-Covid world will reward you very well because in post-Covid world the education is going to be more and more autonomous and less and less centralized and that is where I see IIT Gandhinagar having a huge advantage because to begin with we were very decentralized with lot of autonomy to the students, lot of autonomy to the faculty and we think that post-Covid world will give us therefore additional benefits and I

would say that same thing we need to think about, if you look at Indian education, more autonomy, more accountability, autonomy doesn't work without accountability and of course more trust and people will deliver.

Prof. Jose; Thank you Prof Jain, this has been a very fascinating conversation right the time you started out with the establishment of IIT Gandhinagar, you built it up into the profile that it has today, the ranking, I think it has jumped very rapidly in the ranking, you said ranking was not important to you, you have a great faculty body and a great campus and you have managed this transition. From what you have said it appears you are doing exceptionally well in the Covid scenario. Thank you so much for sharing your leadership insights with us. Now I am going to hand over to Dr. Susheela who will continue with this. Thank you, it has been a great pleasure from my side taking these questions on behalf of the participants and then presenting them to you.

Dr. Susheela Venkataraman: Thank you very much Prof. Jain and Prof. Jose. Indeed this was a very nice presentation and very fascinating look into IIT Gandhinagar and the kind of innovations that are happening right here in India. Prof. Jose did a fantastic job of that, that conversation was really very fascinating and interesting. Prof. Jain, you talked about basically that digital is here to stay and in a sense digital will augment physical, you also said that physical has to be there, it is not going to go away because what you are doing is not creating engineering in a particular discipline but fully rounded individuals who are really going to go out there and make a difference especially when you add in the layer of sensitivity, a good understanding of the reality that our country faces and the kind of issues that we face that whole story ties in very nicely and clearly speaks to how we are going to

create a new generation of very successful leaders in this country. You mentioned that innovation at the end of the day is about solving problems and again to solve problems, we do need the whole interdisciplinary kind of way of working as well as the thinking that comes from not just engineering sciences but also the social sciences and where in they bring in to the way we look at problems. You also said something that is really nice which is while we are all looking at this whole Covid situation as a big disaster, obviously it has had its negative impact, you have also seen the positive side of it, you have seen the opportunity and you recognize that you can now have global faculty teaching students of IITGN and you can also have students drawn from across the world and they don't need to come here to learn from faculty who are in IIT Gandhinagar. So this has been very interesting and I must thank you for taking the time to be with us today, talking us through where the education is going and where we potentially are going to see change hopefully in the coming years and finally you also talked about how important it is to create a culture of trust and caring and basically nurturing which is where the best learning can happen and how you can do that even though you are doing it remotely, not just physically. So thank you very much, this was a very nice, interesting and very valuable discussion indeed. Thank you Prof. Jose for being part of this. Thank you audience for participating, asking you questions.

THE POST-COVID INDIAN START-UP: BIGGER, MORE INNOVATIVE, WORLD LEADER

MR. SUDHIR SETHI I JULY 11, 2020

Sudhir Sethi is the Founder & Chairman of Chiratae Ventures India Advisors (formerly IDG Ventures India), a leading VC firm advising AUM of $750M based out of Bangalore, India. Since 1998 Sudhir and his team have advised on investments into 100+ firms across Deep Tech, Digital Consumer, Enterprise Software, Fintech and Healthcare Sectors. He has also served as Advisor on the Technology Innovation and Productivity Council of the GMR Group.

In 2001, Sudhir was recognised by Red Herring as one of the leading venture capitalists in the country. He has been named among the Top Ten IT Professionals by Dataquest and by Bloomberg UTV as "Visionary Venture Capitalist" in 2011. Sudhir has been featured in Subroto Bagchi's book "Zen Garden – Conversations with Pathmakers', in 2014.

Saumil Majmudar is the Co-founder, CEO & Managing Director of Sportz Village (www.sportzvillage.com) India's leading youth sports organisation that aims to get 100 million children to play. Prior to starting Sportz Village, Saumil was the Founder-CEO of QSupport (one of India's first remote tech support businesses) and worked with Wipro (Global R&D) in the International marketing team.

Lecture at IIT Alumni Centre, Bengaluru, by Sudhir Sethi, Founder & Chairman of Chiratae Ventures India Advisors, July 11, 2020.

Link to the webinar : https://www.youtube.com/watch?v=Y5uGrHUy4mE&list=PL0zMQ-70IHIX-df3u2Tto6dkKHCRC6iFL&index=14

Dr. Susheela Venkataraman: Good evening and welcome to this session. Let me begin by introducing our speakers/guests for today. We have with us Sudhir Sethi who is Founder and Chairman of Chiratae Ventures. Chiratae Ventures used to be IDG Ventures, a leading VC firm and they have nurtured very many well known brands such as Flipkart, Healthifyme, LensKart and so on. Two unicorns and two IPOs later they have transformed themselves into Chiratae Ventures. The companies they have nurtured come from variety of industries and address several problems of customers from India and across the world. Sudhir is very well regarded, well recognized and celebrated and what many don't know is that he is a wildlife enthusiast. His family foundation, the Sethi Foundation is supporting people with hearing impairment and back in the Faculty of Management Studies where Sudhir and I were classmates, we did our MBA together, Sudhir was known as fun loving person and someone who is very light hearted that hasn't changed all these years. Our other guest today is Saumil Majmudar, he is going to be moderating the question/answer session. Saumil has been recognized by his alma mater, IIT Bombay, he started his career with Wipro in Global R&D and later the entrepreneurship bug bit him and he went on to do a tech-startup and went on to his passion which is sports, he has set up a new sports entity, Sports Village and they manage physical education programmes in over 400 schools across India and some parts of the world. He is passionate about sports and obviously that is the reason he got into it and he continues to do mountaineering, fitness and also badminton and so on. So he continues to remain very active in sports as well. He believes that sports is not just about physical fitness but also about building other skills such as leadership skills. So thank you both for being here with and so readily agreeing to participate in this webinar and be part of our webinar series here. My colleague, Mr. Anand Talwai is going to be moderating the session together with Saumil. We are not going to have a Powerpoint presentation, I am going to ask Sudhir a few questions on behalf of all of us, the background to that is that we had the IIT-Industry Conclave in February of this year, we had Directors of several IITs who participated and many eminent speakers from industry. There were several industry panels and across them certain themes emerged. Today we are going to pick up three themes out of those which are Innovation and Strategy, Operational Excellence and Collaboration, these were the three big themes that emerged at

the time and what we are going to do is ask questions and Sudhir is going to tell us what he thinks start-ups should look at when it comes to each of these aspects. We would start with the first theme, Innovation and Strategy and can you put in perspective for us, what the role of VC is and why it is so important for us, why is risk capital so important for the economy, what is the impact that start-ups have on a country's economy.

Mr. Sudhir Sethi: Thank you Susheela, Anand and Saumil, the team which is supporting the IIT Alumni Centre. It is really a pleasure, many of our entrepreneurs by the way come from IIT so and it is great to be here. I think it is very important to understand the relevance of the venture industry because it is always capable. First, what is the size of this industry. In the last 5-6 years, the total amount of capital which Indian and private equity venture has absorbed is about 150 billion, exited about 86 billion and if you look at the kind of company by the way venture alone is approximately, if you just take venture alone will be 10% of this total amount overall. Now first and foremost what does the risk capital do. Let me start with the fact that risk capital is very relevant, since risk capital funds businesses which otherwise would never be funded by traditional capital because traditional capital funds known production services, known revenue models and known business models in known markets whereas risk capital funds new products, new services, new business models, new revenue models which have not been seen before broadly, so effectively these are very new companies. We, as a firm Chiratae see about 3000 new companies every year. Considering India it is not a big amount, or large number, but considering what it could be let us say 10 years from now will be something like 15-20 thousand new companies which we will see, if you take the industry it is much better. Now what kind of companies we as risk investors have funded, we as VCs funded and how relevant are they? So, fundamentally companies who solve real problems, these problems were not solved before, they were existing for a long time and younger entrepreneurs looked at it and said, hey in my traditional company I can't do this and so I need a new business outfit and that is where the risk capital comes in. So to give you example, and these I will give you 4-5 examples which will explain the context of high risk. One of our companies is monitoring worldwide about seven million acres of farmlands

for productivity, crop volumes. This is through an artificial intelligence engine which basically uses satellite technology for monitoring. This is fundamentally a new way of monitoring farmland which cannot be done otherwise. Is there any other company in the world - very few, may be one or two, but it is a company from India and, in India itself they are monitoring something like five million acres and give it another 10 years, hopefully 50 million acres. So again this kind of company would never have been funded by traditional capital. We have a company called Healthifyme, which is a company into the fitness space using AI. Curefit is delivering fitness at home, Aether which is a company which is in the bionic space intelligent upper limbs in a very complex market but that kind of product at that price point does not exist in the world, it's entrepreneur is 24 years old. Incidentally risk capital recognizes that you do not need to have experience to start a company, you need to have an enormously powerful idea which can turn into a product in the service in due course of time and that is where risk capital comes. You know a company called Emotix from IIT Bombay which gives a product called Miko2 companion robot for children. What the world's first robotic product which initiates a conversation recognizes emotion with children and the list goes on and on. So fundamentally there is a huge relevance because these kind of companies will never get funded otherwise. So this is innovation, coming back to your point Susheela, this is the innovation which gets funded by VCs at a very early stage. The second point is what value does a VC create and obviously since I am familiar with our own numbers, I will quote that but just as you know we today have funded about 90 companies, we have today active about 55 companies and their total revenue in March was one billion dollars, market cap was $7 billion. Incidentally that is .3% of GDP, that is the significant impact which only one medium size VC can have it, you take the whole industry then we are talking about anywhere between 2-3% of GDP just the VC industry in market cap created. Now compare this to the fact if you look at the public markets there are technology companies which are 100% software, they have over 30 years created 7% of India's GDP whereas in the last 10 years just technology companies have created somewhere close to 3% of India's GDP. This is very very crucial to understand that this capital creates an enormously disproportionate value which otherwise cannot be created. I will give you an example of this, it is also linked to the fact that some of

these companies will go IPO, in fact if you look at the US public markets, the US public markets in 2015, they were 1.4 times US GDP and in 2019 the public markets were 1.8 times GDP but if you look underneath the cover there, the top 15 tech companies in 2019 accounted for 30% of US GDP and five years before that they were 15% of US GDP. In India, public markets in 2015 were 0.67% of GDP and they have declined and it is now 0.57% of GDP because enough companies are not coming in which are technology oriented in the public markets in India but if you look at the private markets in India, the market cap created is over $200 billion which is almost the same as public markets but in 1/3rd of the time. So if VC industry can create enormous value like this, it is a supply chain to public markets. If it is the only way you can fund risk capital, then there is a big message out there. In fact the interesting part is that 98% of this capital comes from outside India. I would encourage Indian capital and government in policy terms to open up. India has enormous amount of capital, family wealth is somewhere close to two trillion dollars, if you look at the public funds, the private funds, the insurance companies, corporates, corporates is a very good example the top 10 IT companies in India gave dividends and buy backs in 10 years of $38 billion by the way, which fundamentally means the IT companies don't know what to do with the cash. So effectively, one of the reasons why by the way this cash does not come into alternative assets and risk assets is because there is an adverse tax regime. International capital gets more taxation benefits than Indian capital. So a long story but it is very crucial to the ecosystem of producing brand new companies which never existed before.

Dr. Susheela Venkataraman: Let us talk about the brand new companies. Obviously there are lot of brilliant ideas out there, there are lot of people who come up to the prototype stage, there is a lot of jugaad in innovation also taking place, there are incubators in the IITs, all of that is happening and it is brilliant but there are very few of them that seem to be coming to commercial success, what are the imperatives, what should a start-up today keep in mind as they do their design or start looking at what they are going to offer.

Mr. Sudhir Sethi: Number one, the ecosystem evolves over a period of time and fundamentally it is very important to understand if an entrepreneur has an idea, it is very important to pursue that. So I would always encourage youngsters to go and start a new company if they have an idea. Those days have gone when only a job will do as such and there are two ways of funding that idea, there are incubators in the country, there are grant mechanisms, you know BIRAC has government grants coming in for that sector, there are angel investors who do the needful, so fundamentally if you look at the market space, there is at the start up level, there is actually lot of capital available. Now the entrepreneur may think it is a good idea but the investor may think it is not, or may be it needs fine tuning. So at the early stage, it is very important for the entrepreneur to go and present the idea to five investors. The proof of pudding is will it be funded. So that is the first thing which I would suggest and gather as many people as you can around you who got experience, who got knowledge in that particular sector. Today there is enormous amount of risk capital available at that stage of the market space, is it enough, no but there is still quite a lot. In fact the number of companies which get funded at that level are quite high and they are increasing day by day because the capital requirement at that level is anywhere between Rs.13 lakhs to may be Rs.2 crores overall and I think Saumil is here, I don't know how much capital you started with Saumil, but it was probably in that range overall. Yes it is very crucial to go and find out whether that idea, product or service will succeed and by the way do recognize that there are so many bright people in the world, you have to make sure that somebody else has not thought of it, the only way you can do that is talk about it, so don't keep it inside and say this is the best and I will not tell anybody. It is better to go and tell a hundred people and find out if does somebody know something like this which exists outside. Covid by the way is not a dangerous area for start-ups, in fact some of the best companies in the world have come up during economic distress.

Dr. Susheela Venkataraman: I remember when we chatted earlier you were saying that this pandemic is not something to be afraid of, you see it as a huge amount of opportunity creator

rather than as something that is going to pull everything down. So tell us a little more about that where for example in deep tech, what kind of opportunities are you seeing.

Mr. Sudhir Sethi: We have seen in aerospace, robotics, we have seen in the whole area of biotech, alternative modes of transport, in artificial intelligence space everything you can think of, we have seen innovations in business models, revenue models, products and services overall but interestingly the number of deep technology companies which are coming up has actually increased in the last three months. We ran a deep tech programme to identify companies in the market space about three months back and in 15 days we received about 250 companies applying for the programme and in three months we have invested in three companies out of that. The ratios are like that, you know many companies we will see, but fundamentally we invested in three and I am sure many people would have got invested otherwise. They would run into medical devices, they would run into fintech, the whole space of digital, online spaces, innovative ways of getting products in supply chain efficiencies, in distribution chain efficiencies. It is not just deep tech, it is the application of technology over brick-and-mortar or smoke stack businesses which need to be efficient in this market space. To give you an example, the large e-commerce companies could not deliver products for 45 to 60 days, it was the kirana stores who did that, so one of our companies called Peelworks is a technology enabled platform which enables FMCG product companies to deliver to kirana stores and they grew during this time because the innovation of delivery at the local level on the ground by the kirana stores was enormous. They grew because in fact they ran short of supplies. We are looking at another company which is a technology enabled platform for ensuring farmers to have a facility for storing grains in the country, because grain wastage is very high. The whole agricultural space is enormously inefficient. I don't know if you know what is the income a farmer net after expenses in a year, a successful farmer, because the averaging holding is about two and a half acres. It is after all expenses and everything put together may be about Rs.40-45 thousand. Fundamentally for me, traditional farming is a perpetual cycle of poverty, so how do you make that efficient, how do you make it productive. If the farmer is forced to sell his grain immediately after he harvests that means

he will get a lower price. If the farmer has a platform which can find markets using technology which can give him an optimum price at the time he wants to sell it which means he needs storage, which means we need an entrepreneur who knows how to do this, that is the kind of technology platform we are about to invest. SMEs need credit, India has a lot of credit by the way, but it doesn't reach the SMEs, so there is technology platform which in a three year time has distributed $3 billion worth of credit with NPAs which are insignificant compared to what the financial markets talk about, but what did they do, they have a technology platform by which creditors can come on to the people, lenders can come and do that and there are thousands of SMEs who can say using this technology they can get money, by the way you want to go to the bank and ask for loans I doubt it, it still takes three to four months.

Mr. Saumil Majumdar: This is of course fascinating, you are always, with the knowledge you have. On the question entrepreneurs looking at pandemic as an opportunity, I think across the board there is enough data around how recession has created the best businesses and robust businesses for a variety of reasons. The question I have to you is, as an entrepreneur who is at an idea stage, how should a person think about it, should I think about pandemic as an interim and design for post-pandemic, post-Covid in this case, what is your view, your outlook in terms of how the market has changed or is changing during Covid and based on that outlook I as an entrepreneur to design some product or services, so what is your sense on how that has changed or what is changing.

Mr. Sudhir Sethi: I think the markets today are in demand, the question is, is the company going to be dependent. So let us say an entrepreneur has an idea and a product or service at various stages of its life cycle, I think the question which the entrepreneur has to think is, is the market going to be dependent on the product as an essential service or is the company going to be dependent on the market. That is a very important question. The pandemic or any distress, this is my fourth down cycle which I have been through and I have learned one thing the market is very choosy you can grow companies which are essential to the market,

the market cannot do without them, that to me is given, if the market finds that it can do without the product or service then that company will not scale and it can't be a nice to have product by the way.

Mr. Saumil Majumdar: Before I go to the next question, I want to get a sense of what do you think has changed at the market side from a consumer behaviour, from a demand side because as an entrepreneur you are designing for a certain outlook of demand, what is your sense of what is changed there.

Mr. Sudhir Sethi: I think enormous amount of change, first the consumer is now really thinking where do I spend my money, there is also the safety net there, there is also the health factor, the risk of Covid, so to that extent allocation of surplus budgets inside a home are undergoing massive changes. The second thing is will it be spent on more education, will it be spent on more health care, on basic items like food, safety, to buy a new car, I think those questions are going to be asked by every consumer and consumer family absolutely. In fact, those questions are going to be asked by businesses by the way. Do I need a new office, I believe a big chunk of the IT Services companies, more than 60-70% are still working from home, so they are really saying if I can work from home why do I need costs in terms of real estate, so it is bad for the real estate industry but from IT perspective why do I need it. Any distress downturn basically changes the models upside down. It is topsy-turvy worldwide which means from a company's success point of view there is nothing which you can't do and there is nothing which you should be leaving, no stone unturned. What do you do, of course I am sure everybody has heard, take costs down etc. all that is fine. But I think the magic wand is an innovation, what can be an innovative magic wand, so there are four or five pillars in which we have discussed with our companies, we have learned a lot from our companies the best teaching for a VC is by the entrepreneur by the way they become extremely agile, digital products have come in, at-home is a big service, careful at gyms, and we certainly have online at-home services in various formats. Incidentally what have companies done, introduced at-home services, introduced deeper technology platforms because that is easy to read

physically, you can't travel, so if a customer has to be serviced, somewhere how do you service the customer and the person who is able to figure that out, if it is a doctor you need live health services have come in so fast, it is unbelievable. I think there is a whole gamut of agility technology, new services, very new revenue models which have come in. Incidentally, I must tell you that this agility is reflected in the revenues of companies. I will give you some anecdotal evidence, the total revenue of all our companies put together in the month of March was just about a billion dollars, that is Rs.7500 crores and in July it has come back to a billion dollars. Now how did this happen? It is not obviously every company, some companies are doing faster and at least I would say more than half of our companies have now executed changes which are very different which they never did earlier. They have introduced new products, digital products, they have introduced at-home services, they have now gone to adjacencies which they never thought of and many of our companies have gone global because digital allows you to go global, in fact out of our 55 odd active companies, 23-24 have a digital footprint in now 50 countries. So effectively the way the entrepreneur is thinking and by the way it is a stressful time for the entrepreneur. Incidentally it is also very stressful time for the board member and the VC thinking how to grow the company. Is international footprint is going to be easier now, in fact it is easier now.

Mr. Saumil Majumdar: Wonderful, I thank you so much.

Dr. Susheela Venkataraman: Thank you, some of what you just talked about also talks to the fact that there is convergence of what used to be traditionally different industries and many of these things are coming together and we are seeing a whole new slew of services and opportunities. Let us move on to the next theme which is, Operational Excellence. It is great to have an idea, it is very good to bring it out into some kind of form of a service or product offering but at the end of the day to be able to scale and for it to have some kind of impact in market, operational excellence is what really matters and again you talked about the fact that there is technology in all of these new start-ups that you are seeing, that is just one element. What are the other elements that a typical young company or a young start-up should be

looking at, to be able to convert all of that into solid offering that can then scale and make an impact in the market.

Mr. Sudhir Sethi: In operational experiences, excellence is the buzzword. Operational excellence will take it to the stage where it is very difficult for competitors to do the need for it. During a normal time when the economy is not under stress, typically companies do spend much more during distress time. the extent of expense or cost bloating can be anywhere between 10 to 30% and that all depends on the expense, the extent of supply chain, this capital to some companies could be excessive available and those companies will spend more which means costs will get bloated more, companies who have shortage of risk capital will obviously not bloat their costs as such. Incidentally all companies post Covid went through cost management and reduced their costs in every single element you can think of with a fine tooth comb anywhere between 20 to 40%. This is also meaning shutting down businesses which were not profitable, shutting down business which were consuming too much of capital, shutting down businesses with the customer saying "you know what this may not be necessary, I am going to know stop the subscription of it". Travel is a good example, people stop travelling, hotel is a good example, so effectively if a company is in travel then the question is what do you do, if the company is in hotels what do you do, if the company is running gyms what do you do, because on the whole people coming together is gone, so many of these companies have transformed themselves into businesses which can still make money by going to adjust adjacencies or going to digital and so on and so forth. Fundamentally operational excellence also means what cannot be done earlier had to be done today and the fact that at-home delivery of food, fundamentally India did not at least in the urban areas much of a challenge because of the 10 million odd Kirana stores in the country was operationally excellent thanks to the 10 million entrepreneurs, but it took some time for the larger entrepreneurs to come back because they had to sort out processes and SOPs overall whereas the younger entrepreneurs basically said "I have to do something and let me go and do it." I think in every area the excellence operation also means removing fat from a chain so if between FMCGs and Kirana stores, if the traditional supply chain absorbs 12% margin, a

technology supply chain should release that as additional profits to either the manufacturer or to the Kirana store or result in a lower price as far as the product is concerned. Do look at the fact that anywhere between 8 to 12% is your margin which can be released and that means operational efficiency. Companies were always facing losses by delivering one piece at a time, they started doing cluster deliveries, identify an apartment building, club all the orders and instead of companies saying I will deliver now in 30 minutes and I don't get in 30 minutes I will do the needful, they started saying. " I am going to club orders that is when the need of the hour was not 30 minutes, need of the hour was two times a day and reduce your cost and by the way consumer has changed, consumer has massively changed". Today consumers are saying what I don't need I will not buy, consumer is saying because of risk please deliver everything at-home. Innovation and contactless delivery, innovation and payment mechanisms, everybody is coming back into digital, it is just enormous right now.

Dr. Susheela Venkataraman. So that brings us to the next questions, which is that the traditional businesses or the way the organizations have been doing things have had certain skills and with all the technology coming in what kind of new skills you see are going to be required and how do we bridge this gap of skills as well as experiencing although start-up doesn't need experience to start but somewhere along the way I guess there is that need to bridge the gap of experience as well. So what can we do for this?

Mr. Sudhir Sethi: Admittedly we must all be cognizant of the fact that at the lower end of the skill chain there is enormous amount of stress and reskilling there is very very important because the gig worker is losing his or her job, it is important that it is taken care of; VCs must recognize that and do something, we have done something, we opened a thrive fund to make sure that some amount of pain goes away for those people in our companies but it is also important to reskill them, number one. Number two, if you go a bit higher where physical businesses shut down, then I think it is also important to notice that reasonably skilled people, the availability has gone up. If many retain outlets shut down, then if somebody is now thinking of an entrepreneurial sector business where you need retail outlet people as an

example, those are available today. In fact those may be available possible at somewhat of a lesser price. Assuming that this will be inside the same town, I am not getting into migration and all the stuff, but skill workers as you move up the value chain the demand will increase because of the technology element coming in. So many of the companies are hiring new technology people because they can work from home. This is a great opportunity for gender parity to come in because you can now actually hire women because fundamentally due to compulsions of family they may be at home but highly skilled, you will find those people coming back into the work force because they can work from home and they can add value, etc. I think there are many examples in this space but the bigger challenge of course lies in the fact that there is stress at the lower end of the skill base and that is very difficult to retrain again.

Dr. Susheela Venkataraman: During the conclave one of the other themes we heard repeatedly from everyone of the panel was about the fact that cross-functional thinking and working is extremely important. So if an engineer in the past who was a computer scientist and really focussed on the computer science, now they are going to have to think about not just computer science but also the behavioural aspects that come into the use of the computer, how are you seeing this whole thing shape up and therefore what kind of implications are there for organizations that are in the training space say or for IITs for that matter.

Mr. Sudhir Sethi: Let me start with the IITs. I think that is very very crucial and when I say IITs I mean all engineering colleges. This is a great time for IITs and all engineering colleges now make sure that technology programmes run and in every field, whether civil engineering or whether it is the space of mechanical engineering, electronics and cross functions, the reason why Aether came up with the bionic arm because it was cross functional between physical human medical knowledge of amputated limbs and the whole space of mechanical and electronic engineering. The best products come out when multiple streams which are parallel in nature try to converge, whether it is an AI, whether it is in technology for amputated limbs,

whether it is in the space of solving distribution channels problems of supply chain problems, you need to think laterally and I think it is very very important that that be done in the market space and I think engineering colleges, to my mind industry, entrepreneur industry interaction with engineering colleges must shoot up right now. This is a great opportunity and the other things is for all this funding is required. I don't think the engineering colleges in the country or even the management institutions are built for capital formation to fund some of these with grants overall. The grant mechanism in India is very weak right now. This is a great time to solve, there are many Indian professionals who are willing to do this in the market space, we are meeting them all the time. Cross functional expertise without losing their in-depth expertise, if somebody is a scientist in the area of biotechnology and focusing on solving a code problem, that is important you don't turn them by that is a specialized area but then you do need practitioners who can take this cross function.

Dr. Susheela Venkataraman: You mentioned a while ago that the world is now turned upside down and in this scenario, if a young entrepreneur was starting off with an idea, how do they build change readiness into everything in that because you don't know hit us in March and no one knew the depth of it or the breadth of it or what was going to happen to it, we still don't know how long it is going to last for what is going to happen, it is given that scenario and the way you have given us examples of how organizations are changing looking at adjacencies and all the rest of it what is it that needs to go into the culture of start-up as it starts because it needs to be change ready and it needs to be agile. So what needs to happen and again what happens to management education in sense that the traditional notions that we have been trained about are those going to a undergo change.

Mr. Sudhir Sethi: I am not going to go into whether our education system is good or bad. I think it is reasonably good if it produced some of the best entrepreneurs in the world whether they are in the US or India, so that is a separate topic what should be done there but fundamentally there is enormous opportunity in the new model. There is enormous opportunity for excellent products, reasonably priced, very high quality, excellent services

which never existed before. There is a market now which never existed before called adwords that never existed before. It is important to answer and think what can I deliver at-home. Incidentally in every family budget there is a saving. I used to travel 20 days a month and every day for the last three months I have been thinking why the hell was I travelling 20 days a month when I can do all my work sitting at home may be go around and meet, may be one or two travel days a month. I think everybody is thinking the same thing. So people actually have more time today and again I am talking about people who have disposable income, as I said we are fortunate that we can do things like this, there is a large population whose needs have to be met, fundamentally needs have to be met in re-skilling, fundamentally needs have to be met in every employment, employment is no longer is a traditional one, there are so many arts/crafts, you can think of hundreds of things but disposable income in some sense in middle class households in the country has actually increased by the way because of expenditure on travel has gone down, expenditure on eating in restaurants have gone down, expenditure on many many things have gone down. There are expenditures like petrol, petrol prices have gone up but you don't travel that much overall, so think where surplus disposable income is there, what is absolutely essential to: (a) at home, (b) at business, how can technology be used and I keep hopping back on technology, even a conventional brick-and-mortar business today in my mind if it doesn't think of using technology, it's value proposition will go down. Asian Paints is a very good example. Asian Paints brought in an anti-bacterial paint a few months back, you must have seen the advertisements, that is use of technology. We are just about to fund a company in the space of producing colour from applying stress to bacteria. Now colour is all chemicals, colour is all vegetation harmful to the ecology. There are only three companies in the world who do this one in UK, one in France and one in India. That means there is a potential of a brand new product which is possibly a large company down the line that needs this capital. We are about to fund a company in the anti-bacterial catheter space. India consumes somewhere close to three crore catheters a year and how are they made, broadly they are in the lower end of the price range of Rs.150-200, latex comes in is extruded into a pipe and that is what a catheter looks like broadly. Hospitals are the biggest source of infections especially ICUs, catheters are the source of infections. So an anti-

bacterial catheter is possibly a large market. I think there is enormous amount of new thought which is already in the system and it is going to shoot up right now, because the demand for new products is shooting up right now.

Dr. Susheela Venkataraman: How does start-up think about building this agility into its DNA as it grows.

Mr. Sudhir Sethi: To my mind the start-up by definition is a young entrepreneur. It is already agile, the fact that we are seeing entrepreneurs between 24 to 28 years of age, it means that the part of the agility, innovation is already running in that person's mind, young at heart, fundamentally I am saying there is innovation to some extent the age group matters because there is no legacy, it doesn't mean that people who are older can't do this because there are sciences which we need research for 10-15 years, that is a separate issue, but the legacy part holds people back. Why is it that a software service company does not produce products? It is very very crucial that a software service company does not produce, it hasn't produced one for twenty years, why is it that the same person from a software service company comes out and then builds a product company because there is no legacy.

Mr. Saumil Majumdar: I have a whole set of questions of my own but I will probably request these for a coffee separately. I was going through the rest of the questions from audience, this is very fascinating so far, there are broadly two categories of questions, one category around sectors and investment areas, other category is around journeys. One immediate question was, you referred to a portfolio company which is a farmland satellite imagery company, somebody asked the name of the company.

Mr. Sudhir Sethi: It is CropIn.

Mr. Saumil Majumdar: Otherwise space and nuclear tech as an area especially given increased expected focus on localization, what is your view on that.

Mr. Sudhir Sethi: Space is extremely important, when I say pace I mean Avionics, anything which can fly, whether it is height of one meter, one km, thousand kms or somewhere close to the moon. The rub off effect of those is enormous and I do believe regulations need to change there. I will give you a very good example, India is producing entrepreneurs and we have seen so many of them. Some the best drones in the world but drones are permitted to fly across kilometres in uninhabited or rural areas, but in a city it is not. If plasma has to be delivered from one hospital to the other, nowadays traffic is not there, but if due to traffic the plasma delivery would take three hours where as the drone will take 20 minutes, why is the drone not allowed to fly in the city? I understand that the fear could be it falls of the cliff but you know drones are safe, it is a proven technology. By the way, there are many regulations which can come and say you need to have proven drones but today there are regulations which need to change rapidly, I think India has changed a few regulations not many where it allows space, India should be allowing entrepreneurs to build satellites, India should be allowing entrepreneurs to fly from India, should be allowing small rockets to be flown from India by the entrepreneurs, that is not there right now. That stranglehold must go.

Mr. Saumil Majumdar: Assuming the question is from somebody who is a potential entrepreneur looking at the Space, if I read your answer correctly unless the regulations get released the venture capital or the risk capital will still not come in, is that the right way of articulating it.

Mr. Sudhir Sethi: Yes, risk capital typically does not find it difficult to manage regulations. Risk capital and entrepreneurs can bring this in front of the government and change this. We were about to invest in a company in the Space segment and we had committed capital there, we could not because actually the entrepreneurs broke up the company and left the shores of the country. One of the things happening is many successful innovations because of regulatory and other reasons ship out themselves out of the country, it should not.

Mr. Saumil Majumdar: A related question is also around real estate technology, your view on that whole space.

Mr. Sudhir Sethi: I don't think I am an expert in that but look anything which can improve efficiencies in the market space, real estate is under deep stress right now. So effectively that sector one has to be very careful what to do with this.

Mr. Saumil Majumdar: What about MSMEs?

Mr. Sudhir Sethi: It all depends on what do you mean by MSME, if you go to the government, the traditional MSME is brick-and-mortar as such. Let us move away from the traditional word MSME because there are some definitions on how much revenue and so on and so forth. Any new company which delivers value and has the potential to deliver value in an innovative manner for the next 10 to15 years has enormous amount of potential to get funded especially if it has deep technology inside.

Mr. Saumil Majumdar: One of the questions was is there investment interest around companies that create jobs in rural or semi-urban areas.

Mr. Sudhir Sethi: There are impact funds in the country who do that and their goal is somewhat different from VCs like us here we measure impact, the fact that I gave examples of how much farm land for productivity we measure the impact because if you are solving a real problem using technology the other side of the point is, is it having impact or not. There are funds in the country many of them who actually go for employment provisioning companies.

Mr. Saumil Majumdar: One of the question was around sector-wise break up roughly of the 90 companies that have been funded by your company so far.

Mr. Sudhir Sethi: Consumer and Health form the two big sectors, almost the same as such and next would be software especially the SAAS Cloud Space, Fintech and Agritech.

Mr. Saumil Majumdar: Another question was, if I am an entrepreneur whose pre-revenue, how do I reach out, what kind of VCs look at pre-revenue, how often what kind, how do we reach out to them:

Mr. Sudhir Sethi: If you are pre-revenue, there is a very efficient agile system, there are angel networks across the country, there are organisations like Lets Venture who look at that, there are angel networks across the country. People like us also fund pre-revenue companies, it is not that we don't overall. Those are not constraints at all.

Mr. Saumil Majumdar: Let us move to the other questions in the question box around the journey aspect of this whole trading value. One question is: have you come across risk-averse entrepreneurs, where people do not want to take venture capital for scaling up and if so how did you convince them to take up risk capital.

Mr. Sudhir Sethi: Risk averse entrepreneur is an oxymoron. Every entrepreneur is taking risk, whether they are taking it from their own money or whether they are taking it from outside. Whether companies wish to take venture money or risk capital in any form, I think that is separate question altogether. At the end of the day, companies can be funded by customer revenue which means profits which is a slower process and alternately companies can be funded by external equity capital and over a period of time get replaced by customer capital. If it is funded by equity capital, the pace of growth has to be much faster and third party people coming on the Board, the decision making is jointly and at the end of the day a third party person coming on the Board. Many entrepreneurs may not like that, which is fine then they don't get risk capital to come in. Once risk capital come in, there is also the exit issue, many entrepreneurs do come back and say “I don't want to potentially sell my company, I

want to take it public but it may not be possible". So I think when VCs come in there is this element that VCs have to exit and entrepreneurs need to think about that. So I think our dialogue with entrepreneurs is very simple. It is an open dialogue in terms of what should be there or whether that funding can take place. I think in the technology space because those entrepreneurs don't actually have a legacy, they don't have parents running companies. They are all engineering, science, commerce, a lot of people who have got a different background and they are all first-time entrepreneurs. There is no legacy and they have also seen worldwide, whether in the Bay Area or other parts of the world that companies grow with risk capital. I don't think that is an issue at all running in their mind. Those kind of questions do come up in traditional legacy companies.

Dr. Susheela Venkataraman: Let us look at the third aspect we wanted to explore today which is collaboration. We have seen collaboration between older companies and new companies, collaboration between businesses and as start-ups and specialization and the time to market reduces you are going to see in specific organizations, obviously the need for collaboration and collaborative working is trying to increase a lot more than it was in the past. When you factor in the complexities of agility and the need to change depending on market forces, how do you see all of this panning and what would your advice to start-ups be.

Mr. Sudhir Sethi: Collaboration is the name of the game, collaboration in start-ups is actually much more for the simple reason that it is always good to have two brains doing the same thing and trying to succeed. Today collaboration possibilities have shot up, to give an example, there are many start-ups in the early days or maybe large start-ups so supply chain dependency on China is very very high. Not to move away from supply chain dependency on China requires collaboration and it also requires, let us say if a manufacturing unit in robotics has to move to India, there may not be that kind of complex robotic manufacturing units here but there may be start-ups who are doing this, who never thought of saying, "hay let me do it for another company, I will just do it for my own product". I think collaboration is shooting up right now, because it is a survival issue in the supply chain, in the whole area of

product discovery, in the whole area of marketing, in the whole space of product development, in fundamentally bouncing of ideas. I will give you a very interesting example which we saw. By the way, collaboration has also increased amongst VCs, I would say in the last three months it is more than what it used to be. It used to be pretty high but it has gone higher. When the lockdown was declared in the country on 22nd or 23rd of March, within about three weeks or so we organized a webinar for all our companies and there was a lot of interchange happening in terms of ideation how they are dealing with it but there were two classes of entrepreneurs there. One class of entrepreneur was a serial entrepreneur who were basically into the second and third stage or they had already built a company to a massive scale. Then there was the other entrepreneur who was just starting but there was a third category of entrepreneurs who did not believe that this pandemic will last long. So we saw enormous amount of opinions, there was a set of entrepreneurs who had already started taking action within the first seven days and in three weeks there was a set of entrepreneurs who had not taken action though a much smaller number, we could see their level rising now. Suddenly collaboration started, suddenly supply chains talking to each other for business started. Today many of our active 51-55 companies are buying and selling from each other. We have a company called Bizongo in the packaging space, it is the largest multi-category packager which is technology enabled in the country, it is a platform, they have delivered over 400 million pieces of packaging to the industry so far and they were supplying to CureFit as an example. So fundamentally they are now experts but suddenly they are now talking to many of our other companies and that has shot up in terms of collaboration. So it is a survival instinct, collaboration has to shoot up in these times.

Dr. Susheela Venkataraman: One other thing you mentioned about China and recently we have had a number of Chinese apps being banned here and obviously there is an opportunity somewhere with all of that, do you see it that way?

Mr. Sudhir Sethi: Whatever the reason the government had, I believe at least these 59 apps should have been banned a long time ago. I think it has created a space for Indian

entrepreneurs to bring out the me-too apps with some modifications which should have been done long time ago. Do understand that China has been practicing that no international apps coming to China for a long time which is why many of these things could grow and become world leaders and to that extent even I am not getting into the politics of it. I am fundamentally saying it has created enormous space for entrepreneurs to bring out innovations where consumers are within their country and then go global, there is no question about it and we are seeing that deal already.

Dr. Susheela Venkataraman: So you are saying that when there is a shortage of supply you will see entrepreneurs flocking and making a beeline to make sure that all of those needs are met and now we are used to certain kinds of apps so it makes a lot of sense. That brings me to the other big question that we have which is at some point of time, when we were talking about development challenges that India faces and how start-ups can actually meet a lot of those challenges and how they can address many of them and so Saumil you are also doing some of that work too. So what is your thought around that.

Mr. Sudhir Sethi: There is innovation happening in the start-up arena and that coupled with government deregulation is a very powerful and potent combination. We have seen it in the medical devices field, we have seen it in PPE, Ventilator manufacturers, that is the need of the hour, we have seen lot of entrepreneurs now starting to take advantage of this regulation which was there in the farm sector which said that farmers can sell only in their own State. It is ridiculous, so fundamentally in the space there are some announcement but I think there is no teeth to it overall in the defence area. Really really I am hoping at some point of time we see 400 to 500 LCAs flying. This would give enormous amount of boost to the defence supply chain industry which India has the capability. There are in the aerospace industry - Bangalore has over 100 start-ups right now over all and they need to scale. So this is the time to unleash that power because of entrepreneurs are already there and more are coming in, the regulative layer, we have to treat the regulatory layer as a 1991 crisis and remove that. It can't be in bits and pieces, other we would have lost this opportunity.

Dr. Susheela Venkataraman: The other aspect of this whole India and looking at problems for India is given India's diversity, given the complexity we often hear this and in fact Nandan Nilekani told us about how if we were to solve a really large problem for India, we are probably solving it for the whole world. So again what are some opportunities, specific opportunities that you see where start-ups can play .

Mr. Sudhir Sethi: Health, health is a very large opportunity, the fact is there are not enough audiometrics in the country, the fact is there are not enough ophthalmologists in the country, fundamentally not enough GPs. Please understand in the month of early April we found out from one of our company HealthPlix, 67% of doctors were sitting at home and not practicing. The number of doctors is not very high, so we have to be innovative in making sure that in the area of health, in the area of finance, anything; the world is wide and I am not getting in to sectors, if a large problem in agriculture is sorted out in India it is available to the world. CropIn is today managing territories in farms across developed world, forget Africa because that technology is relevant in that area. So anything which has a large impact as far as India is concerned in solving a challenge in any sector, in any field it is valid for the world because India has one peculiarity that it is a frugal country, it produces a solution at a cost effective rate and that when Indians go outside the country by the way increases the margin for the company. When an international company comes in to India it decreases the margin. It is important that that be recognized. Today Lenskart has a dominant market share in the country. An international company coming into India will face Lenskart, very difficult for an international company to be at that level of cost. I am not talking pricing by the way and first try it is a dominant company in the market, Policy Bazar, dominant in the market, if you look at Curefit, dominant in the market, if you look at Emotix or Playshifu, CropIn, I can give you a list of companies, these are reasonably large companies, them going to the outside world means increase in profit and I think entrepreneurs must understand that.

Dr. Susheela Venkataraman: Let us now take audience questions as we have only 20 minutes to go. Thanks very much Sudhir, we have talked through a number of issues around innovation and around the need for collaboration and there is no other way to be. That last bit was very inspirational for all of us I think in terms of saying that the opportunity is large and something that we do here can be extremely relevant in today's technology enabled world can be absolutely relevant for anywhere in the world and therefore thinking on global lines is going to be extremely important. Thank you for that and Saumil, over to you.

Mr. Sudhir Sethi: May I just mention one thing, I just saw a question in the chat session, I think it is very important to think that the hub of activities in India will no longer be the urban centres. The hub of activities can be the 100 odd cities or towns in the country distributed organizations will be the name of the game. It is not necessary to have one central office where people will converge everyday in the morning and go back in the evening, it is ok to have people sitting in 10 cities and working for the company which means you are now de-urbanizing the country, the moment you de-urbanize the country then fundamentally you have entrepreneurs in smaller terms.

Mr. Saumil Majumdar: Some more questions, there are sector related questions, there are journey related questions. One was around your views on opportunities in the smart irrigation and organic farming, you already referred to one of that as your CropIn, broadly that space your view on opportunities.

Mr. Sudhir Sethi: Look irrigation is a big area, for water there is a shortage in the country as such so fundamentally how to provision water, I know that the Deshpande Foundation is doing enormous work in Karnataka in terms of provisioning water in villages in the country but can that be scaled outside Karnataka and they have done a wonderful job. Technology, enablement of irrigation services is absolutely critical, there is no question about it overall. So in farms there is so much, right from warehousing management to supply chain to distribution chain, from farm to consumer, farm to retailer, I think the world is completely

open as far as the agricultural sector is concerned, right from the products not being sold, a tomato can be sold as ketchup and not just as tomato will have enormous value to the farm and enormous value to the company who does it, I mean that is a simple example of course.

Mr. Saumil Majumdar: There is one question which you addressed earlier which is around drone services and you have to answer that once the regulation part is covered, businesses around drones would be of interest.

Mr. Sudhir Sethi: I think India is falling behind the regulations around drones must be changed, I would encourage the government to change it in the next 90 days so that drone services can be available, I am not talking about Pizza deliveries. Fundamentally health is a massive need to provide health services, a patient needs a blood transfusion in Hubli and Hubli runs out of blood, it can be provided from Bangalore. It can be done by drones, long distance drones. To my mind, India should be having a web of drone services like we have a web of aircraft services across the nation.

Mr. Saumil Majumdar: One question which is familiar from your Wipro days, what innovations are you seeing in the software services space?

Mr. Sudhir Sethi: Software services are enabling more technology, there are sectors in which for instance if you look at these software services or if you look at the corporate, in the pandemic what has happened is the call centre business is shorter, the number of people who make calls to call centres is shot up and call centres are suddenly running out of people and call centre volumes have shot up by two or three times. We have a company called Uniform who enables call centres to take out massive volumes without adding people. So that is an example of a product or a service being embedded in the digital world.

Mr. Saumil Majumdar: What is the potential for green start-ups in India?

Mr. Sudhir Sethi: Let us call it fundamentally eco-friendly, is there an opportunity there, there has always been an opportunity there, that market of course is too expensive right now for the consumers. To my mind green products cannot be expensive, it cannot for the elite part of the middle class. If it is mass volume in the country and that is where I think the challenges lies.

Mr. Saumil Majumdar: Do you see the investment requirement as a cost game here on the green side?.

Mr Sudhir Sethi: It is a pricing game and a cost game, if I have to buy tomatoes at two to three times the price it will be only for a smaller market. Let me ask the question in a different way. Fundamentally Indian entrepreneurial companies in the last 10 years have serviced the top 100 to 250 million people. It is time now for entrepreneurial companies and it is going to happen by the way to service the next 400 million people or the next 500 million people. The next 400-500 million people will not have the same disposable income as the first 100 but they will want the same products. They will want the same services, the same quality, the same expectation of timing. How do you deliver what we have delivered in all aspects of products and services to the next 400 million people, that is the market in India.

Mr. Saumil Majumdar: Interesting, Let to come to some questions around the journey, on the whole entrepreneur to value creation, value capture. Lot of ventures have good initial success without funding or early customers but they don't scale up. In your view, what are the key things come in the way and what is your advice to people who might be hitting that problem?.

Mr. Sudhir Sethi: There could be many reasons. Capital is one of them. The ability of the entrepreneur to hire the right people is another one, because if a company wants to scale up, need to have very good people under you which again requires capital. There are many reasons, the market size all that is fine, whether the product is selling properly, assuming all

that is in order, the fundamental issue is under capitalization and under capitalization means dilution of equity. At the end of the many companies must think of that, am I in the business of creating a valuable large company or am I in the business of staying where I am and by the way there is nothing wrong or right, both are right, it depends on the DNA of the entrepreneur. There are many companies which VCs may see no returns coming in after investing but the entrepreneur says I want to run it for the next 10 years, perfectly fine.

Mr. Saumil Majumdar: How does the VC industry look at failure, how do they respond to it, how do you support entrepreneurs maybe in your portfolio or otherwise dealing with that if something is not working.

Mr. Sudhir Sethi: If something is not working, cut the rope very fast and start again. It is hard, it is easy for a VC to say that, it is very hard for the entrepreneur to do that. That is the best advice I can give because we don't want companies more than five years old because the half life of a product is six months now, things change, market change, consumer behaviours change, business behaviours change, new companies come up the same field within six months, so effectively if something doesn't work go to the next one.

Mr. Saumil Majumdar: If your entrepreneurs fail and come back to the VC world, how do you see them.

Mr. Sudhir Sethi: We see them very positively. Half of our entrepreneurs we have funded in the last few years is all serial entrepreneurs. It doesn't matter whether they failed or not, failure is not a taboo, failure is a big learning experience, in fact those unknowns will do very well because they know what not to do.

Mr. Saumil Majumdar: So all things being equal for the same idea, same everything else, would you prefer somebody who is failed earlier?

Mr. Sudhir Sethi: it is a hypothetical situation, there is nothing called the same idea. Serial entrepreneurs any day, these kinds of questions are nice to ask, I don't know the answer to that, fundamentally we like talking to serial entrepreneurs, we also like talking to younger entrepreneurs who have not had experience behind them because the kind of innovation which comes in is enormous and those entrepreneurs are in the age of, I mean the youngest entrepreneurs due to various reasons we could not fund was 19 years old and he still had to complete his college. It was a great product which he had, the youngest we have funded is 23 or 24 years old and there are many of them.

Mr. Saumil Majumdar: While people look at you as an investor, lot of my other VC friends reminded me that the VCs are also entrepreneurs. You as an entrepreneur have gone out and raised money and you are then deploying it and you are also an entrepreneur on your own right while you know there is an investor badge in front of you at all points. As an entrepreneur, you Sudhir Sethi as an entrepreneur had an idea today, what would you do?.

Mr. Sudhir Sethi: Number one, I call ourselves venturepreneurs. If I had an idea, it will be basically starting new funds over and over again and there have been different sectors all the time. By the way in the venture field, there are many innovative structures which come in to fund different kinds of entrepreneurs. India does not have an institution in the risk asset class, in the financial markets there is no institution of name in the risk asset class which is Indian in nature. Our goal is to fill that gap, we would like to be and we are already on our way to be the institution in the risk asset class in the country and that is something which makes us proud, to contribute cumulatively 1% of GDP value creation and 0.3% of GDP trust me it is a big motivator for all of us in the team.

Mr. Saumil Majumdar: Last question and this is about the name of your venture, people want to know the story behind the name of your venture.

Mr. Sudhir Sethi: The name of the venture is Chiratae. Chiratae is a Kannada word, it means the Leopard, we due to various reasons we had to change our name two and half years back so we said how do we change our name, three or four of us in the firm are wildlife photographers, me and my wife are wildlife photographers and amateur of course, so before any question comes into which camera I am using and what is the setting, no, no, no and at the end of the day if you look at the series of funds which we have named, we have named them Pandara, Panthera and this was Chiratae. It also gelled well because we believe the VCs should be risk takers, we believe in our firm being at the top of the ecosystem, nurturing the ecosystem as a leader and to that extent that is what the wild cat is all about, so that is how we named it.

Mr. Saumil Majumdar: I have been told I have chance for one last question, so I want to talk about the distinction between the value creation and value capture, I think a lot of value creation happens because of support from investors like you, entrepreneurs work on the idea and so on but value capture of getting an exit, listing and actually getting the money back to investors, to shareholders, to entrepreneurs hasn't happened as much as we would like it to. What do you think is holding that back.

Mr. Sudhir Sethi: I think that is not correct, the VC industry in the last five years has returned more capital than invested every year, I am talking about the venture industry. Effectively, there has been as we followed venture capital, venture value capture, there is no question about it. Today India is returning capital year by year.

Mr. Saumil Majumdar: Let me reword that question may be. At an aggregate level I am sure it is true but at a number of ventures level, percentage of ventures that actually return capital is lesser than where let us say where we would like it to be.

Mr. Sudhir Sethi: I don't have the numbers in front of me right now, but fundamentally it is not possible for every venture to return capital, it is not possible for every venture to be a

unicorn, there will be people who do ventures who do enormously well due to a host of reasons and there will be a lot of people who may not do enormously well in the context of a VC, but they are running very successful organisations and I think the definition of venture is capture not just exit, exit is of course a major and important one. Venture is also building a sustainable organisation, it could be a small organization, you are delivering enormous amount of value, your consumers and they cannot do without it. That is crucial, they cannot, the market dependence on a company is crucial to the entrepreneurial success.

Mr. Saumil Majumdar: On that word `Success', thank you so much, it has been a pleasure, over to you Anand.

Mr. Anand Talwai: Thank you Sudhir, thank you Saumil and also Susheela. Sudhir, it is a great insightful and wonderful session. I think you really brought in your last 20 years experience in this field, working with Indian entrepreneurs on the ground and in the context here and bringing up all the aspects of entrepreneurship and the importance of this capital in this field, I think that is a very good take away for all the start-ups in the group here and also in the sense that importance of technology in each of these things, anything you do, how do you build a technology enabled company or technology based company and build it big to solve Indian problems and that can grow a Google again, enormous opportunity up there I think and you brought in those aspects very well and what I found out and many of the feedback I am getting on that chat is also that you just did not like many people do predict the past into the future, you take the trends of past and say how what will happen next two years, three years and all that. You use this call it as an opportunity and how things are getting accelerated. What could have happened in five years may happen in six months, one year kind of thing, how lot of trends are getting accelerated, coming together kind of stuff and all that. I think you are giving importance to that, creating the future, visualizing the future in all sectors and characteristics are the same, whatever is the sector in terms of entrepreneurship and all that and bringing that to present moment and how to use this crisis to reach the future faster and go in a step-by-step approach. I think you brought that very well. There is also lot

of opportunities for the young entrepreneurs to go global, if you look our journeys in entrepreneurship for many of the entrepreneurs, so earlier experienced people working in industry coming out and starting companies and all that, then it started with people like Saumil and all. Now a lot of youngsters coming in, just out of college, out of incubation centres in the college in fact almost all the IITs run incubation centres, they promote a lot of start-ups and all that, I think you brought up opportunities for them in all the sunrise areas like farming, agriculture or aerospace, those kind of things and your importance of taking this regulatory thing as a crisis, that is a real thing actually, take out the bits and pieces, one shot take out all these impediments and allow entrepreneurs to grow, I think that will help a lot and again you can use this opportunity to see how it can be done. I think from our IITACB side, we will try to go to the government and with the importance of this much more stronger than what you are doing now and I think that is a very important step and also on getting the Indian capital into the system although in the earlier generation lot of VCs raise foreign funds and some money went back to other countries, now there is a lot of capital available in India in terms of family trusts, dividend payouts and all that and bringing that in, so really you are talking about big Indian technology based companies going global using Indian capital.

Mr. Sudhir Sethi: Absolutely, if I can just add on two more things, the birth of entrepreneurship is going to grow exponentially in the country, if I may take the liberty of suggesting anybody who is in college, please do your internships in entrepreneurial companies and not large companies, go to small companies, do your internship, it is a great way of a non-structured, entrepreneurship is what they don't teach you in college, number one and number two is I think India's opportunity is shot up because capital flows into China are reducing due to a host of reasons which all of us are familiar with which fundamentally means that capital flows into India logically should increase because it is the second largest contiguous market for entrepreneurs in the world after U.S. Effectively being a democracy, being transparent, very high forms of governance in the country and already a proven track record in venture industry that enables an entrepreneur to actually look at something which

they can build because a lot of capital flow into China should come into India, but obviously to deserving businesses.

Mr. Anand Talwai: That is a good point and your observation and operational excellence particularly both on efficiency front and effectiveness front and how that is, it was getting people who were doing something but again everything was done in delta, what you call incremental way, now everything is to be done in a much more disruptive way and I think that part has come out very well and also on the collaboration part even start-ups can play a big role in the value chain, there you can add value and in the value chain they can play a big role, that part has also come out very well. Thanks a lot, it was a very wonderful session and I think people have a lot of takeaways there for all the people around.

Mr. Sudhir Sethi: Thank you Anand, Susheela and Saumil for inviting me here. It has been a pleasure.

IIT ALUMNI CENTRE

saturday WEBINAR

FLEXIBLE ELECTRONICS AND THE FUTURE OF DEVICES

DR. SIDDHARTHA PANDA | JULY 18, 2020

Prof. Siddhartha Panda is a Professor of Chemical Engineering, and a participating faculty in the Materials Science Programme, and is currently the Coordinator (i.e. Head) of the National Centre for Flexible Electronics (NCFlexE), at IIT Kanpur.

His research focuses on chemical sensors for healthcare applications and the accompanying transport, reactions, transductions materials processing, and intelligence, utilizing flexible printable platforms.

Prior to joining IIT Kanpur in 2006, he was a Staff/Advisory Engineer at the IBM Semiconductor R&D Centre, New York, for over six years. He obtained a Ph.D. from the University of Houston in 1999, an M.S. from the University of Cincinnati in 1995 and a B.Tech. from IIT Kharagpur in 1992, all in Chemical Engineering.

Mr. Suraj Rengarajan is the CTO of Applied Materials India, based in Bangalore, India. He started his career in Applied Materials, Santa Clara in 1997, where he held different roles ranging from process engineering, program management, and product marketing in metallization, silicides and new memories.

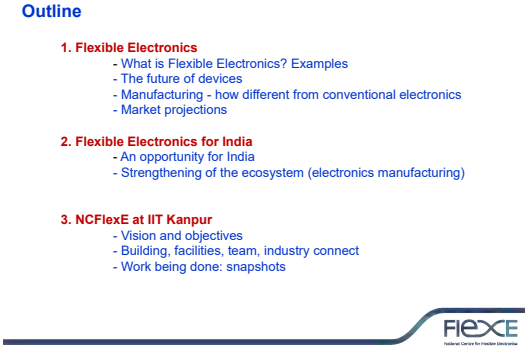
Lecture at IIT Alumni Centre, Bengaluru, by Prof. Siddhartha Panda, Head of the National Centre for Flexible Electronics (NCFlexE), at IIT Kanpur, July 18, 2020.

Link to the webinar : https://www.youtube.com/watch?v=_zufN6i-Nj8&list=PL0zMQ-70IHIX-df3u2Tto6dkKHCRC6iFL&index=15

Dr. Susheela Venkataraman: Good evening, welcome to today's webinar. Arthur C. Clarke said that any sufficiently advanced technology is indistinguishable from magic. Today we are going to hear about one such magical technology, Flexible Electronics. Speaking to us today is Prof. Siddhartha Panda, a Chemical Engineer who graduated from IIT Kharagpur, did his M.S. at the University of Cincinnati and his Ph.D. from the University of Houston all in the area of Chemical Engineering. He joined IIT Kanpur in 2006, before which he was with IBM's Semiconductor R&D in New York. His research is predominantly in chemical sensors for health care and in particular with flexible, printable platforms. He is currently the Head of the National Centre for Flexible Electronics at IIT Kanpur which has been set up with funding from the Government of India. Thank you very much for being here Siddharth and we really look forward to this talk. He is one of the foremost authorities on the subject in the country, so we couldn't ask for a better speaker in this area.

Moderating this discussion is Mr. Suraj Rengarajan, another alumnus of an IIT, he is from IIT Madras where he did his B.Tech. in Metallurgical Engineering, subsequently did his M.S. and Ph.D. in Materials Science from the University of Texas at Austin. He is one of those people who has spent an entire career in one organisation which is Applied Materials. He is currently heading an innovation centre where he and his team work in emerging areas that leverage the company's core competencies in materials engineering and thin film deposition techniques. He, like Prof. Panda has a number of patents and publications to his credit. Thank you very much for being here Suraj, I really appreciate your taking this up. We also have Mr. Ashok Kamath who will also be moderating this discussion together with us and he will be summing up at the end as well. Over to you Siddhartha.

Prof. Siddhartha Panda: Thank you Susheela for the kind introduction and I would like to thank IIT Alumni Centre, Bengaluru for this invitation and the opportunity to present my lecture. As I am sharing this screen, I would like to extend a very good evening to all the audience, from the IIT Kanpur campus and I am going to talk about Flexible Electronics and the Future of Devices. I am going to break this presentation in to three sections, first I am going to talk about flexible electronics and give some examples of what do we mean by flexible electronics and give a glimpse of what the future devices could be and then I am going to briefly mention how the manufacturing paradigm of flexible electronics is different from that of conventional electronics and then give some market projections. In the second part of the talk, I will make a case for flexible electronics for India and show how this is an opportunity for India to become a leader to play a role as a leading manufacturer in this field and also mention how the current steps for strengthening the ecosystem in manufacturing also bode well for the field of flexible electronics. Let me then take a small break here for about 7-10 minutes and take some questions and then I am going to wind up with the last part of the talk which will be on the work that is going on at the National



Centre for Flexible Electronics at IIT Kanpur, where I will mention about the vision and objectives of our centre. I will talk about what we have done so far, coming up the state of the art building and facilities, putting together a team having the interesting connect and having the project started and completed and give a few snapshots of the work which have been done. So let me start with the first part of the talk which is Flexible Electronics.

Now the word itself, flexible electronics what it indicates is that we will have electronic circuits on flexible substrates and here is a picture which gives an example. What does it enable? It enables making them bendable and stretchable and that opens up different applications, this opens different product paradigms which are not possible with conventional semiconductor glass substrates. There are several attributes to this flexible electronics devices and some of them are listed here. These are flexible and stretchable, these are light weight, they have a possible cost advantage and they are rugged in the sense that like one that the packaging and other applications may not be as stringent and all these things add up to give a strong indication that the field of flexible electronics has the potential to revolutionize the electronics industry. In the next few slides I am going to present some of these examples of flexible electronics as we see in the industry today. The first is flexible displays and these

Flexible Displays

https://www.androidauthority.com/best-foldable-phones-922793/

https://www.flexenable.com/technology/flexible-olcd/

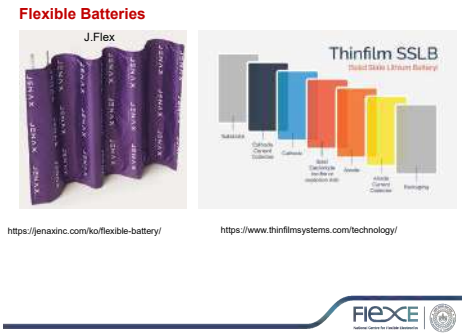
https://www.cnet.com/news/lgs-rollable-oled-tv-is-incredible-and-its-actually-going-on-sale-in-2019-ces/

are examples of OLED based smart phones and these being shown are from Samsung and Motorola and here is an example of organic LCDs as a bendable display and here is an example of rollable OLED TVs from LG and in fact about a few years ago this was considered to be a futuristic technology and last year this has been demonstrated. Then we have flexible lighting and what we see here are examples of this OLED based panels which are made by LG and there are several other applications for these. Another area where flexible electronics has made its mark is this flexible solar cells, what we see here are the organic photovoltaic solar tapes and organic photovoltaics are the third generation of technologies.

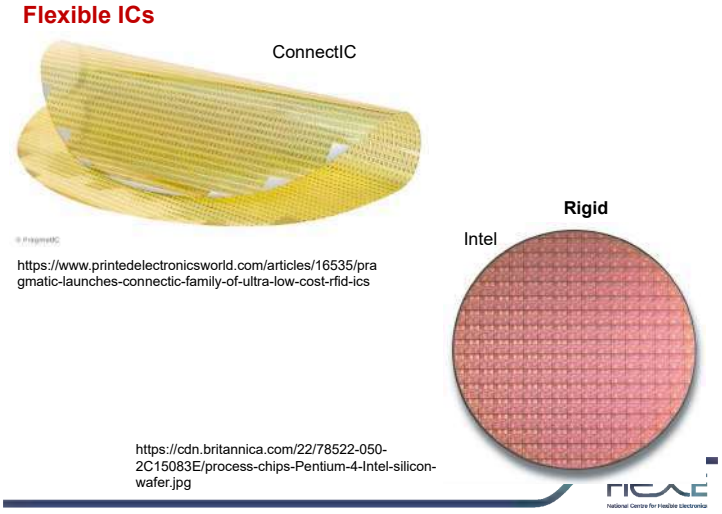
Flexible Lighting

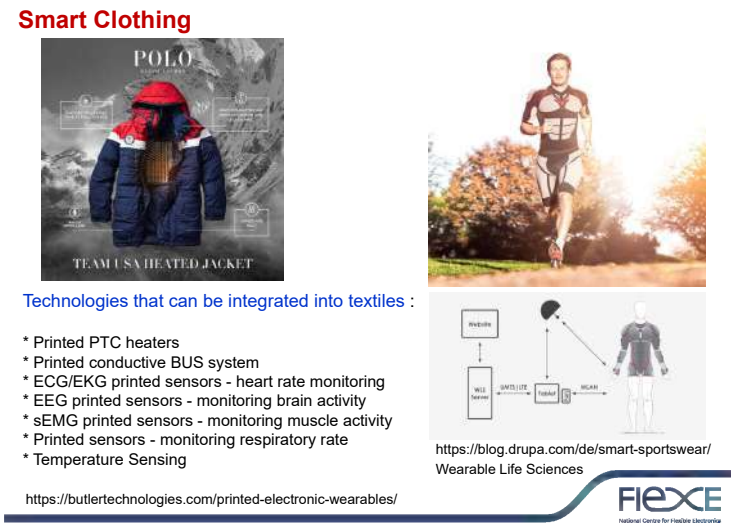
Lighting products with various types of OLED panels provided by LG Display

http://www.lgdisplay.com/eng/product/oled_light.jsp



So if we see these kind of tapes out there and they can be put in and can wrapped around different materials, different shapes and that also enhances its ability to be used in different places. Then we have got flexible batteries, these are examples of lithium ion batteries, typically these are polymer layers and again these flexibilities of these batteries enable them to be used in a large number of applications and devices. Then we have flexible ICs, this is something we are very familiar with, people in semiconductor industry are very familiar with. And here these are the different chips and these are diced and that they are used for different applications but now what we have is these ICs now are made of flexible substrates and these will be diced and being used for different applications. Then we have smart clothing. So, flexible electronics provides the capability of giving additional functionality to clothing and thus making them smart, so there can be different categories of smartness



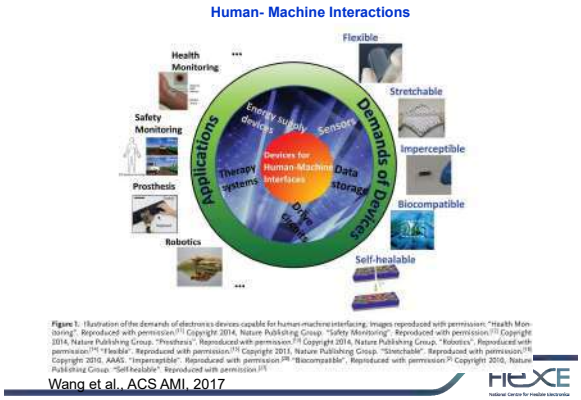


one that could be passive smart in the sense that the clothing has devices by which it is able to collect the information of the surroundings, it can become active smart in the sense that in additional to collecting information from the surroundings it is able to react in a limited way then you can have ultra-smart clothing that in addition to that it can adapt itself to the surroundings. Here is an example of a heated jacket which is used by the US Winter Olympic team and there are many more capabilities which can now be added to these kinds of clothing, for example in addition to having these safe heaters one can have a different kind of sensors, for example one can have these ECG sensors for heart rate monitoring, EEG sensors for monitoring the brain activity, EMG sensors for watching muscle activity, respiratory rate efficiency and temperature sensing and so on. So keeping this in mind that there are several companies who have already started working on it and here is one example where these sensors have now been embedded in this clothing and from this one can get the information about the physiological conditions of a person. As of now the focus has been mainly on wellness and sports activities but this has the option of opening it up also for healthcare management.

Next we look at flexible sensors. When we talk of sensor, there are so many kinds of sensors and in this presentation I am just giving a snapshot overview of a few of them. These are pressure sensors and these have multifarious uses. If you look at these kind of pressure sensors, these can also be folded or can take the body of interest and here is an example of a seat where this can measure or map out the body pressure and can utilize for getting ergonomic seating conditions and here is an example of designing grippers and here is an example where it can be used for arthritis testing. Here is another example that can be used for this plastic tummy and so on and so forth. Here is a picture of this unique sensors and an application of this image synthesis as a security feature in smart phones. Here is a picture of a flexible temperature sensors and this again has multifarious applications. Then we look at flexible RFIDs and this is a picture of a tag and this tag can be utilized as symbol in different packages so what it does is this flexible RFIDs enables to track and trace the different objects and also make

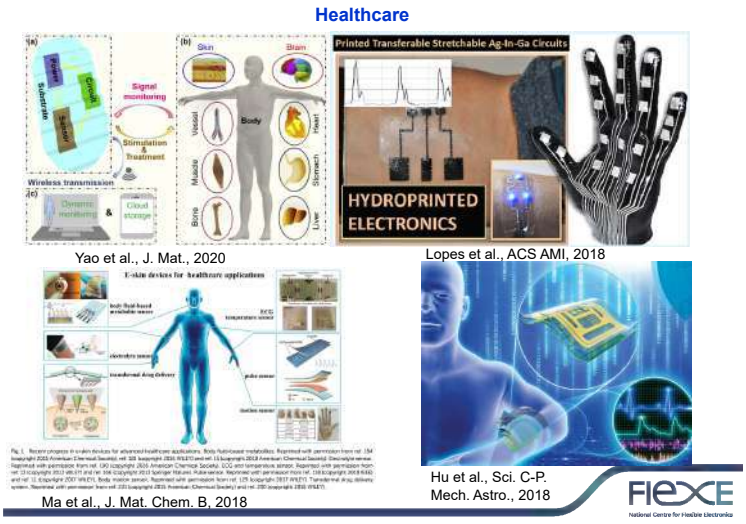
them interactive. In addition to this having interactive packaging, this RFID also has uses in the field of pathology and something which could be very pertinent for the conditions which are existing now, for example, when there is a huge load of the samples to be tested and then these processors can help in tracking the samples and consumables so that all these things will happen in this manner.

Now let us look at the future. What was considered a futuristic technology a few years ago is becoming a reality today, again these are some snapshots of the future of the futuristic devices what people have envisioned as a good possibility. Some of them are going to be reality in the next few years. So what I have taken are three examples and one such example is that of sustainable cities. This is the picture of a building and let us imagine that this building is covered with flexible solar cells, not only walls but also windows and the window curtains so they can now utilize the sunlight coming in and utilize this to power the buildings. Another work which is going on is coating the window panes with certain molecules that they absorb the sunlight, store it and then they raise the energy at a later time so that one can distribute the energy and once that energy is taken up from the natural system like



Wang et al., ACS AMI, 2017

the sun that can be utilized for lighting of these buildings and the city. Another area where flexible electronics has a huge potential to play is in this IoT, Internet of Things that requires a large number of sensors and flexible electronics and has the capability of providing a large number of various kinds of sensors and this can be used for the management of cities for example for its emergency services, for transport, for health, environment and many more. Another topic of the future is the human machine interactions. Now what if electronic devices can be compatible with human tissues; if that would happen that would open the door for several applications in health monitoring, safety monitoring processes, robotics and so on but in order to do that there are several demands on these devices which include the device being flexible, stretchable, imperceptible as one does not want to feel that this is something which is an external foreign body which is there, they have to be biocompatible and self-healable that if something happens to your device that it should have self-capabilities and these flexible electronics based demands have indeed



Yao et al., J. Mat., 2020

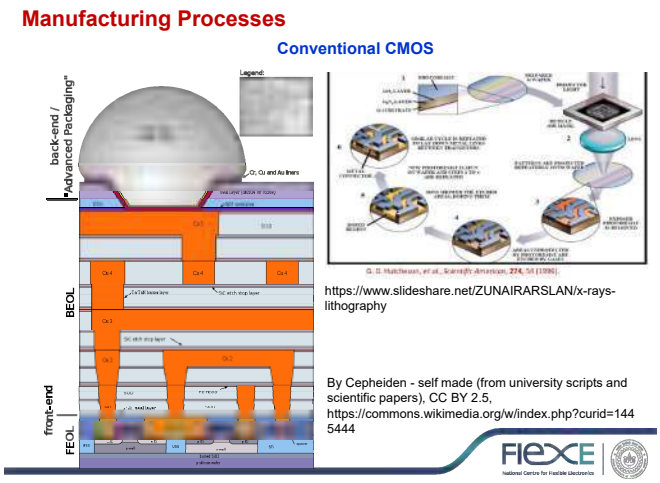
Lopes et al., ACS AMI, 2018

Ma et al., J. Mat. Chem. B, 2018

Hu et al., Sci. C-P. Mech. Astro., 2018

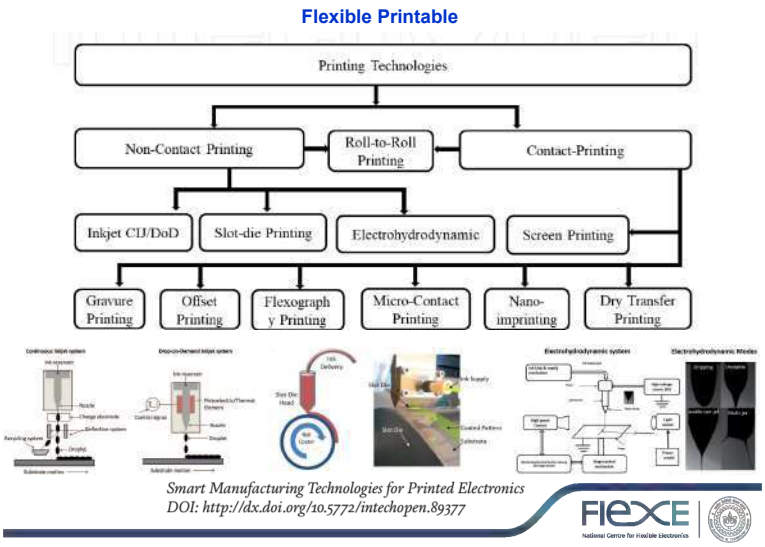
shown these characteristics. Of course, there are challenges but that is what research is for and there are researchers who are working in this area and there is hope that we will be able to see many more deep human machine interactions be possible because of this industry of electronics. Just to go a little bit deeper into health monitoring, let us look at the next slide.

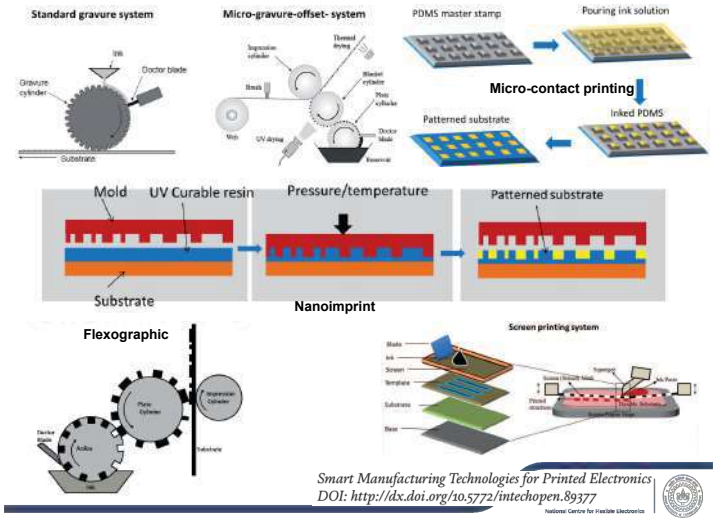
Let us see this is the human body and here are the different parts like the bones, muscles, vessels, stomach and so on. These emit certain signals and these signals can be monitored by these devices which are in/on the human body, say the human skin and these collect the signals and then get transmitted and then there is a analysis of the signals and on the basis of that one can get the understanding of what is happening in the human body. At the same time, signals can be fed back and then also there can be devices which can be utilized for stimulation as well as treatment of some of these features. So again, going a little bit deeper into this electronic skin, what we see here are more specifics like having a body fluid based metabolic sensor and electrolyte sensor and an ECG and temperature sensor and so on and then taking these information and having an actuation. And here is an example of a printed electrode on a human skin and what it does - it measures the signals from the muscles and so on and so currently there is research going on in many of these areas and we can expect to see developments in the coming months. So having looked at these different features of what the futuristic devices could have a promise, now let us look at the manufacturing process of flexible electronics and let us see how this is different from that of conventional electronics. In this slide, I show the typical process of conventional electronics which is seen out here, for



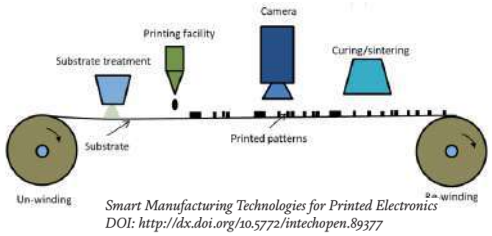
example like these are several unit processes which are involved in the manufacturing of conventional electronic products, for example we have this wafer treatment, thermal oxidation, lithography, doping, chemical vapour deposition, metallization, etching and so on and these processes are used to build these chips and this shows the cross-section, a typical cross section of our typical CMOS chip. And here what we see are the transistors and then there are the different stacks and these are the front end applications, the back-end applications and this is the packaging and this is what are typically what we see in a typical IC module and these are the typical processes. As far as flexible electronics are concerned and especially with fixed printable electronics the processes are different. So when we talk of flexible printable electronics what we have is we print the different circuits just as we print, say our paper using a regular printer and that is the philosophy of it. In a regular printer we have ink which could be of different colours, we have a colour printer and we gave a command and then what happens is that different features, different shapes get printed on our particular paper and we obtain other desired shapes on the paper which could be a regular or of any shape. So now similarly can we print circuits on substrates and that is what we have in this flexible printable platform? So what we have is that we have got different printing technologies which could be non-contact printing or could be contact printing and among non-contact printing there are

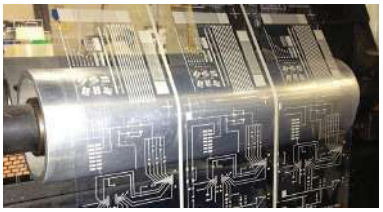
different kinds of classes of non-content printing there are different kinds of classes of content printing and we will briefly go over some of them. As far as non-contact printing techniques are concerned one of them is the injector printing mode which could be continuous or could be a drop on demand, we also have a slot dye and we also have this electro hydrodynamic system and so on. As far as contact printing is concerned, they are again of different types, for example in the standard gravure system, we also have this gravure micro dragon offset, then the micro contact printing, nano imprint, flexographic, screen printing and all of them have different principles behind this and that is for the nature of the ink. For example, if you want a print the ink also has different properties for example a different density, viscosity and so on and hence one ink cannot be printed for any kind of using any chemical system and there are many different kinds of systems. So what we have seen here are typically what we call sheet-to-sheet printing, essentially we take a sheet and printer but also what we can have here is a roll-to-roll just like a newspaper is printed we can also print devices that way, so what we have is this substrate and the substrate could be that typically it is plastic but it could be paper, it could be cloth. And what we have here is that as a substrate it has been in unwinded rolls



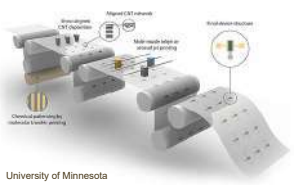


then has a substrate treatment, then the printing which happens and then we have a visual inspection of the printed patterns and if any intervention is needed, curing, centering and so on. Here is a photograph of one such process and later in the presentation I will show a brief video clip of one of such a printing process from the roll-to-roll venture we have in our centre and this schematic again there is a little bit more details about how this printing is done. Now let us look at a different paradigm which is posed by this platform of flexible electronics. This is the schematic of a transistor so we have got a channel, we have got a dielectric, we have the gate material, the source and the drain and in a conventional electronics typically these electrodes are two silicon, they are dielectric typically silicon dioxide or some other dielectric and active channels is primarily a silicon. As we move from rigid transistors to soft transistors which could be

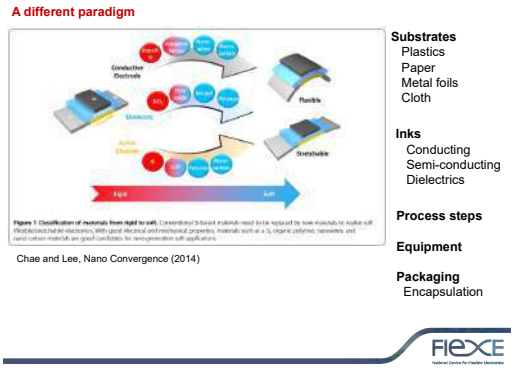




https://www.printedelectronicsnow.com/equipment/manufacturing-equipment/

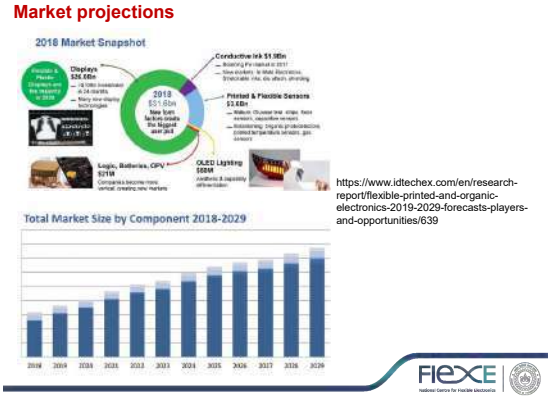


University of Minnesota



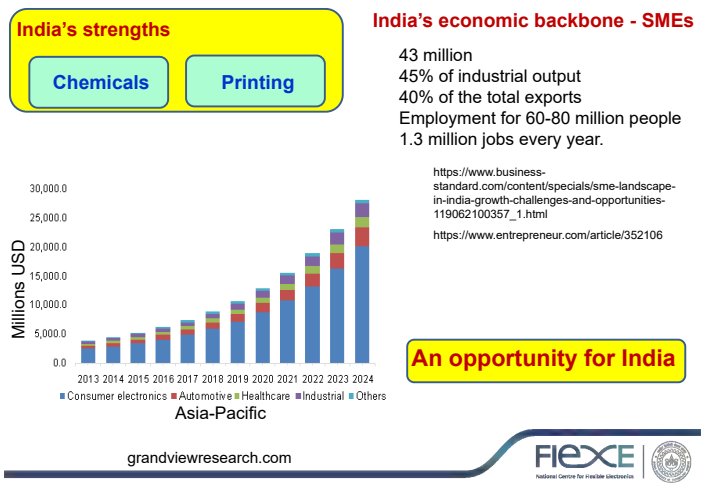
either flexible or stretchable what happens? We are again use different materials, so what this shows is that we now need different conducting symmetry and dielectric materials in order to dispense them. These materials have to be in form. Now once we have in form then what we do is these inks have to be again compatible with the different substrates and the substrates with the plastic paper, metal foils or cloth and again as we saw earlier the possible steps are different and again process optimization and process development needs to happen and then again these have got different effects - primary equipment and then ancillary equipment and again this requires an encapsulation and packaging is different from that which is used for convection. So the manufacturing of this print, flexible printable electronics is different from that of conventional electronics but at the same time what I would like to say is that when we look at the different materials, there is again a large scope of lowering the cost of the materials because of the proper nature of processes which are involved and could talk a little bit about that in the subsequent sectors.

Now let us look at the market projections. The 2018 market projection, it was projected around $31 billion and primarily they were in different segments for example the segment of these displays which were

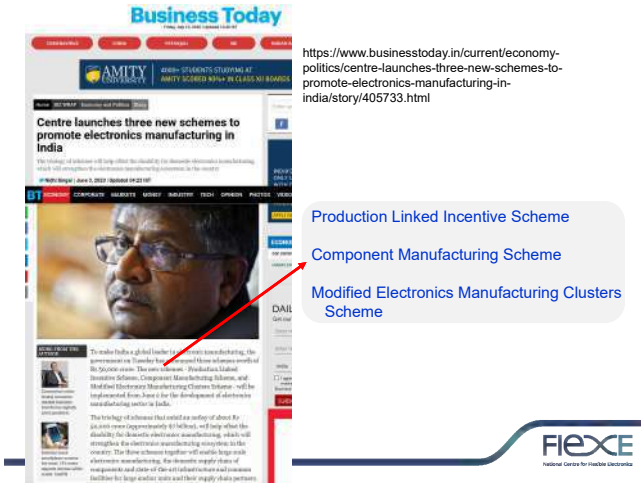


the main divers of this flexible principle of printable electronic devices, then we had the logic and package OPV and then we had OLED lighting, we had printed flexible sensors and then it is connecting and then this market is projected to grow and what we see here is a projection of flexible electronics market and this is in billions of US dollars and each bar is representing about 10 billion US dollars, so in 2018 we were about 30 and by the time we reached 2020 it is expected to reach 87 billion US dollars. So having said that this is a very favourable market projection for the speed of flexible electronics the world over. I have completed the first part by talking about the market projection and then make a case for the flexible electronics for India.

There have been discussions that India has missed the bus as far conventional electronics have been concerned and again the setting of these apps have been a challenge because these are very capital intensive but then let us look at one of the advantages which India has. As we have seen earlier, flexible electronics involves flexible printable electronics involves printing of materials onto flexible substrates and these are the strengths of here in chemicals and printing. India is number six in the world as far as production of chemicals are concerned, number three in Asia after Japan and China. India is number four in the world as far as the printing industry is concerned, so there are anyway some important strings as far as printing and chemicals are concerned. As of now we do not have electronic materials but at least the platform and as I mentioned setting up of typical semiconductor fab is expensive and if I give numbers based on my recollection, it was around 2009, it was estimated that setting up of a single fab was costing around Rs.25000 crores and that was the number upto 2009. Now this possibly has been a road block or



has been a predictor and for setting up the manufacturing facility out here but what we see in India is the backbone of Indian economies are these SMEs. We have 43 million of them which contribute to 45% of the industrial output, contribute to 40% of the total exports and they have provided an employment of about 60 to 80 million people a year and generate about 1.3 million jobs every year. So the belief is that these SMEs perhaps because of the lower capex involved in the SMEs perhaps would be able to absorb this technology and set them up and again if you look at the market for the Asia-Pacific sector for this flexible printed electronics again we see that we have an opportunity to grow and hence by taking the advantages of the platform which we have in chemicals and printing and that we do not need such a high capex. This gives an opportunity for India to seize the opportunities which are there and become a contributor and not just a contributor but as a leader as far as manufacturing of flexible electronics is concerned. While we are talking of these inference strengths, let us look at some of the things which have been happening recently and I have a snapshot of a newspaper, Business Today of June 3rd, 2020 and what it mentions here is that the Government of India through the Ministry of Electronics and Information Technology has announced these schemes, the production linked incentive scheme, component manufacturing Scheme and



https://www.businesstoday.in/current/economy-politics/centre-launches-three-new-schemes-to-promote-electronics-manufacturing-in-india/story/405733.html

modified electronics manufacturing clusters scheme, totalling to about Rs.50,000 crores and that is to strengthen the electronic manufacturing ecosystem and when this electronic manufacturing ecosystem in the country is strengthened, the field of flexible electrons will indeed benefit from that. Also what we are seeing is the response from the global industrial players and this is a snapshot from a newspaper taken on July 9, 2020 and Samsung has mentioned that it just started manufacturing smart watches in India and developed the facility as a part of its Make in India efforts. This seems to indicate a very positive theme for electronics manufacturing and further strengthening the ecosystem and all these bode well for India to take up the manufacturing of flexible electronics and possibly become a leader. So here having completed the second part of the presentation, we can take a break and answer a few questions.

https://economictimes.indiatimes.com/tech/hardware/samsung-starts-manufacturing-smartwatches-in-india/printarticle/76872729.cms

Dr. Suraj Rengarajan: Thanks Prof. Panda for lot of interesting data points and perspective on flexible electronics, there are more than 20 questions at this point, I will bring up few of them and some for the end of the discussion. Also just to give some perspective, our company is working with Prof. Panda and the NCFLexE on some of the areas that he had indicated, display sensors and all that. So one of the questions was, are there collaboration opportunities possible with the Centre, of course there are and the next section will cover those collaboration of opportunities. There were a couple of broad areas, one I think everyone was interested in the clothing example that you gave and there were lots of questions on how do you do this printing on textiles and can you then wash it and how does electronics survive that wash, recyclability and things like that, so maybe you can address all of those together an then later may be you can address the very specific questions. General thing was with respect to clothing, printing and recyclability when you talk about flexible electronics inside clothing.

Prof. Siddhartha Panda: When you talk of clothing yes, maybe I can elaborate on that. When we have clothing either we can have discreet devices or we can print them. Now we can print the clothes or we can use conductive yarn to make different kind of devices, so all these things are being worked on and then again in our Centre we have got programmes where we are printing on textiles and one such application is to make these textiles for EMI shielding. Now coming back to washability, yes obviously that is where the research is needed because now when we have an application that we want to put this devices, print them on clothes and these have to be washed and have to withstand the standard wear and tear that is where the research comes in and that is something where the players in this area

are indeed working on it and that is where they are developing appropriate materials and developing appropriate technologies which can withstand these kind of things. Of course there many more things which we can discuss perhaps more in detail once the third part is over, lot more things will become clear when we present the third part. As far as recyclability is concerned, yes e-waste is indeed a challenge not only for flexible electronics but also for our conventional electronics and there are indeed programmes and there are research activities where we can convert this waste to wealth, more specifically for the Indian condition, we do not have organized sectors where we are extracting the useful materials from the e-waste and again there are lot of discussions which are happening and there are lot of activities which are being planned how this e-waste is to be handled. Again this is not only for flexible electronics, it holds for the entire field of electronics. Again let me add one of the things about flexible electronics is that one can again use substrates which are more environment friendly - for example, people are indeed working on this degradable paper. People are also working on this degradable plastics, so research is going on this area how to address this problem.

Dr. Suraj Rengarajan: You addressed the question about the conductive inks that are used and one of the questions was when you finally recycle all this will enter into the water and things like that, so is that being considered, are the ink that are being used environmental friendly and things like that? So the entire supply chain, all the cycle on how this is built is recyclability being considered during the entire process. That was one of the questions.

Prof. Siddhartha Panda: When we look at the functionality of our devices, right now our concern is not functionality, now obviously once the lifetime of the device is over then it is to be processed or the way the material is going to be recycled but that is a different sector. So as of now to address a very specific question, in fact what I will show in the next part of the presentation that is one device for example organic photovoltaics. This is now being done on paper and that is taking into consideration that this is going to be relatively more environment friendly. Indeed those things are being taken into account but we don't have all the solutions as of now but again these things have to go in parallel like we have to go ahead with the devices trying to look in to the functionality while looking into the recyclability and other aspects.

Dr. Suraj Rengarajan: One of the things that set off some alarm bells by people was when you started putting these into the body, I think people are now getting a little bit worried, can they hack into that and things like that and how biocompatible these materials are with the body and things like that. There were a few questions related to how electronics compatibility with the body have you done testing and do you know?

Prof. Siddhartha Panda: Let us move away from flexible electronics, let us look at some other implants. Right now we have pacemakers put inside the body which is an accepted technology, putting titanium implants in the bones which is also an accepted technology, again these required a reasonable R&D to find out whether these could be implanted in the body or not. R&D is going on and obviously there will be stringent tests before anything can become a mainstream technology, so that is one aspect of it, the second aspect is can it be hacked or not, yes indeed that

is a concern because whenever you have an electronic device there is always potential of hacking. At the same time all these things have this end-to-end encryption, so whatever encryption technologies we have for other systems also have to be utilized for these systems and again there are different protocols which have to come up here too before this become fully mainstream.

Dr. Suraj Rengarajan: Then there seems to be a lot of questions on the VLSI portion and the electronic portions, maybe you can help to clarify that, there was some question on what generation technology it is, can you use VLSI electronics into this and all that. Maybe you can clarify the electronics goes on flexible substrate and at this point we are not doing cutting edge electronics on this because we are using printed methods, may be that is a portion that you can address:

Prof. Siddhartha Panda: Flexible Electronics as of today cannot match conventional electronics when it comes to complexity - flexible electronics is not competing with conventional electronics. We start to complement conventional electronics in areas that perhaps conventional electronics cannot find solutions. So we are not looking at competition as of now, we are looking more at it as a complementary technology so that it can further enrich the offerings which electronics devices have.

Dr. Suraj Rengarajan: There was a series of questions how these are powered because the way that you described all of these, it looks like they are almost stand alone, the questions was how do they get their power, just like any other electronics you have to have a source of power. The other thing is that in your application pie chart, flexible batteries are going to be a big part of how flexible electronics also

enters into the main stream. Smart watches right now are a growing segment, actually the latest data shows that Apple watch is going to sell more than all the Swiss watch industry put together, so powering of those watches, if your band can be a battery, that in itself can be a huge market. So I see flexible batteries becoming a big portion of how flexible electronics makes it into main stream. May be that is one area that you can expand on the flexible batteries part. Is the Centre doing anything and there was a question on collaboration in that area.

Prof. Siddhartha Panda: Yes, as of now we have a small programme on flexible batteries, it is not mainstream yet but if people are interested, we will be very happy to talk to them and we can talk about modes of engagement offline.

Dr. Suraj Rengarajan: The last question in this session is the question on Space, are we using any of these in Space applications and things like that:

Prof. Siddhartha Panda: The answer is yes, our Centre has projects with ISRO which will have applications for Space but for reasons we will not be able to elaborate it here.

Dr. Suraj Rengarajan: So now let us go to the second part of the presentation. Audience, please continue to put in your questions, and we will take up and discuss them as we close the session. Over to you again, Prof. Panda.

Prof. Siddhartha Panda: In the final part of the presentation, I will tell you about our Centre, the National Centre for Flexible Electronics (NCFlexE) at IIT Kanpur. This

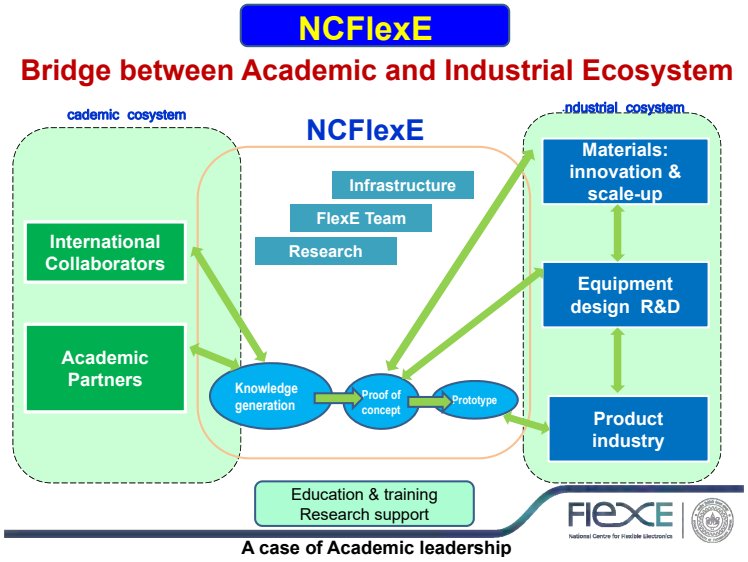
Centre was set up in November, 2014 with a grant from the Ministry of Electronics and Information Technology and support from IIT Kanpur and the vision of this Centre is to conduct R&D in the large area of flexible electronics so that it helps to catalyze the development of domestic industry in this case. So what I would like to emphasize is that the Vision Statement of the Centre has the word Industry in it. The Vision is: "Conduct research and development in large area flexible electronics that serves as a foundation for development of domestic industry in this field".

In order to realize its vision, there are several objectives:

- R&D: in the field of large area flexible electronics;
- Manufacturing: Partnership with industry leading to manufacturing;
- Ecosystem: Facilitate formation of industrial ecosystem;
- Entrepreneurship: Incubate small scale industry;
- International Partnerships: Build strategic partnerships;
- Human Resources: Skill development.

Let me elaborate on some of these. We do not have the basics of a flexible layer. As a country what we have is that we have got capabilities for example we have got the materials industry, we have got the printing industry as I mentioned in the previous slide but as far as production of chemicals are concerned we hardly have any production as far as electronic materials are concerned. While we are number four in the world as far as printing is concerned, there is hardly any contribution as far as printing of electronic materials are concerned. The questions is, can we have the materials sector, chemicals sector for electronic materials or electronic chemicals, can we have the printing sectors move towards or open up their facilities or invest or go into electronic systems. Even if these two sectors come together, we also need the equipment sector, because we need specific equipment for them. How do we get all these people together, how to get all these sectors together that is something which we want to catalyze. Another objective is to have entrepreneurship and incubate small scale industry as I mentioned, unlike conventional electronics which is highly capex intensive, when come to flexible electronics, it is not which means that there are several technologies which now can be taken over and we can start companies, incubating these technologies and eventually hopefully they grow. Another objective is to

have national/international partnership because we realize that one centre will not have the capability to have all the technology components and hence strategic partnerships critical and finally human resource development. We have to develop the human resources needed to support the hopefully growing domestic industry.

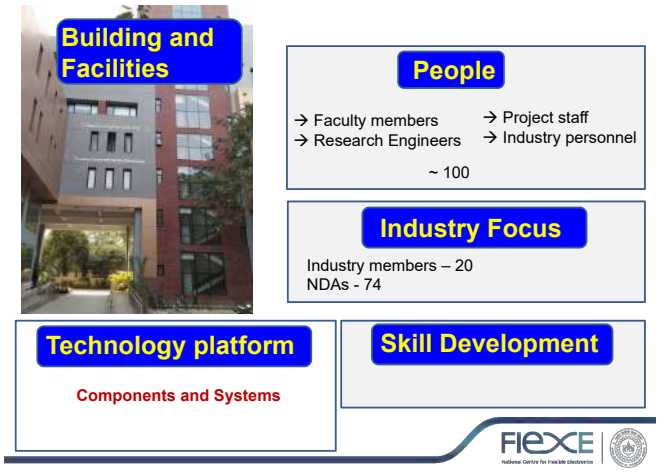


Next slide tells us about the philosophy of this Centre. This centre serves as a bridge between the academic ecosystem and the industry. We have the academic ecosystem and there are a lot of ideas, some of them are very futuristic which come out from this academic ecosystem, sometimes this idea remains simply as you know what just a proof of simple demonstration on a lab scale and because of some lack of enablers they are not able to reach the industrial ecosystem and the role of this centre is to provide these enablers or provide a bridge between these two ecosystems. In academic ecosystems primarily many of these ideas which are generated are taken up by the team here and as these are taken up we march along the technology readiness levels and go beyond the proofs-of-concept and make a prototype so that it becomes easier for the industry to accept it. Now, in the industrial ecosystem there are different segments, there is a material segment, the equipment, a design R&D segment, the product industry

segment and we have a strong interaction with the industry and our preferred mode of interaction or engagement is the core development mode, that is we have an idea and we have the industry join hands, but together we take this up along the different steps along the technology levels so that we minimize the time and we minimize the uncertainty as we go towards commercialization. When it comes to electronics what is state-of-the-art today is going to become obsolete tomorrow and time is an essential factor and working in the industry and the rationale for working in the industry is that we cut down on the time and hopefully we can move to commercialization as soon as possible. While doing that we also provide education, training and support, research support comes to the team here so we are generating a trained manpower which can now support the industry and what I would like to say is that this is a case of an academic leadership.

Now let me tell you what is that we do in our sector. In the first half of the presentation, I showed you pictures, examples of flexible electronics which are taken from what is happening across the world. We have seen a folded cell phone, a rollable TV, some exotic lighting but what we are focusing on our centre is trying to address the unmet technological needs of our country. What are some of these unmet technological needs? Here we see is a picture of some medicines – tablets. It is estimated that a reasonably large fraction of the medicines which are sold are

counterfeit. Now what we had in our centre developed is anti-counterfeiting technologies. Another specific problem from India is to provide accessible and affordable health care and more importantly diagnostic point of care that is something which we are working on. Another problem of India is food adulteration and again we are working on systems how to detect this adulteration of food, again a part of our country which are still off-grid, can we provide energy to those parts of the country at the same time there are also several components which need a degeneration because we are importing them, can we now come up with processes which can be taken up by the companies and have the intervention. At the same time can we come up with educational kits so that education reaches the remaining fraction of population. These are some of the activities we are taking up in our centre.



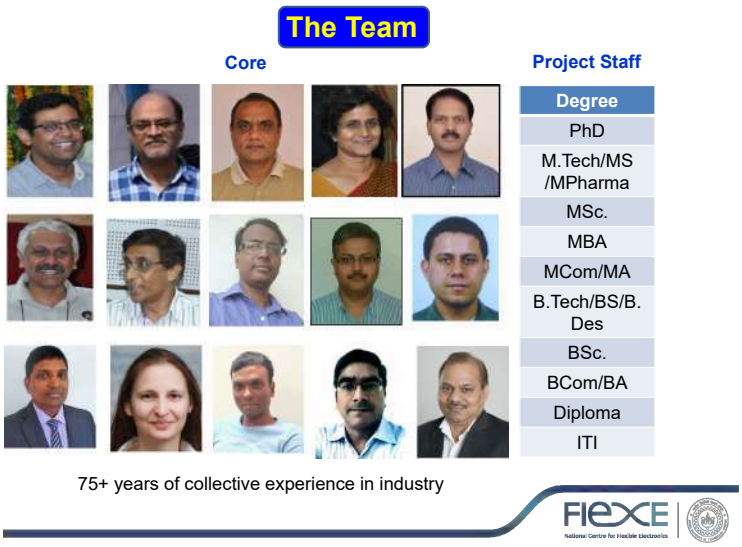
I will now talk briefly about the building and facilities of our centre and then I will talk about the people. We have faculty members and research members, who are the core faculty members of our centre who also have project staff and we also have industry personnel who are stationed in our centre. About a hundred people who are involved in this - we have a strong industry focus - we have a membership model and the number of past and present members is 21 and a large number of non-

disclosure agreements have been signed and many of them are at a very advanced stage of discussions. Then we have a technology platform for development of compounds and systems and we are also looking at different aspects of skill development.

Let me start with the building, this is the picture of the building, entrance of the building, it is a six storey standalone building with an area of 5000 sq.m. and the thematic labs, one shown in the picture and we have an industry friendly ambience. When I say industry friendly ambience, we have a certain section of the building which is for our industry partners who have their people stationed in our centre, which is kept isolated from other part of the building for sensitivity issues, at the same time when we work with different industries, we also ensure the sensitivity of information and many more things which we take care of. Here are some of the pictures of the facilities, we have state-of-the-art facilities and primarily on printing, so what would like to say the philosophy of our facility, we have all the way from the lab scale to the industry scale and this is something which we would like to showcase to the industry and there are industries which perhaps would shy away from investing in the field of flexible electronics even if they find it attractive because of

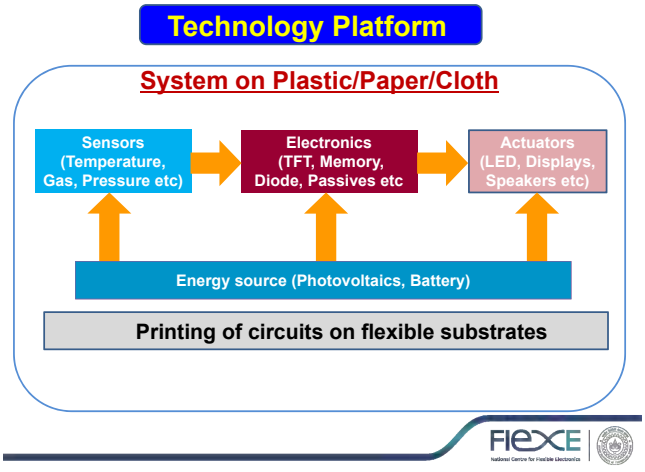
the risks which are involved. They perhaps would not like to invest in it and this is where we provide a possible solution. All these equipments we have now are open to the industry for the projects they do with us. So they do not have to invest on their equipments - rather they can utilize the equipments we have here. So things can be taken up at the lab scale and then they can be scaled up all the way to the industry scale. This is an example, picture of a roll-to-roll printer which is almost of a semi pilot scale. So many of these uncertainties can be addressed and once a certainty has been established as far as the device and personnel are concerned, then the industry can take that up and replicate this process at their place. So this is something that we offer to the industry. What I would like to say is that our centre is a one stop shop for flexible electronics.

Now I will talk about the team. These are the photographs of the core members, i.e. faculty members and research engineers including the Chief Operating Officer and what I would like to say is that most of these core members i.e. the faculty members and the research engineers, they worked in the industry, more specifically in the semiconductor industry before they joined IIT Kanpur and the collective



experience of these members is more than 75 years, in North America, in Europe and in Asia apart from India. So this is what the experience which the core team brings to the people. This is a very interdisciplinary team, we have got electrical engineers, materials engineers, chemical engineers, physicists, chemists and so on and all of them are under one roof in a building. In additional to the core team, we have our project staff who come with variety of experiences, people with Ph.D., degrees all the way to Diplomas, ITI and all kinds of academic background. Having looked at the team, now I will go to the Technology Platform.

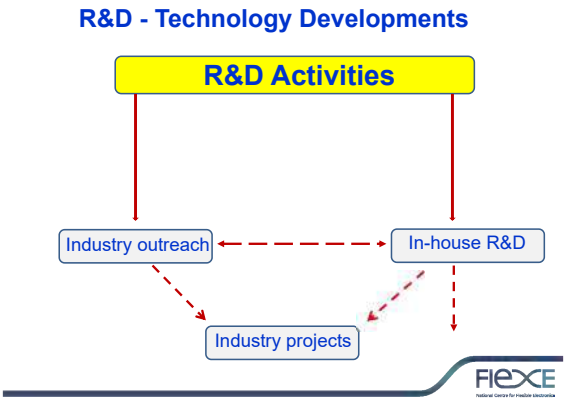
As I had mentioned earlier, when we talk of flexible electronics, we are printing circuits on flexible substrates which could be plastic, paper or cloth. Now what are we printing? We are printing different components like sensors, actuators and these are driven by electronics and can have an energy source and



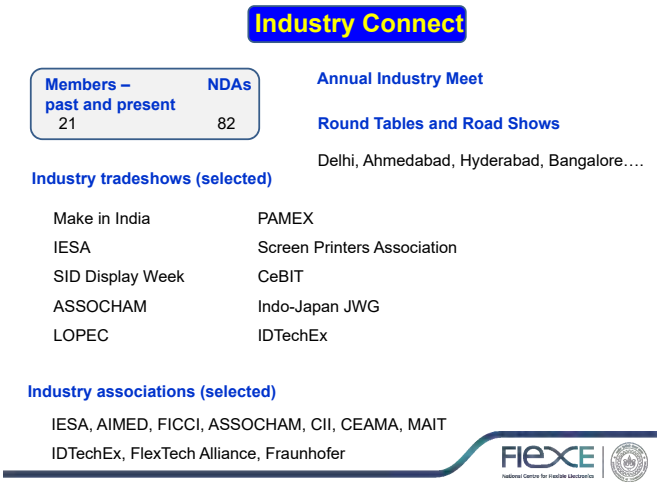
NCFlexE Technology Matrix

Technology Platforms \ Technology Integration		Memory and logic circuits	Flexible solar modules	Anti-counterfeiting	Healthcare devices	Flexible Displays	Smart Packaging
Large area printing and coating / Substrates and encapsulation / Patterning technologies	TFT	√		√	√	√	√
	OLED					√	√
	OPV		√				√
	Sensors			√	√		√
	Inks		√	√	√		√
	Battery	√	√	√	√		√
Common platforms		Passive components					
		Electronics and device integration					

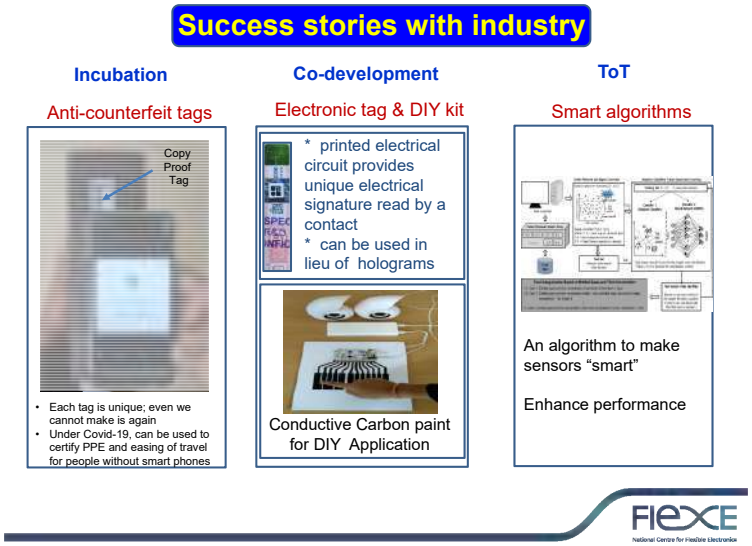
so on. In order to have a technology platform what we have is a technology matrix. What we have on the horizontals are the different components like the thin film transistors, organic lighting or telephoto vertex sensor and battery and then also on horizontals what we have is the different subsystems and systems like memory logic circuits, flexible solar modules and so on and we have teams who are dedicated, who have taken responsibilities for each of these different components and there is a process across with the responsibility of putting them together of integrating them into these different systems. At the same time, we also have this programme on device integration and also programmes on this large area of printing and coating. So having said that let me tell you how do we go around interacting with the industry and how does our R&D reach out to the industry. We have some baseline R&D activities which are going on in the centre and we have a strong industry outreach. We show them what our capabilities are and ask the industry what is their interest. Sometimes we propose something what we would like to do the industry takes it up and sometimes the industry comes out with their requirements and we pick it up and that results



into an industry project. Sometimes we go forward with our in house R&D and reach out to the industry and perhaps slightly later stage again go through the same process or we go for high level maturity on our own or we incubate a company or we have a technology transfer. So we have got all modes of interaction with the industry. Now let me talk about our industry connect activities. As I mentioned earlier, we have a membership model with the industry and as of now we have got two tiers of members and that is based on the facilities and what the requirements are and we have got 21 past and present members and a large number of non-disclosure agreements which we have signed. We hold an annual industry meeting both at IIT Kanpur and at other places so as to enable a larger audience. We also have held round tables and road shows. If people for the industry would not be able to come to Kanpur, we have gone to them. So these are some of the places where we had our round tables and road shows, for example Delhi, Ahmedabad, Hyderabad, Bangalore, etc. We have showcased the capabilities of our centre and there are a large number of trade shows which our centre regularly participates both in India and abroad, some of them are Make in India, Pamex, IESA, Screen Printers Association, SID Display Week CeBIT, ASSOCHAM, Indo-Japan JWG, LOPEC, IDTechEx, etc. There are large number of Industry association with which our centre is strongly engaged with both

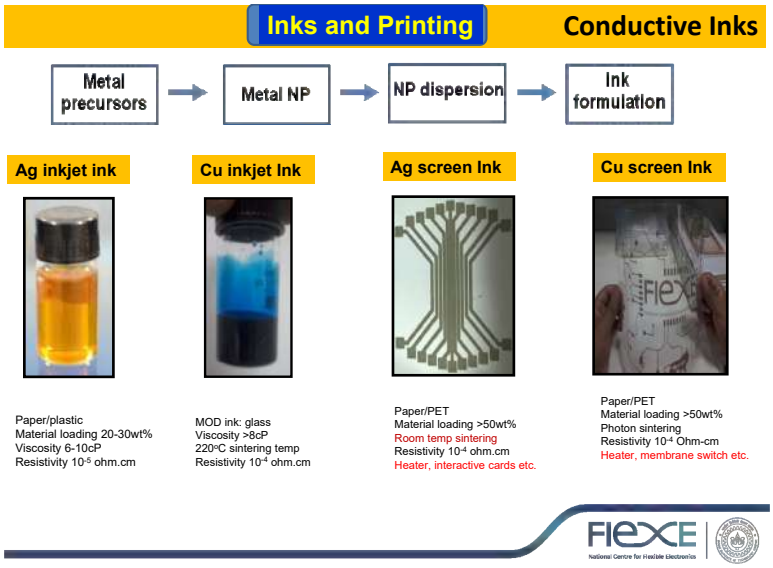


in India and abroad, some of which are IESA, AIMED, FICCI, ASSOCHAM, CII, CEAMA, MAIT, IDTechEx, FlexTech Alliance, Fraunhofer, etc.

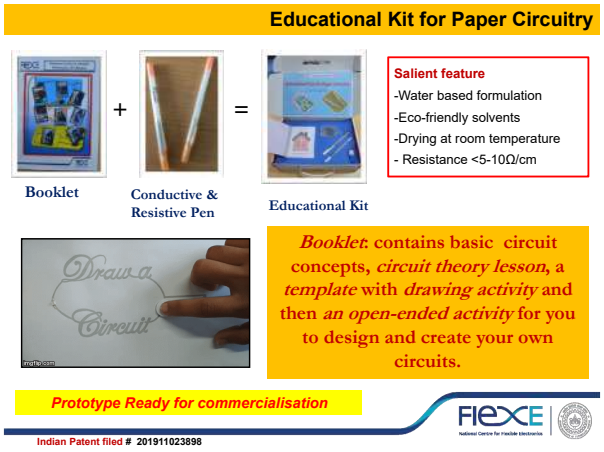


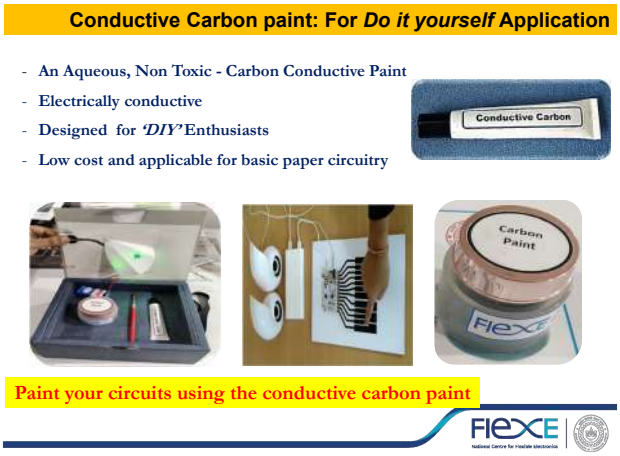
Now let me share with you some of the success stories of our centre with the industry. As I mentioned, we have had engagement with the industry in all three ways, Incubation, Co-development and Transfer of Technology. Here is an example of a success story, a technology developed in our centre has been incubated as a company, Transpac and this company makes anti-counterfeit tags and this is based on a very proprietary technology which makes 3D features on the base and again these tags have got an attraction for various industry segments. Here is an example of a technology which has been handed to the industry with the whole development code and what I would like to say about this particular part is this conductive carbon paint and this is an example of indigenization. This company had given a challenge to our centre to indigenize some of them, this particular material and our centre has been successfully been able to do that. Another example is by the transfer of technology, we have transferred a technology, algorithm to make smart sensors, to a particular industry. These are the success stories as we speak, we are working with several industry partners in different sectors and this was one of the questions which came

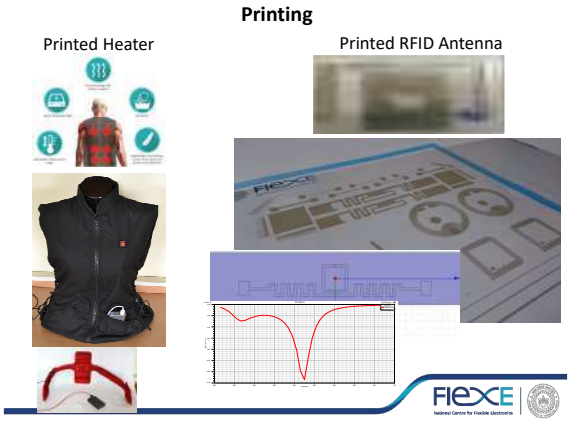
up, are we working with industry partners, in strategic sectors, yes we are working with strategic sectors both for Defence and the Space sectors, we also working with companies in health care, track and trace: supply chain, smart packaging, food adulteration and materials validation and as we speak we are also collaborating with several companies and going to have more engagements soon.



I will now give a snapshot of some of the things which are happening in the centre. Let me start with inks and printing and conductive inks. We have developed silver and copper ink both for inject as well as screen printing applications and these are some of the things printed shown here. Here is one example of educational kit, Educational Kit for Paper Circuitry. Salient features of this Kit are: water based formulation, eco-friendly solvents, drying at room temperature, etc. The Kit contains Conductive & Resistive Pen, a booklet containing basic circuit concepts, circuit theory lesson, a template with drawing activity and then an open-ended activity for design and create own circuits. This opens up a new paradigm of having experiments. This becomes more relevant when we have online education that if students cannot go to school and have labs, they can take these kind kits and still play around and make the electronic circuits at home.







Here is another example which I had mentioned earlier, Carbon Paint and this is a demonstration which has been given at our centre where a Piano has been printed, I don't have a video of this, but people who are interested can share this and one can just print a Piano and play it. Coming to printing, different activities are going on and here is an activity, we have got a printed heater for putting in jackets and is something which we have a prototype of this jacket which has been tested on our security guards on campus on December nights they have given very enthusiastic feedback about the prototype which has been developed. Here are examples of the printed RFID antenna and this is the schematic of this printed electronics R2R line and this is a photograph of the line which we have in our centre. What I would

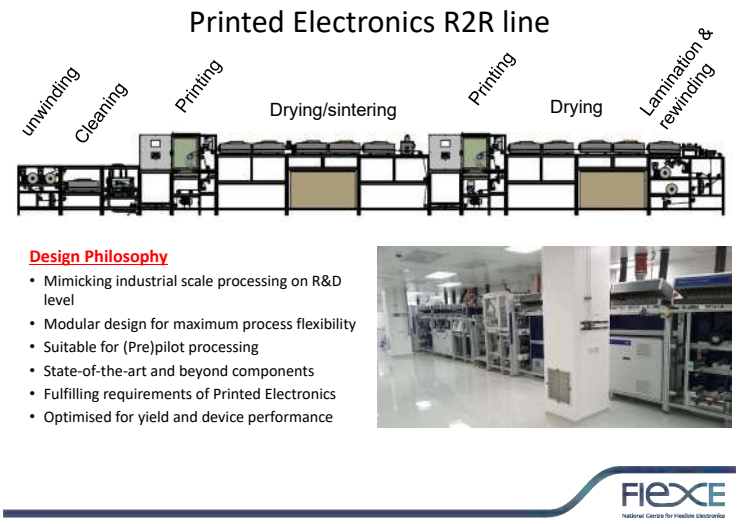
like say is that this is one of the unique design, definitely in India, perhaps one of its kind in the world. This has got different modules. This is something which should be of interest to the industry because now what happens is that the industry would need some of the models not all of them, these are very modern which means whatever is now needed can be taken up and one can take up the modules which are of interest and then utilize it for printing devices of the specific application. The design philosophy is:

- Mimicking industrial scale processing and R&D level,
- Modular design for maximum process flexibility,
- Suitable for (pre)pilot processing,
- State-of-the-art and beyond components
- Fulfilling requirements of Printed Electronics
- Optimised for yield and device performance

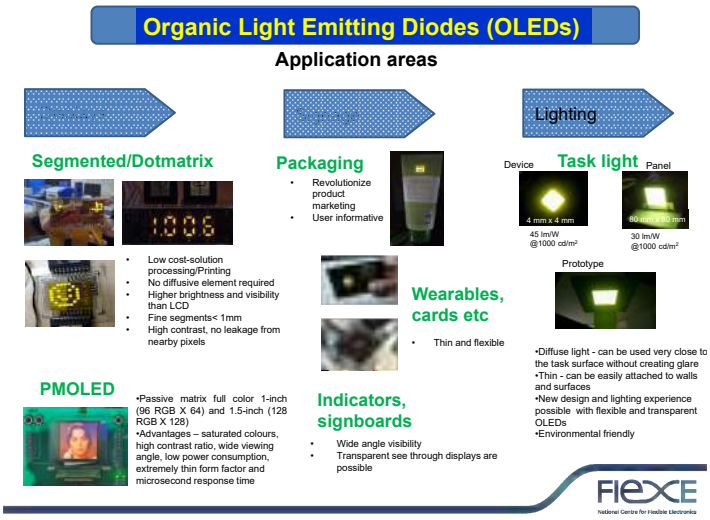
In the next slide I will show a brief video clip of how we are printing devices on this machine. What is shown here in this slide are some of the things which we have printed on our own machine and I will talk a little bit about this Smart IV Label later on.

Now let me play this small video clip.

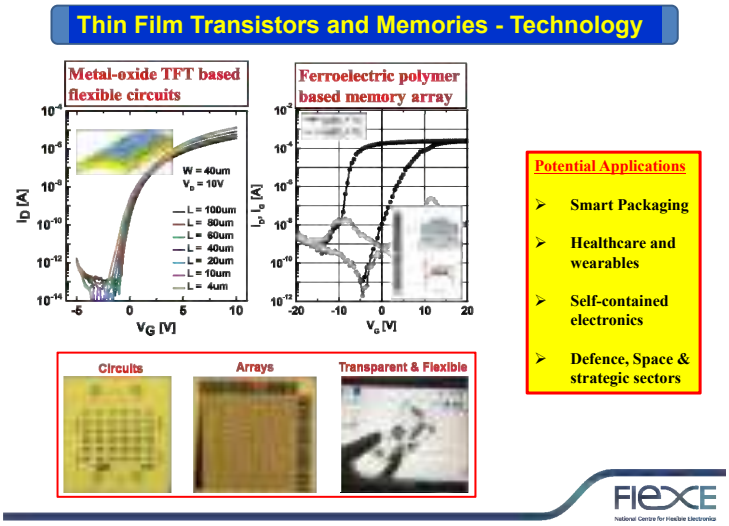
(video played)



What you see is the roll-to-roll machine in our centre, these are the different processes which are happening and you can see this is the plastic substrate and the different structures which are printed.

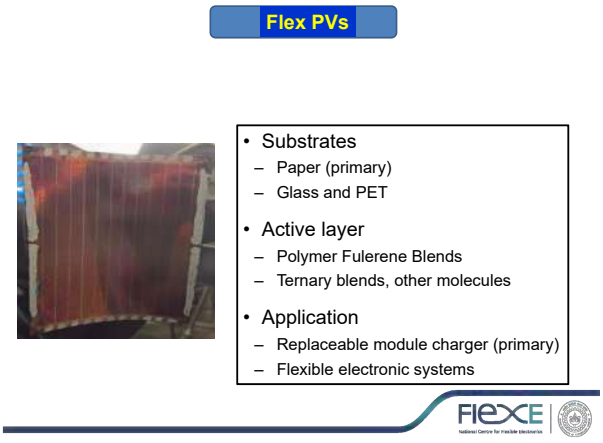


Now after having talked about printing, let me given a snapshot of what is happening in the field of organic light emitting diodes (OLEDs). Again work is going on in the area of display for signages and also for lighting and this shows what the different prototypes and demonstrators which have been built for segmented dot matrix, for packaging and this is for interactive packaging and with this variable cards and indicator and sign boards and for lighting, for different applications and so on.

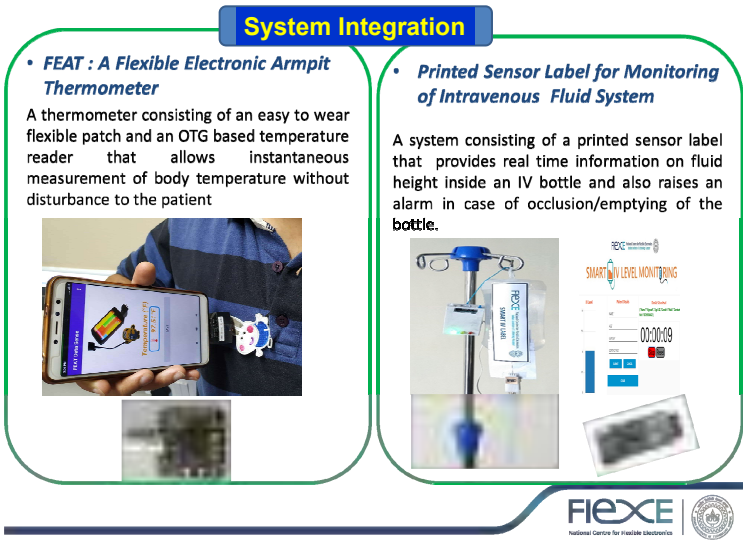


Another area, where our centre is working on is the thin film transistors and memories and this is a unique facility we have in the centre and it has drawn the interest of Space and the Defence sector as I mentioned earlier. Now what you see the snapshots of some of the work which are going on in the centre and this has different applications in packaging, healthcare and different strategic sectors and so on. There are several sensors which have been worked on, thermal sensors, gas sensors, metallic sensors, biomarker sensors again for different applications such as smart packaging, diagnostics and variables and some of the things are shown out here and again we are working with several industries in this area.

Next I will go to flexible photovoltaics. One question had come up during the break. Are we being cognizant of the environmental aspects. What we see here is that these photovoltaic modules are now being primarily developed on paper and in different application areas this can be used, in

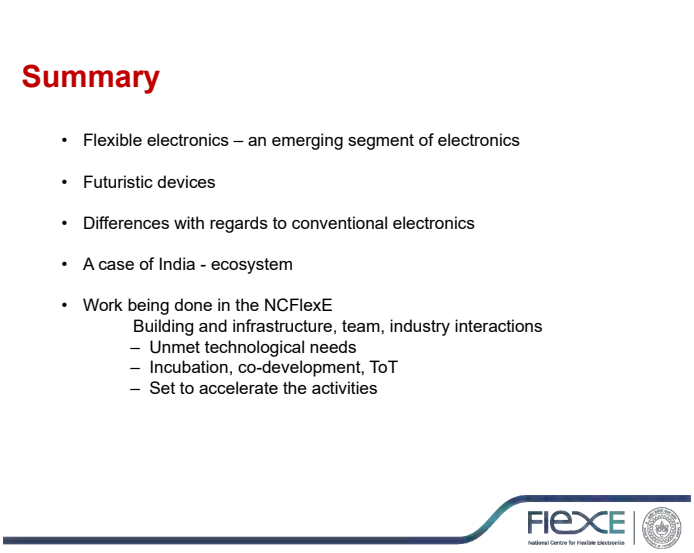


flexibility systems or can be utilized as a replacement module charger. So these are some of the results of these modules on paper substrate and with all these details what I can say is that the levels shown here are very promising. Having said this, close snapshots with the examples some system integration and we are trying to come up with solutions which are typical which try to address on the typical Indian problems. Let me take an example here. This is an IV bottle and when the IV fluid in the bottle goes below a particular level and that not taken care that can pose a lot of problems to the patient and sometimes the medical person may not be around to take immediate action when the level goes down so then can we come up with a system like a cancer the chief system which can now help those indications.



This is what I showed during this printing, here is a sticker which is now put on the back side of this IV bottle and when this level goes below a particular level, there is alarm which beeps so it can alert either the attendant of the patient or the medical person so that appropriate action can be taken. Here is another example of a simulated thermometer where the temperature measurement part is a variable one and so that it does not disturb the patient. While closing my presentation I would like to say that our centre is interacting with a large number of organizations not only within the country and across the world and lot of interactions

going on and that is also helping us to learn a lot of things and lot of collaborative work which are in place.



Now let us summarize what I have presented. Flexible electronics is an emerging segment of electronics and it has a potential to provide solutions which cannot be done by conventional electronics and I would like to emphasize that the flexibility products are not competing with conventional electrons but rather is complementing the conventional economics and then we looked at the possibilities of future and what we call futuristic today could become reality and we discussed the differences with regards to conventional electronics and then in the second part of the talk I made case for India for flexible electronics and we say what are the elements in place which favour India to take up flexible electronics manufacturing seriously and how the efforts are being made to strengthen the electronics manufacturing ecosystem. In the third part of the talk I presented about the work which is done at the National Centre of Flexible Electronics at IIT Kanpur, I mentioned about the building, the infrastructure team, interaction with industry, the success stories, the work we are doing with the industry and what are things which we plan to do. Our focus is trying to meet the unmet technological needs of the country and also talked about the different modes of engagement we have with the

industry that is incubation, co-development, ToT and with the continued support from our funding agencies, Ministry of Electronics and information technology and we are set to accelerate these activities. With this, I would like to conclude the presentation. I would like to thank you all for your attention and I would like to invite all of you to visit our centre when the covid condition normalises and see for yourself what all we are doing, our website address is:

www.ncflexe.in

You can get lot of information from our website. If there are any further questions please be in touch, our email address is: flexe@iitk.ac.in

Thank you once agian.

Dr. Suraj Rengarajan: Thank you Prof. Panda, now time for some questions. I think you covered a large breadth of topics. There are a few more questions that came up during the discussion, I tried to bundle some of them. There were some questions on Solar Cells, you did show some examples on solar cells, there were questions on what else are you doing on flexible solar cells, organic, inorganic, efficiencies are low, what can be done to improve them and things like that generally in the area of flexible PV. So may be your thoughts on flexible PV and how they find a place in PV in general.

Prof. Siddhartha Panda: There are different parameters, if you are looking at efficiency then some of the technologies are indeed more geared towards them. In our centre we are working on paper based models which are flexible utilizing organic molecules on paper pages primarily for the reason that like looking into the future where you know what products like this will have lesser burden on the

environment. Question is then where they can utilize it if every technology sector has its own window where it can be utilized. Now if you look at PV as a whole, yes there is an entire gamut of technologies and different centres which are focusing on different sectors and in this particular case our centre is focusing on organic PV and primarily on paper substrates.

Dr. Suraj Rengarajan: Talking about substrates there were lots of questions on what substrates you use, you mentioned some plastics, are there preferred substrates, more flexible, compatibility issue with electronics, things like that generally on the issue of substrates and then there were lots of questions on rare earths given that we have this issue of rare earths being difficult to procure and some China issues and stuff like that. Can this be a substitute for that. I know that it is a difficult combination to play in but just address the issue of what substrates are used and do rare earths play in any of this from a substitution perspective.

Prof. Siddhartha Panda: When we talk of substrates as I mentioned paper, for example as far as paper is concerned there has been work which is going on photovoltaics but also we are also looking at some other applications utilizing paper substrates. Now we are also using plastic substrates and also we have utilized cloth as I mentioned or making this conductive cloth for the EDMA shelling applications. So again utilization of different substrate becomes specific to the end application. Hence we are using different flexible substrates for different applications and then we can take it more on case to case basis as to why we are utilizing substrates for this application, for example, suppose we want to put a particular device on a particular package, what kind of a package perhaps determines what kind of

compatibility issues are. I would rather like to invert the problem, we have an advantage that even we get plastic, there is so many kind of plastics which are there. If you want to have paper we can take paper, different types of paper, so depending on our end requirement we can utilize various types of substrate for the specific applications.

Dr. Suraj Rengarajan: One of the follow up questions was there was the temperature, thermal budget, how high, what is the temperature that the substrate needs to handle for the process flow it goes through different steps.

Prof. Siddhartha Panda: It depends, some of them can go up to say 300 degree Celsius, some of them may be up to 150 to 200 degree Celsius. Again if you look at what I did not present here because of paucity of time, the choice of the substrate there are so many parameters to choose because in each experiment what one chooses a subset based on what requirements, it is not necessarily that a substrate can meet all the requirements, so what the way is chosen is based on how to maximize the benefit which a substrate has. Again for example, there is a process which perhaps means a slightly higher temperature especially if you are looking at those flexible devices which undergo vacuum processing, some of them perhaps would need higher temperatures and for that obviously one need to have a substance which is able to withstand those high temperatures which can go to 300 degrees for sputtering and other applications. On the other hand if you want to have a substitution primarily done by the printing, at the same time you have a centering which goes to 120-150 degree Celsius, you may not need those

substrates which you need to go to high temperatures, again the choice of a substrate depends on so many other factors.

Dr. Suraj Rengarajan: Follow up to that the way the flexible electronics industry is looking at is to go towards a hybrid model. As we said in the beginning electronics is better done conventionally where you want performance and the functionality can be done by flexible process and how do you integrate those two and come up with a flexible hybrid electronics. One of the question was in this centre, do you do that and how do you accommodate soldering or something conventional electronics into the flexible devices.

Prof. Siddhartha Panda: As of now even at the worst I don't think we have all the components which are fully flexible which meet those standards.

Dr. Suraj Rengarajan: I think the industry is headed in that direction so I think we will get in that direction.

Prof. Siddhartha Panda: Yes. There are relatively some simpler components which have reached a certain level of maturity while some components of course which have not reached that level. As far as the world is concerned in many many cases what they do is they take the conventional IC and it is polished and made so thin then mounted on this flexible substrate and once they are made and once they are polished what happens is that it take the ball and grid array (BGA) and then just put it on top. So those things are handled up to a point. As far as our centre is concerned the answer is yes. We are also going by a flexible hybrid approach. In

some cases some of the components which need a certain level of performance but perhaps the flexible components do not have the level of performance they go with the rigid ones. When the sizes are so small, we mount them on a flexible substrate that does not come in the way of our required formality. These are the things going on right now and parallelly effort is being made to develop these fully flexible components but that is a long road ahead.

Dr. Suraj Rengarajan: Just a follow up on that again with respect to the industry itself, what is the maturity in terms of manufacturing, yield performance, when you look at flexible electronics, what percentage yield you get, what repeatability of products and all that, how is it comparable to VLSI electronics in that sense.

Prof. Siddhartha Panda: I would like to say that this is still an emerging field , let us broaden the canvas. If you look at VLSI, if you look at the design set tools all these things are already well established. Flexible electronics system is still emerging, obviously we cannot expect the same level of performance as far as the VLSI is concerned but then that is a long way to go but that is the direction in which the industry is heading. As far as the specific questions are concerned, numbers and all that I don't have, but the industry could share the numbers.

Dr. Suraj Rengarajan: Switching applications, there was a question about photonics, are you looking at photonics and then there was also about antennas, millimetre wave and things like that, are you guys looking at that, is flexible electronics compatible with that kind of applications both photonics and transmission antennas and things like that.

Prof. Siddhartha Panda: We are working on these flexible antennas, in fact I have shown one such antenna, we are utilizing our facility for printing antennas and looking for field communication application that is where the initial work is going on. The answer is yes and such activities are indeed going on in the centre. As far as photonics applications are concerned, as I mentioned earlier, we have a programme on organic light emitting diodes and I showed the different applications whether it is for display application, lighting application or making interactive variables and other things, all these active onsite application and other activities are going on in our centre.

Dr. Suraj Rengarajan: Another application was on gas sensors, are we doing anything on gas sensors, what kind of sensors do we use, what kind of materials do you incorporate, what can you detect things like that.

Prof. Siddhartha Panda: We are working on gas sensors, in fact there are two companies with whom we are working with. All I can say is that this with smart packaging and food adulteration and as some materials are concerned, we are utilizing materials which can have more like a room temperature processing. That is all I can say as of now.

Dr. Suraj Rengarajan: That is a big area of interest from India perspective, right in India it is a big food packaging center and I think this is an area where flexible is already used and now you can build more use cases on top of that. Then there were

a few questions about paints, where do you get these paints, can I buy silver paints, carbon paints, who makes them and all that.

Prof. Siddhartha Panda: There are companies which sells these inks/paints and at the same time we are also in a process of incubating a company in our centre based on technology developed at our centre and on its own making of these inks/paints, that is something which we expect to happen in a few months from now. But if there are any specific needs, they can get in touch with us and depending on the kind of needs and definitely we will be able to give a response as to what we can do.

Dr. Suraj Rengarajan: A couple more generic questions: Are there standards in this industry, communication standards and things like that? If you need to do Bluetooth communication, is there a standard that exists, are there companies that we should be following in this space to learn some more. Which are the other centres that are working in this space and all that areas for general knowledge, general learning.

Prof. Siddhartha Panda: When we talk about standards, there are different standards for different sectors, for example, if you look at photovoltaics, that is one sector, display is one sector and again communications has its own standards but as far as utilization of flexible electronics is concerned, that is something which can taken up by the people who are working in the field of communications and perhaps they will be able to give a more specific answer to this question.

Dr. Suraj Rengarajan: I think we can't attend any webinars without mentioning about covid. What are you doing with respect to covid, are you making any covid

specific device. Somebody actually had a recommendation, says we do a lot of teaching, we have to wear a mask, can you integrate a microphone into my mask, so you need not take off the mask while speaking and quality things like that.

Prof. Siddhartha Panda: Although I didn't use the world covid in my presentation, when I was making a presentation on RFID tags and I did show a picture to say that how RFID tag can help in the field of pathology. Right now in a situation like this, when there is a huge load of samples to be tested, RFID technology can play a big role. If you look at this flexible RFIDs, they have big role so that you know what the samples and it can be utilized for tagging and to bring shape conformality for this particular sample tubes. In fact we are talking about some ideas, for example, if you have a mask and can some sensors can be put in the mask itself which can give information, we are talking about it and we will see how we go forward with this.

Dr. Suraj Rengarajan: There are lot of questions on how do we partner with you and whenever things open up, we will come and visit you and things like that and then one specific question, do you help with design aspects, say if I have an idea can you design what the solution will be and all that and what more do you provide in addition to these materials and fabrication.

Prof. Siddhartha Panda: We are a National Centre for Flexible Electronics, it is not that our electronics is flexible but our approach is very flexible, we don't say what all we can do, we don't try to put it on pen and paper because that tells if we don't say anything which means that by default we don't do that. That is why we keep a very minimalistic information out there because we are also growing as a centre,

flexible electronics is growing at a speed and we want to work with the industry, work for the industry and we want to work at different levels based on our capability of course. So the answer is yes, we are very happy to talk to the industry because as I mentioned, the vision statement of our centre has the world industry in it. How to get in touch, please drop an email and that is how it start, simplest way to get in touch. We can take it forward from there. We look forward to hearing from the industry.

Dr. Suraj Rengarajan: One more phrase without which any webinar will be incomplete is graphene. Do you work with graphene and then by association with other similar materials and things like that.

Prof. Siddhartha Panda: Graphene is used in some of our devices. There are people working with 2D materials but they are at a very initial R&D stage, we need to go beyond a particular stage before we start seriously utilizing that.

Dr. Suraj Rengarajan: There is lot of confusion on 3D printing and printing that is done over here. Maybe you can clarify for people what printing here is more like printing that is done on paper whereas 3D printing is more of building up material, may be something that you can explain.

Prof. Siddhartha Panda: 3D printing is different, like all you do is if you want to have a 3D structure and also if you look at the dimensions these are larger dimensions. Here we are looking at microns that is the level resolution which are printing, of course it cannot reach the level of sophistication what you have in CMOS

technology but what we are using is essentially where you are looking at trying to print circuits utilizing conductive materials, semiconductor materials and dielectric materials but indeed we also utilize our 3D printers like we have pictures out here for making some of the things which are needed for our systems. We also have this utilization 3D printing in our centre

Dr. Suraj Rengarajan: From my perspective, this is a field that has been there for a long time. People have talked about flexible electronics and one of the things that needs to happen is scale. We have had lots of small applications all of which have moved but this to go the big arena we need one big killer app, one app which takes a huge area because when you do roll-to-roll processing you generate lot of material at one shot so you need an application that can also support the amount of material that you are creating. I hope that with all these different opportunities and things that you presented today, one of these become that killer app and flexible electronics also gets its day in the sun. Thanks a lot and I hand it over to Ashok.

Mr. Ashok Kamath: Thanks Suraj, thanks Prof. Panda. Susheela had begun this session with something from Arthur C. Clarke and that also led me to think about there was a series in the mid-1970s called the bionic man, some of us a little older may have seen this. The bionic man essentially ended up with a huge amount of flexible electronics and we are talking about the 1970s, which today I think are almost a reality if you look at all things that can go into the medical domain. What was fascinating is that Prof. Panda took us through what he rightly calls unmet technology needs of this country. If you look at our big industries, automotive, lot of opportunities there for flexible electronics in instrument panels, in under hood

controls, in ABS and stuff like that. I think there are lots of places there where flexible electronics could be used, clearly in industrial and medical there are dozens of applications starting from glucose measuring strips upwards, there is a whole lot of things that could be done and as India is becoming recognized power when it comes to space and satellites and so on, flexible solar panels that can go up in spacecraft and perhaps even drones and stuff like that eventually, there are opportunities there in the strategic electronics area for us to play a big role.

Finally with all these noise around us we are seeing that India is probably going to be a large centre for making cell phones and that is perhaps an area where as Suraj was saying, what is going to be the killer app, I am saying could it be the cell phone manufacturing area that could be the killer app as many more device phones are coming in with flips and so on. We got a little glimpse of potential interdisciplinary research into base materials, bonding adhesives, metal foils which are the areas where India could lead the way and perhaps dominate over time. We got a fabulous glimpse into all the magic that Arthur Clarke talked about. Thank you so much Prof. Panda for sharing all this with us. When this talk about bringing the National Centre for Flexible Electronics as part of our webinar came up, very few of us actually knew of its existence unfortunately. I think today we had over 200 people who have been watching this and at least 200 people will go home knowing that there is an area of technology where we are at the forefront and so thank you so much Prof. Panda for sharing this. Not possible to have these things without a smart moderator and you perfectly fit that role, thank you so much Suraj for taking time out to do this. We had close to a 100 questions in the Q&A box which has been some kind of a record, we

had a large number of questions, I am sure not all of them were answered to everybody's satisfaction but we had a 90 minute limitation on this webinar.

Thank you audience for being there.

Thank you very much audience, Suraj and Prof. Panda.

ECONOMIC GROWTH AND INEQUALITY

DR. AJIT RANADE I JULY 25, 2020

Dr. Ajit Ranade is the President and Chief Economist at Aditya Birla Group. He has a PhD in economics from Brown University and did his B.Tech. in Electrical Engineering from Indian Institute of Technology, Bombay. He is an alumnus of Indian Institute of Management, Ahmedabad.

His career has spanned both academia and the corporate sector. He currently serves on the boards of some companies as well as research and academic institutions. He writes regularly in the press, on current economic and social topics. He is also a co-founder of the Association for Democratic reforms, a civil society organization working in electoral and political reforms. He received the Distinguished Alumnus award from IIT Bombay in 2009.

Prof. Sudarsan Padmanabhan is an Associate Professor of Philosophy, Dept of Humanities and Social Sciences, IIT Madras. He received his PhD from University of South Florida and prior to joining IIT Madras, he worked at Kenyon College, Ohio, USA. He specializes in social and political philosophy, and Indian philosophy and culture. His research interest lies in the confluence of law, democracy, and ethics in the public sphere.

Lecture at IIT Alumni Centre, Bengaluru, by Dr. Ajit Ranade, President and Chief Economist, Aditya Birla Group, July 25, 2020.

Link to the webinar : https://www.youtube.com/watch?v=n9hCi6Y-Img&list=PL0zMQ-70IHlX-df3u2Tto6dkKHCRC6iFL&index=16

Mr. Ashok Kamath: Good evening, welcome to the Webinar hosted by the IIT Alumni Centre, Bengaluru. For the last 14 weeks, we were having webinars which were more technology and science oriented and today we are taking a slightly different track, but eventually it will link up to technology and our speaker today are Dr. Ajit Ranade, Chief Economist at the Aditya Birla group. He is a Distinguished Alumnus of IIT Bombay who went on to do a management degree at IIM Ahmedabad and then a Ph.D. in Economics from Brown University, USA. Since then he has been more devoted to Economics, with a slight bias towards Technology. Ajit will talk about economic growth, which we all desire, and inequality. We have seen and heard a lot about this in the media. Oxfam, in a report published that there are so many millionaires in India and everyday between 2018 and 2022 we would be adding 17 new millionaires a day. These were the facts projected by Oxfam and you get to wonder at that point what happens to the bottom half billion and you see that the numbers are very skewed; then the question becomes whether it is desirable or not and how do you help all that. To moderate, we are fortunate to have Prof. Sudarsan Padmanabhan who teaches at IIT Madras in the Humanities & Social Sciences Department whose focus area is law, democracy and ethics in the public sphere. It is in this confluence of these three areas that Sudarsan did his Ph.D. from the University of Southern Florida and after a short academic stint in the U.S., he came to Madras and since then he has been in IIT Madras. Ajit and Sudarshan have been working and conversing about this topic for some time and when I talked to Ajit and asked who do you want to be as part of this team, he without hesitation said, Sudarsan Padmanabhan. So here are both of them. The format we will follow is Ajit will speak for about 25-30 minutes and take some questions and have a little conversation with Sudarsan, take up some questions from audience and after about 10 minutes we will continue with Ajit for 25-30 minutes and then questions again. Now Ajit take the floor. Over to you.

Dr. Ajit Ranade: Thank you Ashok, good evening or good afternoon to everybody as some of you may be joining from other time zones. Thank you for inviting me, thanks to Prof. Ashok Misra as well and the IIT Alumni Centre, Bangalore. I am happy to be here today and special thanks to my friend Prof. Sudarsan who has indeed very readily agreed to come as a

moderator. The topic is fairly wide, on economic growth and inequality, just google this you will actually see hundreds of thousands of it. It is a topic which has much insight, much commentary. In today's session I just want to capture some of the thoughts that came to me and what my understanding is. Before I do it, in the current contest, we are in the middle of this pandemic and the first time probably in India's history, modern independent history we experience our economy shrinking. So we are talking about economic growth today but our economy is actually going to shrink. We measure economy every quarter. We are in the middle of the July-August-September quarter and the quarter just ended we are probably going to see a growth rate of -15%. That number would come out towards the end of August. We have never seen such a situation for India, economic contraction of 15% and overall for this year economic growth officially probably going to be -7% which means on an average every Indian household will have at least that much less money to spend. So to talk about economic growth and inequality in this context in the middle of a pandemic seem little odd, it is not like economic growth is doing well. As you know, since 1991, India's economic growth has expanded, has accelerated, indeed from an average of 3% per annum in 1980s have gone up to about 5% and later the average growth went up to 7%. For a short period from 2003 to 2008 or 2009, we have actually recorded an average growth rate of 8 or 9%, we have also touched 10% for some time. Indeed we have experienced accelerating economic growth, so my context is that, what I want to make clear is that we are not going to discuss often the concept of economic inequality is discussed with poverty and that is not the topic for today. As you know, poverty is a definition which is based on basically like nutrition based definition. The person is defined to be poor if you cannot get a minimum calories intake for your body. Based on basic access like food, clothing and shelter and any quality on the other hand is defined about how income or wealth is distributed in society. Poverty definition is based on the individuals, inequality definition defined on distribution. Poverty definition is in terms of poverty line and then we say what fraction of the population is below the poverty line. So it is measured as a percentage whereas income inequality is measured as the gap between the rich and the poor. Poverty is an absolute concept, I mean it is universal, India, America, Europe, Africa because it is based on how much nutrition or calorie you get. Theoretically

only, it is possible to have zero poverty in a society that is nobody under the poverty line but still have inequality. Think of a very rich country, may be Saudi Arabia, it is a hypothetical theory, so it is possible that zero poverty and high inequality there and conversely it is possible to have high poverty and low inequality, think about country like Cuba I would say. Of course these are extremes and perhaps theoretical, most countries are in between. The World Bank defined extreme poverty to be living on less that $1.25 a day. It used to be a dollar a day and now little high in definition and very soon the definition may be $2 a day. The estimate of World Bank of India's poverty is about 12.5%, this is often debated and discussed. So I don't want to go into that debate. There is a huge debate about the poverty line and there is no consensus on it. If you look at the official committee called the Rangarajan Committee which was commissioned sometime back, they estimated India's poverty to be 27-29%. This number of course hides a wide variation across different States of India and between rural and urban, for example a State like Goa, the poverty rate is less than 5% whereas a State like Orissa it is 45-46%. So we are not going to talk about poverty rate. There is an All India poverty rate across different states, even poverty is “unequally distributed”. But if you look at inequality, that is what we are going to talk about. Just by way of titbit, last Friday or Thursday, Mr. Jeffrey Bezos who is the main shareholder in the company called Amazon, he added something like $15 billion a day to his wealth, people say that is more than the annual budget for India's national employment guarantee scheme which employees something like 100 million to 550 million people. That is an example of inequality. Of course, one is the measure of wealth and the other is the measure of spending of income. Just to give another example again from the stock market, a company called Tesla in five trading sessions, every day it was adding something like $14 billion to its market value and it added more value than the combined market value of four other automobile companies like GM, Ford, Chrysler and so on. So this again an example of extreme skewedness or inequality. Indeed in the US stock market, like we have the Sensex in India, which is the average of 30 stocks, in the US the most followed reliable index is called S&P500, but the top five stock in S&P have a market value equal to the bottom 282-285 stocks. That is also an example of inequality of wealth, of valuations. So we are seeing this extreme inequality even within stock market valuations.

Another example I can give you is in India – today, the 20 most profitable companies, this is the data because of pandemic, 20 most profitable companies generate 70% of all corporate profits. There are by the way more than a million companies registered with the Registrar of Companies (RoC). Just 20 companies generate 70% of all companies profit, it wasn't always like this. Thirty years ago, these top 20 companies accounted for only 14% of the profits. So, that is an example of rising inequality, distribution of profits. This concentration that I just mentioned 70% profit comes from the top 20 companies. In the US, 90% of the beer consumption, is produced and consumed by 2%; four airlines account for the entire traffic, airlines are closed during the pandemic or largely restricted. Out of the 2000-3000 banks in the US, five banks control 90% of the banking assets. Google which is a search engine among other things has 90% share of all the search engines. Facebook accounts for 70% of traffic. iPhone, the iconic phone made by Apple has 80-85% profits of all cell phone makers in the world. These are just examples of industry concentration. I am spending a few minutes on this because I am not going to talk about this further. This is of course an example of concentration and skewedness. What I want to talk about actually is the inequality of income in society or economy. You might remember about 10 years ago something called the Occupied Wall Street agitation, that was a sort of reaction to this widening inequality in the US economy and also the other parts of the world. This is the inequality I want to talk about. I could give you some statistics but I don't want to spend too much time for that. What goes as income to the top income earners, you can line up all people in society according to the income they receive, the lowest income earner is at the extreme left and the highest income earner is on the extreme right that is the X axis, if you can line them up then you can draw this percentile. So how much income goes to the people in the top 90% of the income spectrum, the income distribution, it is a property of distribution and there is something called the 90:10 ratio. So the way you can measure inequality, the way statistically measurable entity just like poverty is measured by the percentage of people below the poverty line. Similarly, inequality in income can be measured as what percentage or how much share of income goes to the bottom 10%, the next 10% and so on. So one measure is called the 90:10 ratio. The 90:10 ratio says what share of aggregate income goes to the

people in the top 90% of the income distribution and that ratio to the bottom 10%. This ratio now I think is about 10 or 15 so that is the inequality. Another way of understanding this is as I said what share of aggregate growth in national income goes to the top 10% or top 1%. A third way which is much more popular, is called the Gini Coefficient. It captures on the proportion, so the X axis you have people lined up in increasing way, the xx is the income earners, yx is the cumulative income of the society or the economy. So xx goes from 0 to 100% among the income earners that is if you are at 90 on the x-axis you are in the 90th percentile of income earners and on the vertical axis is the cumulative income earned by the 90%. So the Gini Coefficient is computed as the ratio between the bottom 90% of the society if their share of cumulative measure income is 25%, then the float is 0.9 and 0.25. If it was perfectly equal, if distribution of income is equal then 90% of the people would earn 90% of national income and then their share would be 90%. 15% would have earned 15% of national income. The Gini Coefficient for India has been rising. For India, it is a statistical measure, it is a number, perfect equality would mean that the gap between the 45 degree convex curve is 0. Gini Coefficient zero means perfect equality, Gini Coefficient of 1 means perfect inequality, it means that 99.9% of population earns zero of national income and the last guy, the 100 percentile person earns all the national income. So the curve would be not the convex curve but perfect right angle. The actual Gini Coefficient is the number between zero and 1. For India, this number is something like 0.38 and for the last 15 years it has been rising, it was 0.3, then 0.35 and 0.38, that tells us that the income inequality has been rising. Some OECD countries have done this computation for India and they put India's number as 0.49 which is higher than 0.38. These numbers for other countries let me just tell you for the U.S. it is 0.43, for UK it is 0.38, Italy is 0.37, the lowest among the G7 countries is France which is 0.33. France is relatively less and equal in this G7. According to this data which is a few years old, India is 0.49 but India's own computation shows 0.38, so let us not quibble about the numbers. What I want to say is that this income inequality which is measured in India is actually underestimated because nobody knows what everybody's income is. To calculate the Gini Coefficient you would need to know everyone's income but it is impossible, we don't know. At best we do a statistical sample, few surveys and in fact what the surveys reveal is

the consumption expenditure, how much people are spending not how much people are earning. Notoriously people will not reveal their income. As you know, only 2 or 3% of the population of India pays income tax, so for them we have reliable income data but for the remaining 97-98% we don't have income data. So we can use proxy like consumption which is again done by statistical sampling, which is done by surveys. So what we get is the Gini Coefficient for consumption spending which is 0.3, the actual income inequality is or could be worse. Rich people tend to spend less on consumption and they have higher savings. For poor people their entire consumption is their entire income so the inequality number that you will get is actually worse than what you are measuring on the consumption spending. I would like to tell you that in fact income inequality is worse because it is not only about consumption spending, imagine if you use matrix like access to quality health care or access to basic quality education, access to sanitation, if you start looking at that the inequality in India, some of these concepts may be difficult to define and measure in this matrix, and it is actually worse than we think and inequality can be measured along many dimensions, not just income. As I mentioned, this is about income inequality but you can think about wealth inequality. Wealth is accumulated income, rich people tend to have higher savings, therefore, they invest in wealth and transferred through bequeaths and transfer to their progenies, the next generation. The next generation starts up with fair wealth, so wealth inequality gets worse, it is more skewed than income in any part. So if you start measuring India's wealth inequality it is even worse. I don't have the numbers but if the Gini Coefficient for income is 0.38, wealth coefficient in inequality will probably be 0.5 or 0.6 or worse.

This part of the talk is about giving you the flavour for how inequality is measured. I must also tell you that inequality has been increasing in almost every country of the world for the last 30-40 years. It is perhaps a feature of the post-industrialised capitalist world and despite what you may think actually it is not the result of politics nor is politics likely to reverse it. There are no political solutions for reversing inequality because the problem is more deep rooted and that is going to be my second part of lecture and it is generally more intractable because inequality is an inevitable product of capitalist activity. As you can see, capitalism or

free market economy is essentially about unshackling the entrepreneurial spirit, unshackling the potential of human beings and in doing so, invariably the ones with the more entrepreneurial talent are going to race ahead, in fact unequally and the ones who are not competent will lag behind. The idea is that such an economy will generate economic growth, everybody will gain but the people ahead in the race will actually gain more and people who were falling behind will gain but not to the same extent. In fact I just mentioned to you the Gini graph. Imagine that if you look at the incomes of everyone in the 10 percentile, 20 percentile, 90 percentile and so on and imagine that we have 6% or 7% GDP growth or even 8% GDP growth. So if you apply 8% growth to every income percentile the 8% growth of the rich person is going to add many more rupees or dollars than the 8% income of the lower end persons. So income inequality is going to be worse. Therefore, income inequality is the inevitable product of economic growth and expanding the equality of opportunity, if you say let us making it a level playing field, let us expand economic opportunities available to people, this will only increase it because some individuals and communities are better than others in exploiting the opportunities for economic development and advancement. This is a feature of capitalism. My talk is not about the political theory of capitalism and I leave it to people like Prof. Sudarsan. I am just saying this is the feature and therefore we need to understand this and what it means. I just want to end the first part of the talk by saying that in 2016 you had President Trump tap into the rise and the ultimate victory of President Trump in the election came as a big surprise because a lot of the experts did not forecast, did not predict his victory but it is said that he tapped into the so called red states of the mid-west United States where income has been stagnating, where job losses were higher, these are the blue collar workers and these are the people who are left behind, these are the people who were the victims of inequality, this is not the right word but basically who felt the pain of rising inequality. There was a time just before the financial crisis of 2009, it was seen that 45-50% of all corporate profits were going only to Wall Street firms, financial firms - banks, investment banks, hedge funds, equity funds. So the rise of finance was actually the rise of East Coast the Wall Street, the West Coast, Silicon Valley, the phenomenon I just mentioned, the phenomenal rise of Tesla, Amazon. So the income gains, the wealth gains who were being

sucked by these extreme, very top layer of society and the middle class was feeling left behind. By the way, this also has a social consequence - increasingly these disproportionate gains extends to the social consequences and the educational consequences, all the top talents from engineering schools like IITs, engineering institutions, science institutions or business schools, they get attracted, the best talent get attracted and sucked into the financial firms so that people who were doing the work of shop floor, the nuts and bolts and so on, they are deprived of talent. That is a separate phenomenon which perhaps we can develop on later. I am just saying in 2016 the rise of Trump who eventually became President of USA is linked to inequality. Not to forget the more remarkable thing in 2016 was not just the rise of Trump, was also the rise of a person called Bernie Sanders, amazing rise because Bernie Sanders perhaps after a long time, after a century was an example of a presidential candidate who rose almost with zero financial support, very little compared to his rival Mrs. Clinton, so he represented the rise of the leftist ideology and Trump was of rightist ideology but both of them were tapping into the same containment which is about rising inequality, widening inequality. The same thing was seen in the U.K. The U.K. happened earlier I think, the Brexit outcome also was unexpected because even before Brexit not only the pundits and experts, even the punters got it wrong as you know in places like Ladbrokes and Lloyds you can bet on anything, you can bet on cricket matches, bet on weather, but there were bets on whether Brexit would win or not and the money was 5:1 against Brexit, so even the punters got it wrong. For the punters, it is their business to know to be able to accurately predict. Again same thing, related to inequality. So inequality has been an important force and we will talk about what are the consequences of it.

Maybe we should take a break at this stage and take a few questions on our conversation.

Prof. Sudarsan Padmanabhan: There are a few questions Ajit, there is a question about universal basic income, how does it help?

Dr. Ajit Ranade: I think we are jumping ahead, I was going propose in the second part to say what can we do to reduce inequality. So Universal Basic Income is the lumpsum amount given to every person irrespective of their level of income or wealth, in a way it starts off everybody with some basic endowment, it can address to some extent, at least it can reduce the disadvantage of the people who are lagging behind and we may need to consider something like that but it has to be fiscally affordable. This has to be paid for by money collected through taxes, the budget. There are countries like Finland, very few countries who have actually started, the northern European countries especially Scandinavia, they have a much more generous budget situation, much better but this is something that India's Economic Survey and annual budget speeches have been mentioning, at least the Economic Survey document has been mentioning for the last 3 or 4 years. It means something we may have to go to but in a way we have actually implemented in different ways. Since we can't give money to people, we have created rights, this is called the rights framework. We have created something called the right to employment. Right to employment in the rural areas is called NREGS (National Rural Employment Guarantee Scheme). We have created something called Right to Education (RTE), we have created something called Right to Food but these rights have fiscal costs, it is something that is declared as rights, but we got to enforce the rights, we got to implement the rights, they have some budgetary consequences and people believe that the rights are very imperfectly implemented, clumsily implemented, not everyone is benefitting and some people have an ideological objection to these rights, so what you can't give through the budget you create through by rights. So this is the same thinking, same philosophy.

Prof. Sudarsan Padmanabhan: The next question is, how effective is the Gini Coefficient in measuring the inequality?

Dr. Ajit Ranade: That is the best measure we got, Gini Coefficient is one number, it is a very handy way of capturing inequality, I wish I could have just shown on a slide, it is basically think of x-y axis and a 45 degree line and the curve like under, so the shaded area under this curve

and the 45 degree line, that has a proportion of this is called the Gini Coefficient ratio. That is the best way to measure inequality. Those who are in the audience who have a mathematical orientation, the inequality is a distribution, the distribution can be all kinds of statistical distributions, it is very difficult to capture the property of distribution in just one number. You can calculate it as a variance or as skewedness - all these are technical statistical terms. So, the Gini Coefficient is just one number but most handy and it is very popular. That is why we use it.

Prof. Sudarsan Padmanabhan: Actually you had already discussed this issue, there are also questions about inherent problems or the dynamics of capitalism, inequality as a characteristic of the market or the crony-capitalism being the culmination of capitalism and there are also questions about the impact of pandemic on the poor and tax rates and loss of jobs in the Indian context even all those who earning wealth, how do you address these issues?.

Dr. Ajit Ranade: As I said, I wanted to keep the discussion separate from the discussion about poverty. What the pandemic has done already, it has led to a job crisis, many livelihoods especially in urban areas have simply collapsed, many small and medium industries have shut down, people have lost jobs, people have lost family incomes and people have fallen into poverty and imagine in this situation if we have one vulnerability of sickness, not just Covid but any other sickness than can just wipe out whatever they have with the health expenses, but all the discussion goes towards poverty alleviation which I think overrides the case. I am taking it as given that nobody objects, there is a complete consensus that we must fight poverty and India must aim to reduce poverty rate to 0% or at least below 5%. The Chinese official poverty is below 5%. So poverty reduction as an aim of national policy is a given one, there is complete consensus. Inequality is somewhat more debatable. People say that India doesn't have the luxury to start fighting inequality now because inequality is an inevitable consequence of unequal endowments and unequal capabilities and unequal competences, let the winners race ahead, if they are becoming super rich let us tax them and use the tax

money to give it to the poor, so let us not worry about reducing the gap between the rich and the poor, let us not worry about inequality. So this talk is more about the inequality aspect.

I just want to say that as I said in the previous part, inequality is an inevitable consequence of the world we live in and also mentioned that widening inequality has caused a phenomenal effect after the rise of Trump, the rise of Bernie Sanders and the outcome of Brexit, earlier it was occupied Wall Street and I think many of the social movements in India also perhaps can be traced to the widening inequality. Another funny titbit here is that while inequality has increased over the last several decades in every country of the world, the inequality for the world as a whole actually decreased. It is a funny, apparently paradoxical conclusion but if you take 190 odd countries and you take their own national income and if you compute Gini Coefficient for each country, almost every country has experienced an increase in Gini which means an increase in income inequality in their own country but if you compute the Gini Coefficient for the world as a whole it actually has gone down, the world has become more of an equal place. It is not very difficult to reconcile these two, so apparently paradoxical conclusions because what has happened is that the income growth has come in a big way. If you look at the aggregate world income it is accruing to different countries in the world, including countries like China and India, and, in the last 20-30 years China and India have got increasing proportionate share of increases in incomes, so more people in India and China have come out of poverty than elsewhere and therefore when you measure the inequality, when you put all of in the same bucket as if all of the world population was one country and then you compute the inequality coefficient, the Gini Coefficient, it actually has gone down. So that is an interesting titbit. Why is inequality bad? First of all income inequality is inevitable as I said. Next thing I wanted to establish is that income and inequality will relentlessly keep getting worse, especially wealth and inequality. The reason for that is - it is little bit of a Marxist framework, but this was also revived by in a famous book of 2013 by someone called Thomas Piketty who wrote a book named, Capital in the 21st Century and he looked at this phenomenon of inequality of wealth and inequality of incomes but he did not used data from surveys or consumption spending or national income, he went to income tax data and he did

that for OECD countries, so in his study he did not include countries like India because income tax data was not readily available and as I said only 3 or 4% of the population pays income tax in India. Income tax data tends to be more reliable because people have to report their incomes. So we don't have to depend on income estimates from sample surveys. While looking at income data derived from income tax returns over a period of over 100 years, Thomas Piketty was able to show that the income which goes to the labour - so if you divide the society, if you divide the economy not by income, i.e. 10%, 20%, 30%, 40% but divided into people who are deriving their income from crony-capital and from their own labour - so basically income that goes to labour and income that accrues to capital, it was seen that the returns to capital are higher than the growth rate of income in the aggregate economy that means the capital class in a developed country, people who own capital, who owns shares, who participate in the stock markets, in the financial capital markets, their returns tends to be higher than the growth rate of aggregate income of the whole economy. So this is the famous condition and of course there has been much debate and much discussion on this fantastic book of Piketty which is almost 2000 pages. It is a quite magnum opus but he established that returns to capital are higher than the growth rate of aggregate income. So imagine that the national economy pie is increasing but in that pie the slice which is owned by the capitalists is growing faster, so the share of income going to the capital is faster and capital ownership become more and more concentrated. I just gave you some statistics about business and profit concentration but increasing concentration of capital ownership and wealth tends to get transmitted through bequeaths and inter- generational transfers, so that capital ownership keeps getting more and more skewed so the wealth equality becomes worse and this is the central insight that inequality will get worse. Contrary to the findings of popular wisdom of the 1950s and till Piketty's work, the popular understanding was initially in a development when a country develops initially some sectors race ahead, like the IT sector of Bangalore - they become super rich earlier but sooner or later they start buying houses, they start employing masons, architects, then they access other services, consumer goods so those industry start benefitting and growing, so this is a trickle down theory and sooner or later other sectors catch up, so this gap which was initially wide becomes narrower, that was

the Kuznets hypothesis. Simon Kuznets, Nobel Prize winning economist had said that in the course of development of an economy, income inequality gets worse and then it gets better and then he pointed to Scandinavian countries, Finland, Denmark, Sweden and he was able to show that actually we need not worry about it as initially it get worse and then gets better. But Thomas Piketty has actually been able to demolish the hypothesis, he says what happened is that the two big World Wars which happened in the 20th century which actually ended up destroying a large amount of capital and since the capital stock shrunk, so the return to capital was rising but the capital stock itself was destroyed. So that was wrongly manifested as if the share of capital went down and therefore labour income and income inequality post World Wars, inequality reduced after growth. If you correct for those two accidents/events of 20th century inequality has got worse and worse and I hope I am able to persuade you that income inequality is the feature of capitalism not the bug but I am now going to say that if it starts beyond a certain point, what starts happening is that it starts creating social instability that is for more and more people it creates insecurity to investments. It starts creating conditions which lead to declining law and order. It starts creating conditions where investors will become cautious and risk averse investors will try to cut back and it can also lead to other things like communal tension, other dimensions and if that starts happening then more and more resources will go for maintaining law and order, law enforcements and reduction in crime, etc. so that actually at some point starts hurting economic growth as investments falls, economic growth and income growth will fall. So you can trace that to inequality. I want to say that each society or each economy has to decide at what stage inequality becomes unacceptable because you can't obviously have zero inequality that will actually kill our incentives. If you compulsorily enforce policies that will equate everybody's income it will be completely anathema or incompatible with creating conditions for economic growth and enterprise. The other extreme is that if you have such high extreme inequality, then it creates conditions of crime, social instability, investor nervousness, risk aversion, that also will kill entrepreneurship or new initiative for investment and therefore hurt economic growth. So we can see it is some kind of an inverted U to less inequality having coercive policies of redistribution of money and equating income is bad for

economic growth and too much of inequality is bad for economic growth. So how much is the right level, for that the economy doesn't have an answer to this question. Conventional economic theory can tell you that free markets, competitive conditions, equality of opportunity, create conditions for rising economic and rising incomes. Competition and economic reforms create conditions where you can maximise potential, maximise productivity and you can get efficiency gains, you can have more efficiency or more competitions. For Indians, after 1991 when we opened up the economy, Indian producers were exposed to foreign competition that made Indian firms more efficient because of competitive pressures. So efficiency gains, productivity gains, income gains all that we can explain, but economic theory cannot explain concepts like fairness and justice, this is beyond the domain of economics. That is, inequality is a consequence of economic growth, but economic theory is silent on how much inequality is unfair and that question can only be answered through a process of collective choice, through a political process, we need to have policies which reflect the will of the people. When I give examples of Brexit or the election of President Trump that was a political process. This was the process by which they were able to elicit the public sentiment, this is not an economic process. At some level we need to worry how much inequality is too much and as I have said, you can measure now inequality of income, of wealth, of equality, of opportunities, of access to public goods like primary health care, primary education, even digital, we have to worry about digital divide in India. Even as I speak, we are connecting now over the internet data and so on but almost 400-500 million people in India do not have access to high speed data. In fact I believe 400-500 million people are only 2G subscribers. So it is creating digital divide, people who have access to digital resources have got to race ahead, should we worry about this? Of course, these are guys who are creative, they create more wealth, value and therefore create more jobs and jobs will eventually go to the other people who lag behind the so called left off but at what point do we start worrying about the inequality created by the digital divide. I also mentioned earlier that I also not have much to say about it but the increasing concentration of profits, increasing concentration of ownership of business, in sector after sector, industry after industry, is that a good thing? By the way, you have these level of concentration usually in a

free market economy like the US, to some extent in India as well typically the test that is used, what is it doing for consumer welfare, that is if these large companies, if I am a Google user, if I am getting to use my search for free, I know I am touching topics which lead to very big and deep discussions, I don't want to go into that way, I am just saying that the test that policy makers and regulators or competition authorities use, is that they don't say they have to worry about large increase in concentration and ownership of property. The test is always of consumer welfare. The consumer getting better products at cheaper prices. If that is so, it passes. Getting free data services, free voice telephony, is it good for the welfare of the consumer? If yes, then we don't worry about concentration. For at some point this is going to reflect the inequality that I just described in earlier part and we will have to be facing this issue.

I also want to say something about the fact that inequality has a way of perpetuating as well. That is to say it used to be believed that if you are in the lower income ladder, so long as you are given the opportunity you can rise to the top but what tends to happen is that the people who are in the lower income categories, they also have access to poorer quality schools, poorer quality education, poorer quality food, so in a way that feeds into the human capital formation of the next generation. Imagine a hutment dweller living in a slum or near the highway and infants and children who have to inhale petrol and diesel fumes with lead content, soon affect their brain, so their brain development is going to be arrested or going to be slower right from a very early childhood. So if the competitive economy is going to reward the people on the basis of IQ and competitive exams they never stand a chance, so they will remain in the lower inequality ladder and their children in turn will also remain so. This element of perpetuation, perpetuating of this inequality is also a feature, this is the way the competitive process works. There is one more reason we need to pay special attention to inequality but on the question of how much inequality is acceptable, tolerable and how much is not, maybe we should mark it to the next segment. We should take a break now and come back to the last segment.

Prof. Sudarsan Padmanabhan: There are quite a few questions. I don't know whether you remember this or not, in 2008, at the Pan-IIT meet, you were moderating Prof. Amartya Sen's talk at IIT Madras, many of the question you have addressed were actually raised during that discussion. So Prof. Amartya Sen was talking about people's happiness, he was talking about quality of life, he was talking about equitable and also life of people where potential can be actualized and injustice can be reduced, inequality can be reduced and poverty could also be alleviated. It is more of philosophical exigencies.

Dr. Ajit Ranade: Economics is silent or unable to answer questions of justice and fairness. How much as members of society or citizens of India how much should my rights be, you know our Constitution makers spelt out the fundamental rights, but subsequently in the last 50-60 years, those rights have been expanded, I just mentioned some of the rights, but say something like Right to Life, Article-21 was slowly expanded to include Right to Clean Environment. So today, Right to Clean Environment is linked to Right to Life. These are the kind of things that are beyond economics, as a society we have decided certain rights, some countries have enforced these rights and have implemented the Right to Internet Access, Right to Electricity, Right to Drinking Water, these have been elevated to if not fundamental rights, but to a very high level, I am sure the time will come and I am told that even if you go to prison in country like Sweden, a prisoner has the right to internet access, you cannot deny internet access to him.

Prof. Sudarsan Padmanabhan: I had asked the question about digital hierarchy, who make this digital hierarchy? In Finland, ten years ago and even earlier they made access to internet a fundamental right. There is also the question about the role of technology in perpetuating inequality or economic divide.

Dr. Ajit Ranade: One comment I would like to make on this is that, you know the economic growth in an economy or country happens by investments. So you have capital stock, simplest example is you think of farm producing let us say corn or maize. Let us imagine that you have

a farm land and you produce corn and next year you need to replant the corn to produce corn again, so out of your total output some of it has to be set aside as seed for the next year, so what is available for you to eat and consume is what is called consumption, may be 80% what you consume but 20% of your production is set aside because that is required as seeds to plant it again. That is the simplest way of describing how an economy works. You produce national income, total GDP, some of it has to be devoted towards investment activity, building new factories, new capacities, new farms, new seeds, innovation and so on. It is investment. Investment to GDP ratio in a fast growing economy used to be 40-50%. Imagine 50% of national income was set aside not for consumption but for investment. That is too high, but India also had an investment ratio of 36% in 2008-2011, it has fallen to about 30% or 29% now. This is called investment in capital. Now capital stock itself is the dollar value or rupee value of all the productive capacity in the country, factories and farms, but increasingly a big part of productive capital is human brain, it is human resources, because actually if you have more trained manpower, trained people with college degrees, engineering degrees, technology, knowledge they are the ones who are going to lead the innovation and creativity and increasingly the capital stock of the country then consists of physical or financial capital and human capital. Human capital is nothing but accumulation of skills, education and knowledge and so on. In advanced countries, the rich countries, the north European countries or America, 80% of their capital stock is in human capital form, but in India it is only 20-25%. So the wealth of the country increasingly is its human capital and when you mention these things like agriculture and all, human capital actually resides in the technology, it is much more valuable in finance and technology. I don't think human capital can be manifested in agriculture - agriculture is important but over long periods it has a shrinking role in the economy. Agriculture was like 30% of GDP 20-30 years ago, now it is only 15% of GDP. It doesn't mean food is not important, it just has a lower economic value, bigger value is human capital and there we have seen greater and greater divides, the divide in human capital is huge, the difference between human capital instead of calculating income and inequality, if I calculate the inequality in human capital it is huge.

In the last segment I want to discuss is how much is too much and what can we do about it. Here for me the useful way of understanding inequality is to compare into industrial pollution. Basically no industrial production is possible without some pollution. Just they are not visible to you the particulate matter, it doesn't mean that the SO, the sulphur oxide or carbon dioxide not there. So all industrial activity produces pollution, even talking to each other or through this zoom screen or internet, everything is working on electricity, but this electricity is made possible because we are burning coal somewhere and of course we are trying to make electricity using solar or water or wind energy, for solar energy we need to make aluminium solar panels or those batteries and aluminium is a highly energy intensive product, to make aluminium requires aluminium refining and this refining process requires burning coal eventually. So no industrial growth, no economic growth is possible without some amount of pollution and we accept it as a trade off. In fact there was a time when we didn't even think about this, but increasingly when we realize that we need to look at things as you said like quality of time, air and water quality, particulate matter, when we had new environmental norms that is when we started saying pollution is acceptable but beyond a limit if you are producing sulphur dioxide then you need to put the sulphur scrubbers, you need to convert it to something into sulphur. If you want to produce CO_2 then you have to do carbon sequestering. Of course, it is a global issue. We tried to introduce market mechanisms like carbon credits; we tried to put incentives so that people reduce the production of CO_2. I want to perhaps compare that with inequality with pollution. At some point inequality starts becoming too much and we have to start introducing measures to curtail further increases in inequality. So inequality let us accept it as inevitable and it is a consequence of or a feature of capitalism, it is indispensable almost up to a point but unbridled growth, unshackled entrepreneurship, unshackled capitalist growth, free market economy, needs to have some countervailing mechanisms to curtail inequality. How do we do that? In Thomas Piketty's book, basically if you want to reduce wealth inequality, you got to take away wealth, beyond a certain accumulation you need to take it away. That is called a coercive method, only the State has that power, it is called taxation, you need to introduce wealth tax. Problem is that wealth is very difficult to measure and there will be lot of

resistance to it, valuation of wealth is also difficult, imagine now in India we discuss things like capital gains tax. So one form of wealth is your land but another wealth which easier to measure is the wealth you make in the stock market or through capital transactions. You can do that if you have capital gains, if the wealth that you get through capital gains is expanding then you introduce a capital gains tax. That has got lot of resistance because after almost 20-30 years finally our government is able to pass a legislation to introduce capital gains tax. So if you make capital gains short term, that is you gain within a period of within three years, then you have to pay 10% tax on that and beyond three years it is no tax or zero tax. So we have to have some taxation on wealth. The second way to do it is through income tax, i.e. income inequality to reduce it to income tax. Incidentally I just want to give you one titbit here, about incomes or salaries of Managing Directors. SEBI, the Securities Regulator in India, introduced new regulations saying that all listed companies have to disclose what is the ratio, doesn't want it to disclose everybody's salary but at least as a statistical measure, companies are required to disclose the ratio of the salary paid to the Managing Director or to the CEO to the median wage paid to all the employees in that company. Can you imagine what the ratios are, these ratios are comparable to the U.S. In the U.S. as in the Indian listed space for some companies the ratio is 1:500 that means the top boss is getting paid 500 times the median, not the lowest, the median wage. The ratio in most of these companies is around 1:200 that is also by the way an example of inequality. Interestingly while the ratio is 200 or 250 for private sector companies, if you go to public sector companies including banks like SBI and so on, that ratio is down to 5, 6 or 10 even less some times. So there is a huge difference and divide when it comes to the compensation paid to the Managing Directors, it is now reported to the Stock market Regulator and the question is that what is the basis for this. So the basis for this is that the MD or CEO contribute leadership and is responsible for getting value for the share holders, is responsible for increase in profit or share price of the company. So some people did a study, they looked at the growth rate of profits and share value of companies across these different sectors in private sector and they tried to correlate the CEO salary ratio with increases in market value, share holder value or profit of the company. It is not surprisingly, the value creation was not correlated with these very skewed ratio. Sometimes

it was opposite, that is the companies which were actually less unequal pay skewedness were creating more value for share holders as well as profits. So this is an example where they are actually reducing inequality. I don't want to generalize too much from it, this is from the corporate sector but this does give some clue that perhaps reducing inequality can be value enhancing, can be economic enhancing of wealth. I would suggest that we agree that income inequality should be capped by measures such as wealth tax, for example, one measure that is often discussed but never passed so far. Every year during the formation of the Central Government Union Budget, they discuss about inheritance tax. That is a random lottery, a child born in a rich or poor family why should this random lottery be available with zero taxation. It is called inheritance tax and it gets shot down. It used to say that lot of companies and families have ancestral property and if you try to tax it, it has to be broken out, it has to be liquidated because often these families have value of house they own in prime locations in cities has great value but it is not cashable if you start taxing it they will be forced to liquidate the property to divide it. So for various reasons inheritance tax which is an idea which didn't fly, wealth tax is funny because in Mumbai the city which I live has one of the most expensive real estate, forget the pandemic for the time being, there is slump in real estate prices but the real estate in Mumbai is a gold mine. If you look at the property tax collected from buildings in Mumbai it is miniscule, it goes to the Municipal Corporation, the collection from wealth tax or property tax is very very low. In fact not too long ago, the Mumbai Municipal Corporation, the major source of income was not wealth tax on property which it should be but something archaic called the Octroi which is from the time of Aurangzeb which is a tax on vehicle entering the city either through road or by rail or by sea. Of course the Octroi thankfully got discontinued, and as part of the GST bargain, octroi was removed, the city doesn't have a reliable source of income except the GST share that comes to the State and eventually comes to the city. I am saying that what really logically as you know in developed countries the logical source of income to run in cities and city governments are our first line of interface, in our daily life our interface is not with the central government in Delhi, we don't interface with our state government in our daily life, our daily life we interface with the Municipality or Panchayats or Village authority, they are the poorest of

taxing authority. Their tax economy is very very low. I am saying, ideally the cities should at least be able to tax the wealth at least that is in the form of property, landed property, that is also not done so far. So I would say, going back to income inequality we are struck with second string solutions like income tax and already there is a lot of reservation and grievance against income tax because first of all only 3 or 4% of the population pays income tax, invariably the salary earners and so called middle class, they are not really middle class, pay income tax, so any suggestion for increasing income tax will be met with resistance, often we can't think about it. So we have gone to the third best solution, we have gone to the transaction tax, GST. Unfortunately GST is a transaction tax, it is like on every transaction you pay, it doesn't depend on whether you are rich or poor, person involved in transaction. So, for example, if you buy masala dosa for a hundred rupees, the GST is eighteen rupees, so eighteen rupees are paid whether you are in the lowest income strata or the highest income side. So the GST taxation is efficient in terms of tax collection, it is efficient in theory at least because it removes tax leakages to a large extent to the economy but it can lead to more inequality unfortunately. This is the form taxation called indirect taxation. It is blind to the income distribution. It is just a transaction tax and effectively and actually hurt the poor more than the rich. So while we try to reduce income inequality through coercive methods like taxation, instead of using direct taxes like capital gains or wealth tax or income tax, we are forced to resort to things like indirect taxes like GST or import duties. So we have a long way to go, as I said. These are issues where collectively as a society we need to decide on them and that can happen only through political process. Our political representatives have to debate this and have to try to define the will of the people and then of course deal with competing vested interests and lobbies and counter lobbies but from an economic standpoint I would say income inequality in India is becoming worse, wealth inequality is even more worse, if you have inequality in other measurements like access to public services and so on, it is much worse, regional inequality is widening, I have not even mentioned things like social or gender dimensions along caste lines, along gender lines, along religious lines, so whichever way you look at it, I don't see enough forces in society which are an effective counter-force to automatically reduce the process of inequality. We need to actively build a constituency

which supports anti-inequality measures. I can quote from a speech, as a society and nation as a constitutional republic we have actually started with political equality. In fact, we take pride that we are the only country in modern times, in the modern world, which introduced political equality right away from day one, everybody man or woman, Hindu or Muslim, low caste, high caste. So political equality is one of the key features of our Constitution, but social and economic inequality is the reality and which is even more unequal. So here is the speech which cautions us about this inequality. The speech says that our republic was founded on the principle of political equality but we are facing this glaring show of social and economic inequality. So the person says in his speech, how long shall we continue to live this life of contradictions, the contradiction is between political equality on one hand and social and economic inequality widening on the other end. How long shall we continue to live this life of contradictions. How long shall we continue to deny equality in our social and economic life, if we continue to deny it too long, we will do so only by putting our political democracy in peril. We must remove this contradiction of political equality and social and economic inequality at the earliest possible moment or else those suffer from the inequality will blow up the structure, the edifice of political democracy which we have laboriously built. This speech by the way was made on November 26, 1949. This speech was made more twenty years before the worst incidents of Naxalite movement started in Naxalbari in 1969. A prediction statement made in the Constituent Assembly 20 years before by Dr. Ambedkar. So it is not like a new thing, we really as a society need to reflect how we think about inequality and its dynamics and what public policy can do to address and reverse it. You have so many examples from rest of the world. May be I will conclude here.

Prof. Sudarsan Padmanabhan: Thank you Ajit. Very apt words from the last speech of the Constituent Assembly given by the Chairman of Drafting Committee of Indian Constitution where he also talks about, for the people, of the people, by the people and paraphrasing Abraham Lincoln, that speech also refers to it is for the people, people will actually benefit through the Constitution. It was a fantastic speech by Dr. Ambedkar.

Piketty also talks about this kind of dissonance, but the French school of political theory, economic theory is different from the American or UK models, so Piketty is much more comfortable dealing with public policy, dealing with democracy, republicanism in addressing social, political inequalities. Piketty himself in his magnum opus, Capital in the 21st Century, talks about many of these issues. You have been slightly more careful and not describing any policy descriptions in your talk but I think there are also questions raised by the participants about the role of governance. Since you are also one of the pioneers, founding members of Association of Democratic Reforms and where it talks about governance as the major issue, specially participation in the democratic process, grassroot levels, various levels, reducing criminalization of politics and also financial transparency of various political parties. So on many of the questions raised by the participants which is about how do we cleanse the clauses of public policy, democratization or creating more equal society if not by fixing the process of governance.

Dr. Ajit Ranade: Few more points, think of yourself, think of ourselves as shareholders in a company. So I buy some shares in a company, the company is going to be profitable so I want to buy more shares and then I find that the management is behaving funny, they move around in chartered air planes, they go by first class tickets, they live in five star hotels when they go for meetings. So I start questioning the management, why did you do this and that. So as a share holder I have to be vigilant about what the management is doing, of course if I am a small shareholder my voice may or may not be heard. So as a shareholder keep an eye on the management of the company so that the company is not hijacked by the management. Similarly, we are shareholders in this democracy and we have appointed on our behalf a management to run this democratic form of government who are people's representatives. So I think as shareholders we have to be vigilant, as Churchill had said eternal vigilance is the price of democracy. So basically think of it that way and because we need to appoint this representative, I hope they are well paid, these are the people who take decisions on our behalf, whether we should have redistribute to taxation, we have to reduce inequality, I think thankfully the political people, political class is sensitive to this but the vigilance of the voter

and vigilance of the people is absolutely essential. Incidentally India has only 3% income tax payers but 100% voters, so India is one country where every 3 tax payers we have 100 voters. It is no surprise that the policies are not responsive so much to the tax payers but to the voter. So we have to wear the identity as the voter and ensure more vigilant and more questioning. Governance and accountability should go hand in hand.

Dr. Susheela Venkataraman: Thank you very much. This has been a very interesting discussion, not one of our usual talk, we had discussed about lot of technologies and discussions on start-ups but this has been very fascinating and very hard talk. You took us right from basics of inequality versus poverty, some measures in inequality and what make sense.

You talked about inequality on different dimensions, so wealth, income as well as human capital and how these are actually getting worse and inequality has been growing globally and even inevitable feature of capitalism something that we need to learn to balance. You talked about the fact that the trickle down effect has its limitations and limited income is working, so therefore where the public policy have a role to play and how can public policy be used to address these failed gaps. You also mentioned that the each country and we as citizens of the country have to decide what the tipping point and at what point of time do we say this much inequality is no more and then hand it over to public policy to play a role and things like that, how we really going to address this.

Thank you very much, it was very very interesting and thank you both Dr. Ajit Ranade as well as Prof. Sudarsan Padmanabhan, thank you both for being with us today and for this wonderful discussion for us. I also want to thank all our viewers for being here. Many of our viewers are regulars but there are many new viewers joined today.

ALUMNI CENTRE

saturday WEBINAR

INDIA INTO THE NEW SPACE AGE: OPPORTUNITIES AND CHALLENGES

DR. K. RADHAKRISHNAN | AUGUST 1, 2020

Dr. K. Radhakrishnan was Chairman of Space Commission, Secretary of Department of Space and Chairman of ISRO from November 2009 to December 2014. He provided strong and successful leadership to the 16,000-strong 'Team ISRO' for 37 space missions including several historic feats in India's space endeavor. Most notably, he is credited for steering India's first planetary exploration mission to Mars (aka Mangalyaan) from concept to fruition within four years, establishing India as the first country to have successful mission to Mars in its first attempt and at a significantly low cost. He has been; an astute Institution-builder with a strategic vision; an able and diligent administrator; a dynamic and result-oriented manager; and an inspiring leader credited with nurturing leadership in the younger generation.

An electrical engineer inducted into ISRO in 1971 at the Vikram Sarabhai Space Centre, Radhakrishnan studied management at IIM-Bangalore and obtained doctorate from IIT-Kharagpur. He held key roles in avionics systems, technology management, space economics and space applications for three decades. Importantly, he rose to become Director of a chain of Regional Remote Sensing Centres by 1989 and the Mission Director for a national space application mission during 1997-2000. During a stint of five years at the Indian National Centre for Ocean Information Services (INCOIS) as founder-Director, he became Vice Chairman of Intergovernmental Oceanographic Commission of UNESCO and the first Project Director of the India's Tsunami Early Warning System. Back at ISRO in 2005, he headed the National Remote Sensing Agency till 2007 and the Vikram Sarabhai Space Centre during 2007-09.

Radhakrishnan is a Fellow of Indian National Academy of Engineering and the National Academy of Science, India and Member of International Academy of Astronautics. He is bestowed with 'Padma Bhushan', the third-highest civilian award in India, Emil Memorial Award of IAF and 50 more awards & accolades. The 'Nature' Journal chose

Lecture at IIT Alumni Centre, Bengaluru, by Dr. K. Radhakrishnan, Former Chairman, Space Commission/Secretary, Department of Space & Chairman, ISRO, August 1, 2020.

Link to the webinar : https://www.youtube.com/watch?v=kPWHhGQ_XmQ&list=PL0zMQ-70IHIX-df3u2Tto6dkKHCRC6iFL&index=17

INDIA INTO THE NEW SPACE AGE: OPPORTUNITIES AND CHALLENGES

DR. K. RADHAKRISHNAN I AUGUST 1, 2020

chose him as one of the Ten people who mattered in the year 2014. His biography, "My Odyssey: Memoirs of the Man behind the Mangalyaan Mission", co-authored with Nilanjan Routh, was published by Penguin India Random House in 2016. Presently, Dr. Radhakrishnan is Chairman of the Board of Governors of IIT, Kanpur and Chairman of the Standing Committee of the IIT Council besides being Honorary Distinguished Advisor in the Department of Space/ISRO. Also he is a Member of the Advisory Council of Pranab Mukherjee Foundation and Honorary Member of UAE Space Agency's International Advisory Board.

Dr. Kota Harinarayana, is an acclaimed Aircraft Designer. In his illustrious carrier of almost five-decades, he has held responsible positions covering entire gamut of Aircraft Lifecycle. His experience includes up gradation of fighters, integration of new weapons, certification and ab-initio design of supersonic fighters, transport aircraft and unmanned air vehicles. He has led many complex and technologically challenging aeronautical programmes. As Programme Director and Chief Designer of India's Light Combat Aircraft, he successfully directed the project and developed first of its kind Aerospace Eco-System in the country. Thanks to his efforts, India succeeded in developing a state-of-art, high technology fighter aircraft of world class.

He was Vice Chancellor of Hyderabad Central University, Visiting Professor at IISc, IIT Bombay , DS Kothari DRDO Chair Professor at ADA and INAE Distinguished Professor at CSIR-NAL. He is one of the founders of General Aeronautics, a start-up incubated by IISc. Bangalore. He is at present SERB Distinguished Fellow at CSIR-NAL and Chairman of the Design Division of the Aeronautical Society of India.

He was honoured with Padma Shri by Government of India in 2002 for his contribution to Indian Aeronautics.

Lecture at IIT Alumni Centre, Bengaluru, by Dr. K. Radhakrishnan, Former Chairman, Space Commission/Secretary, Department of Space & Chairman, ISRO, August 1, 2020.

Link to the webinar : https://www.youtube.com/watch?v=kPWHhGQ_XmQ&list=PL0zMQ-70IHIX-df3u2Tto6dkKHCRC6iFL&index=17

Prof. Ashok Misra: A very good evening to all of you who are in India and good morning to those who may be attending from USA and good afternoon to those who are in Europe. To all the participants, I would like to mention that this is our 17th webinar. We have had sixteen excellent webinars in the past and every Saturday we have some programme or the other. Today's webinar is on `India into the New Space Age: Opportunities and Challenges'.

I have immense pleasure to introduce today's speaker, Dr. K. Radhakrishnan. He was the Chairman of the Space Commission and Secretary of the Department of Space and Chairman of ISRO from 2009 to 2014. He provided a strong and successful leadership to a team of 16000+ of ISRO for 27 space missions including several historic feats in India's space endeavour. Most notably he is credited for steering India's first planetary exploration "Mangalyaan" mission to Mars from concept to fruition within a short span of four years establishing India as the first country to have a successful mission to Mars in it's very first attempt and at a significantly lower cost. You will be happy to know that a movie has been made of those if you haven't seen it, called Mission Mangalayan and I would say it is must watch movie. He has been an astute institution builder with a strategic vision and an able administrator and a dynamic manager, an inspiring leader credited with nurturing leadership in the younger generation, specially at ISRO. Dr. Radhakrishnan is a fellow of Indian National Academy of Engineering, National Academy of Science India, member of the International Academy of Astronautics and honorary member of UAE Space Agency's International Advisory Board and a member of the Advisory Council of Shri Pranab Mukherji Foundation and many many more professional bodies. Actually both Dr. Radhakrishnan and Dr. Kota

Harinarayana don't need any introduction to the Aerospace community, but it is my pleasure to introduce them. Currently Dr. Radhakrishnan is the Honorary Distinguished Advisor in the Department of Space, the Chairman, Board of Governors of IIT Kanpur and the Chairman of the Standing Committee of the IIT Council. He was bestowed with Padma Bhushan by the Government of India in 2014. Dr. Radhakrishnan received the Allan D. Emil Award of International Astronautical Federation and many more awards, approximately fifty of them with accolades. Nature named him among the ten most important people who mattered in the year 2014. He is an alumnus of IIT Kharagpur and IIM Bangalore. In addition to his technical and administrative skills, he is an accomplished Kathakali Artist and a Carnatic Music vocalist.

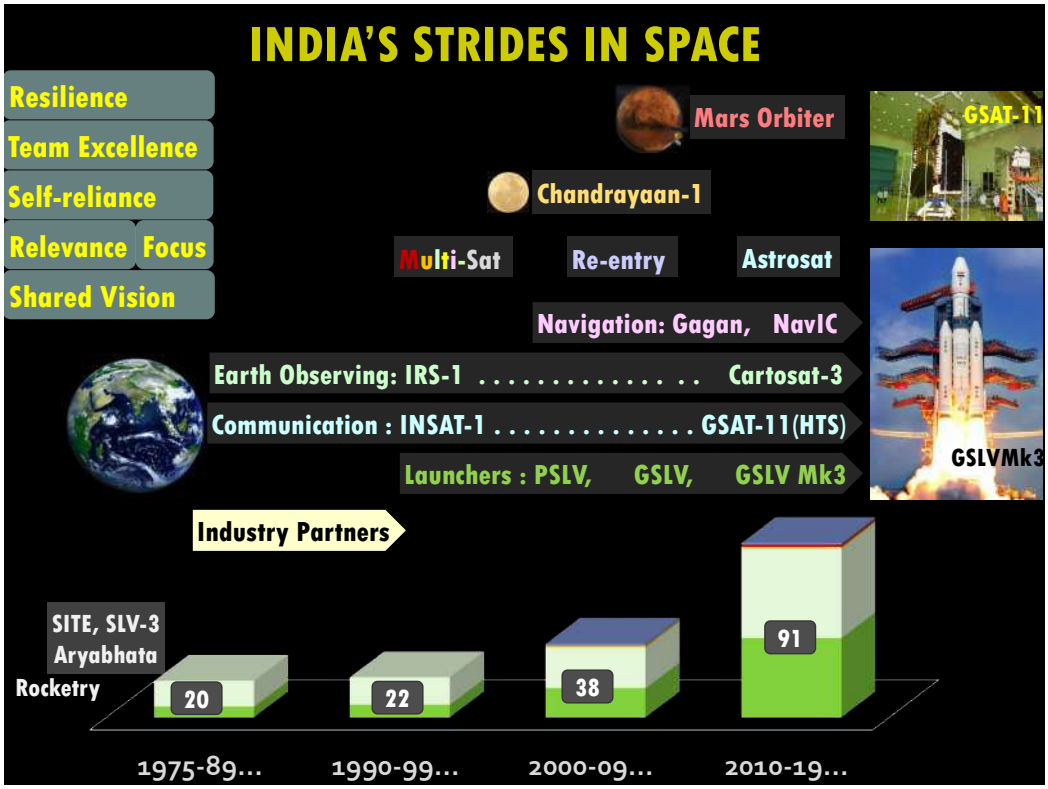
Now I have great delight in introducing our Moderator, Dr. Kota Harinarayana whom I have known for many years. He did his Ph.D. from IIT Bombay and I know him from those days. He is an acclaimed aircraft designer. In his illustrious career of almost five decades he has held responsible positions covering the entire gamut of aircraft life cycle. His experience include upgradation of fighter aircrafts, integration of new weapons, certification ab initio design of supersonic fighters, transport aircraft and technologically challenging aeronautical programmes. As Programme Director and Chief Designer of India's Light Combat Aircraft, then known as LCA, he successfully directed the project to develop first of its kind aerospace ecosystem in the country. India now boasts of developing a state-of-the-art high technology world class fighter aircraft known as Tejas. I had the privilege of seeing the second test flight of Tejas, thanks to Dr. Kota. He was the Vice Chancellor of Hyderabad Central University, a Visiting Professor at IISc Bangalore, IIT Bombay and the D.S.

Kothari DRDO Chair Professor at the Aeronautical Development Agency (ADA). Currently, he is the SERB Distinguished Fellow at the National Aeronautical Lab and Chairman of the Design Division of the Aeronautical Society of India. He is one of the founders of a general aeronautics start-up incubated at IISc., Bangalore. He was honoured with Padma Bhushan by the Government of India in 2002. So participants, ladies and gentlemen, we have two absolute stalwarts in the area of aerospace in the country and we couldn't ask for a better panel, so over to Dr. Radhakrishnan for your presentation and Dr. Kota Harinarayana to moderate. Thank you.

Dr. K. Radhakrishnan: Good evening to all of you, Moderator, Dr. Kota, Dr. Ashok Misra, Dr. Susheela, Mr. Ashok Kamath and all distinguished participants, it has been a great privilege for me to be associated with the IIT System for the last two years and also interact with the IIT Alumni community through the IITACB, Bangalore.

In today's talk I will cover India into the New Space Age: Opportunities and Challenges, essentially I propose to do this in two parts, first talking about India's strides in space and dwell a bit on the space applications in India and then come to the global space sector and the dawn of the new space age.

We could have a few questions taken at that time. In the second part I will talk about the opportunities, the five E's of the new space age and highlight on one specific item, that is India's new frontier into the space exploration with humans and with robotics.

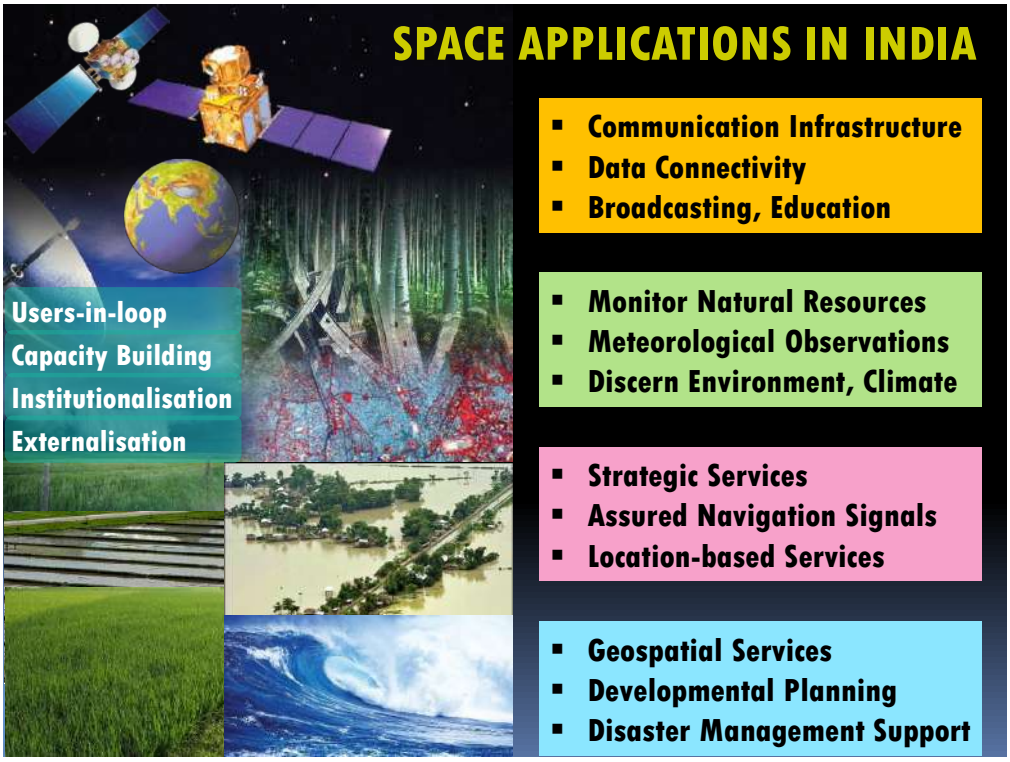


In the 1950s the world talked about the dawn of the space age and India was a new entrant, a start up in those days and an early entrant into this space age. It was 1962 and we started with experiments using small rockets, but the reason it was there is an excitement of doing space science but it is also a responsibility of making using of this medium for the benefit of the common man and the society and that was the guiding indomitable vision of the founder and then came a set of programmes which were to have a few considerations about how that is going to be relevant for the country and what is to be our focus. Self reliance is quite important if we have to stand on our legs for the space programme which essentially looks at applications required for this country. We also from the beginning went with the philosophy of team excellence and in space especially in rocket science which is risky and failures are common and we learnt from failures. So how the organization could become

commercially resilient to the failures that we go through and this has guided the last few decades of the space programme. We started with sounding rockets, they were projectiles but soon in the 1970s we started looking at satellites to be orbited around earth, satellites around there to be used for certain applications and the way to build those satellites. This was an earth-oriented space programme and if you look at the communication scenario the INSAT-1 was the beginning of the Indian National Satellite System in the year 1983 and now we have come to a generation of the high throughput satellites GSAT-11 which was orbited in 2018. This has been a long way as we have put a lot of dots there. The frequencies that we dealt with enhanced from C band to extended C band, S band and now we are in 2 band KA band. Somewhere in 2005, we got into very high power satellites for DTH services and we are moving ahead and if you look at this GSAT-11, we in the world scenario. GSAT-11 is a high throughput satellite to give above 15 gigabits per second data rate and the next one GSAT-20 would enhance it to about 30+ and the world today is at about 100 gigabits per second. High power heavy communication satellites is the direction in which we are moving. Technology is changing and if you look at the earth observation we started using the foreign satellites at one time, we build our own Indian Remote Sensing Satellite IRS-1A that was launched in 1988 and currently the latest one that we have put is a Cartosat-3 Satellite which has a spatial resolution close to 26 centimetre, less than a foot and somewhere in 1995, India became the owner of a satellite which is supposed to be the best civilian remote sensing satellite in the world and commercial applications of that and commercial application of data from that satellite also started. India is having a unique constellation of satellites which can look at land, water resources, ocean meteorology and cartography. Gagan was an improvement of the GPS signal for navigation purposes but assured

navigation signals are being provided now with NavIC constellation of seven satellites. These are all the programmes looking at earth and if you see the bottom part of it, about 170 mission satellites and launch vehicles were done over this period and one could see a progression in the number of missions and essentially the maturity of the technology, the way we have developed and the learning that we had and partnership with industry which started right away in the 1970s - they are all responsible for this quantum jump in the number of missions and the capability for the launch of these satellites came first through the PSLV in the mid-90s and the capability went up when the GSLV came along with the cryogenic stage and the GSLV Mark-3 is the current workhorse vehicle of India which had even launched the Chandrayaan-2 recently. Where do we stand with respect to GSLV Mark-3. If we compare the payload capacity of the vehicles available for launch in the low earth orbit (leo), GSLV Mark-3 has something around 10 ton capability and if you look at the Ariane-5 launcher of Europe, which has done quite a number of commercial launches, it is around 21 tons. Then we get on to the Proton Vehicle of Russia which is about 23 tons. Long March-5 of China is close to 25 tons and the Delta 4 Heavy of SpaceX is about 28 tons. In the recent past we have seen the Falcon Heavy of SpaceX with 64 tons and there are developments going on in the world, in the US there is a space launch system trying to have a capability of launching 130 ton payload and there is a Chinese programme for Long March-9 which talks about 140 tons. This is where we are with respect to the launch vehicles. Now beyond earth oriented space programme, India in the year 2000 got into that was to look at moon - that was the Chandrayaan Mission. There were several new things to be done in this area, one of course is a deep space mission and then we also had to look at the insertion of a satellite into the lunar orbit and designing a

satellite for surviving in the thermal environment around all this happened. It was an international mission, there were 11 payloads and also instruments from India and instruments from other space agencies. We did an excellent job and that was the beginning of going beyond earth. The Mars Orbiter mission was another major inflection point for us in the year 2010 and we started doing that in 2014.



Our orbited satellite is still alive; it was basically a technology mission and we did it quite well. This is the new dimension, Chandrayaan-2 follow Chandrayaan. In the meantime there were other exciting things, one was a re-entry of a module from space to earth that happened in 2007 very well with high precision in bringing it back to earth.

Astrosat was the beginning of a dedicated satellite, a multi wavelength observatory in space to benefit the astronomy community of India and the world and the

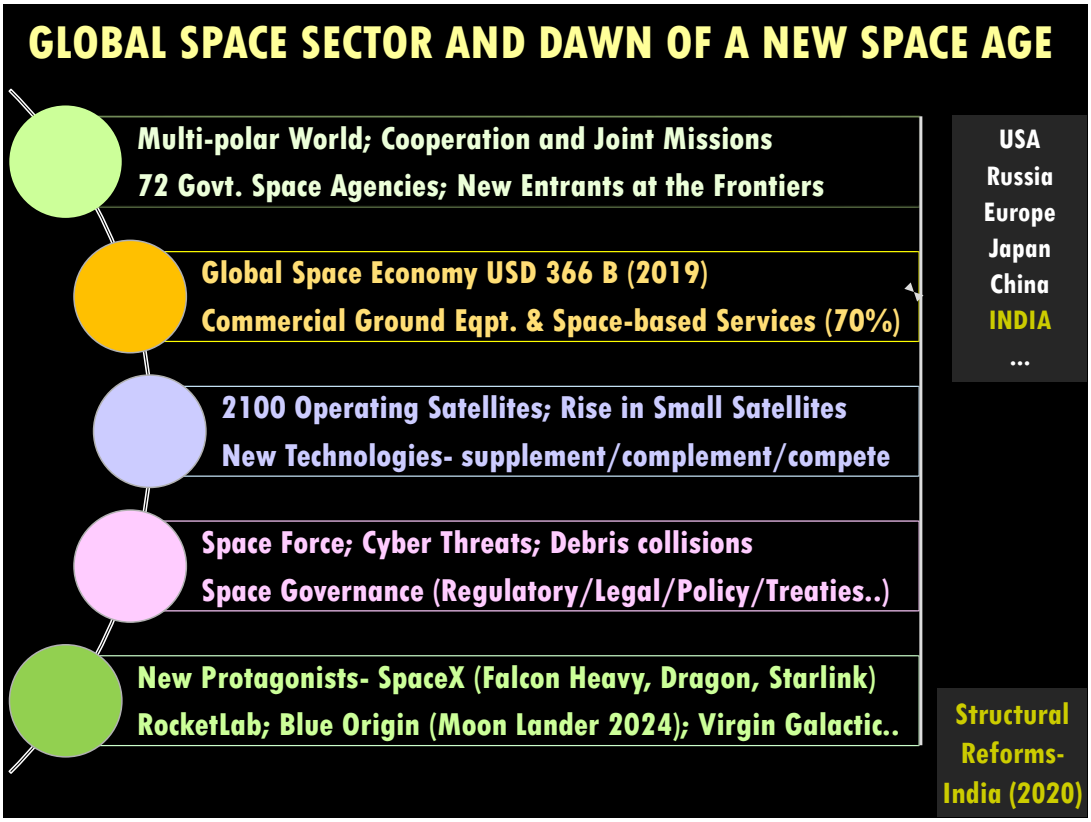
instruments on Astrosat are state-of-the- art and even superior to what we see from other countries. We also see the PSLV launching multiple satellites - we started it in 1999 with launching two satellites and a couple of years ago we had even 104 satellites launched by the PSLV. This is where we are today and we are now at the dawn of the human space programme which we will talk later.

India is known in the global community as a role model for space applications. India essentially starting with the vision with which we started the space programme and the way we planned our satellite systems with the users in the loop from the 1970s whether it is for configuring the INSAT system, whether it is for funding the INSAT system, whether it is for managing the INSAT system or utilizing that for telecommunication, broadcasting, data connectivity or education. When we started the remote sensing programme, the reach was far more for the whole country; central and state agencies, they were all brought into the picture to take decisions together on what we need to build and how do we make use of it, the capacity building required in each of these organizations, to move into the remote sensing data as a tool along with the conventional data system. Doing this as science is good but how do we institutionalize this in the states, in the central agencies, this was the priority of the 1980s, of the 1990s and then slowly started the externalization.It is not sufficient or good if ISRO alone focuses on this, it has to be in the value chain of the user departments and they have to have institutions for doing that. It started with the forest department, with the ocean department and then agriculture departments and there are national agencies today, so externalizing space applications has been another strategy for us. The communication infrastructure, the data connectivity with very high data rates,

broadcasting into DTH, distance education, one of the first priorities of satellite communication, these are all possible through the INSAT satellite system. Monitoring the natural resources of diverse nature, the meteorological observations which support the India Meteorology Department (IMD), ability to look at the environment, the ability of space systems to look at the parameters that are essential to study the climate change, these all came through. Strategic services became very important especially with the Cartosat Satellites. Assured navigation signals using NavIC is also part of that thinking process and the NavIC and the navigation signals provide the location based services. Geospatial services essentially from the remote sensing satellites and the conventional data put together several applications and developmental planning at the state and the central level by all agencies, these are all possible through this system today. Whenever there is a disaster today in India, cyclone or flood, satellite data helps. The National Remote Sensing Agency (NRSA), Hyderabad has a disaster support system working in tandem with the Ministry of Home Affairs and all the States, this has been there for the last 15 years in service and here we get a synergy of data from various governmental institutions processing actionable information is provided in real time to all. This has been a service which India has shown can be done using satellite systems and it is used in many other places. In this area we are the role model.

Global Space Sector and Dawn of a New Space Age:

This is where we are today, the world is here today. In the new space age, we see several new protagonists. SpaceX, whose famous Elon Musk is a role model. Jeff Bezos of Blue Origin and then Richard Branson of Rocket Lab, Peter Beck of Rocket



Lab, Richard Branson of Virgin Galaxy, these are all the new protagonists, new heroes who have invested their money in doing space programme, frontiers of space in a very major way. In 2018, the Falcon Heavy launched a payload and directed it towards Mars. The last couple of months we have been seeing the Dragon Spacecraft delivering US astronauts into the International Space Station. The Starlink with the multiple satellites in the low earth orbit is going to revolutionize the communication. Rocket Lab has done several launches, allowing safe, cheap access to space and at fast pace. The Moon Lander being developed by Blue Origin is expected to participate in the NASA's Artemis Space Programme. So this is the dawn of the new space age with several start-ups coming into the field abroad and in India. Now if you look at the evolution of this over the last few decades from the bipolar world of the 1950s, 1960s, the world got into the multi-polar dimensions

and there are geopolitical considerations of that multi-polar world but one important thing here is that competition has been mostly replaced by co-operation and joint missions together. India also participated in joint spacecraft missions and soon with NASA we will have a mission for remote sensing and disaster management applications. Initially there were a couple of space agencies but today there are 72 government space agencies and the new entrants are at the frontiers of the three Martian missions of this range, one is from the UAE Space Agency an entrant of 2013 which is to be known. Now if you look at the global space economy the number is quite large, US $ 366 billion in the year 2019, this is the estimate by the Satellite Industry Association. There are also estimates which take it to almost US $425 billion, but the point is, it has been growing in spite of the economic gloom all over the world. It is clear that space has got a major role in the current governance structures in the global system. If you look at the 366 billion US dollar and the constituents of that, the commercial ground equipment and the space based services take almost 70% of it and if you look at the government sector, the government budgets like what we provide for ISRO or NASA it is about 25% and the balance 5% goes to the launch and the satellite services. This is the broad profile of the space economy. If you look at the number of operating satellites, it is about 2,100 because small satellites have come to be the favoured technology that has enabled the space agents good performance at cheaper rates. The new technologies are also supplementing the small satellite system and even larger communication systems and also they compete, this is especially so in 5G. There was a time in the 1980s when India started using the communication satellites, there were two kinds of utilization - one was in the golden or the diamond metros traffic if you take satellite support, but when it went to the rural areas, areas which are not

available for the communication, satellite became the main source of services. With 5G now satellite becomes a backbone surface.

Recently in the US, Space Force has come to stay, space is considered the fourth dimension of war. This has been talked about for the last couple of decades and now institutions structures are coming to stay here. Obviously one has to worry about cyber threats ; debris created by the satellites which are in the orbit and their own small parts going at very high speeds affects the satellites which are operating. The new dimension with the small satellite system like Starlinks, like One Web operating in 550 kms orbit is that once the issues of collision are understood and the second issues for astronomical observation there could be difficulties. So these are all the new dimensions to be handy, and space governance becomes quite important. This was quite active in the 1950s, in the 1960s and now again there are several dimensions of it being discussed especially with the exploration of the Moon, Mars etc., so regulatory legal policy matters, treaties these all get provided. So this is the new space age and where India is, India is six or seven in the global committee for the last 15 years Europe, Japan, China and India followed closely by Canada etc. and the recent development in the country is the structural reforms in two areas, to get the private sector as a co-traveller, the private sector to have a major role and also to have friendly policy frame work for satellite. I will stop at this moment and hand over to the Moderator.

Dr. Kota Harinarayana: We heard Dr. Radhakrishnan's excellent talk so far and I think it is an intermission for us to ask a few questions. There were many questions and I

have chosen three-four of them. One questions is from Mr. Dharmendra Kumar, what is the status of reusable space transportation and what are the plans.

Dr. K. Radhakrishnan: Globally if you take the Space Shuttle, this was the main reusable system essentially to use the hardware multiple times to ensure cost effectiveness. But the Shuttle got closed. There was a programme in Russia with Buran but did not operationalize. India got into study of reusable systems essentially for low cost access to space. We had a technology demonstration flight in 2016 that was to understand how this wind body behave as it goes up, and as it comes back. It has the complexity of a rocket as well as an aircraft during this phase but that was only the first step, there are several more steps to be done and there is a programme in this area.

Dr. Kota Harinarayana: So is the programme active - that is what Dharmendra Kumar wants to know. There is another question from Mr. Rajendra, how do we stack up with respect to China?

Dr. K. Radhakrishnan: If you look at the different portfolios of Space, one of course is the launch vehicle. I talked about GSLV R3 with a LEO capability of 10 tons, there is a Long March-5 with a LEO capability of 20+ tons and there is a programme for a larger launch vehicle. In the area of human space flight, China is one country in the world which has grown steadily and fast. We are beginners in the human space flight, but where we excel is the remote sensing satellite system, our constellations are much more versatile and also more powerful. The next aspect is on the interplanetary missions to the Moon - both have done their experiments, and we

had Chandrayaan but if you look at Mars, China tried to piggyback with the Russians in 2010-11 period but that system failed even before it left the earth. But now they have gone with a very ambitious programme and we have to see where do they finally reach as far as the Lander is concerned. So in the nutshell I should say that every country has its own real authorities, every country develops its strength and today we are coming to a world where there is going to be joint working on several missions and of course in applications, India is better than almost everyone.

Dr. Kota Harinarayana: There is one question from Mr. Vishal Sharma, what are the research and academic opportunities in the area of quantum-based satellite communications.

Dr. K. Radhakrishnan: Let us get to the next session and I will clear that.

Dr. Kota Harinarayana: There is one question from Mr. Prasad, lot of space pollution is occurring, are we partnering with other countries to tackle this area.

Dr. K. Radhakrishnan: Yes, in fact that is the worry of everybody, when I talked about debris and collisions, in the orbits where the satellites are operating, there are small parts of the past space assets of the disintegration of the satellites in orbit, altogether something close to 17 to 20 thousand parts going at very high speeds. These are man-made debris we call it, there are also the debris likely from cosmic sources that we will talk about it later. So on the man-made entries there is a system required for observation of these small objects, there is capability required for a modelling and find out how they are going to behave, when they are going to come

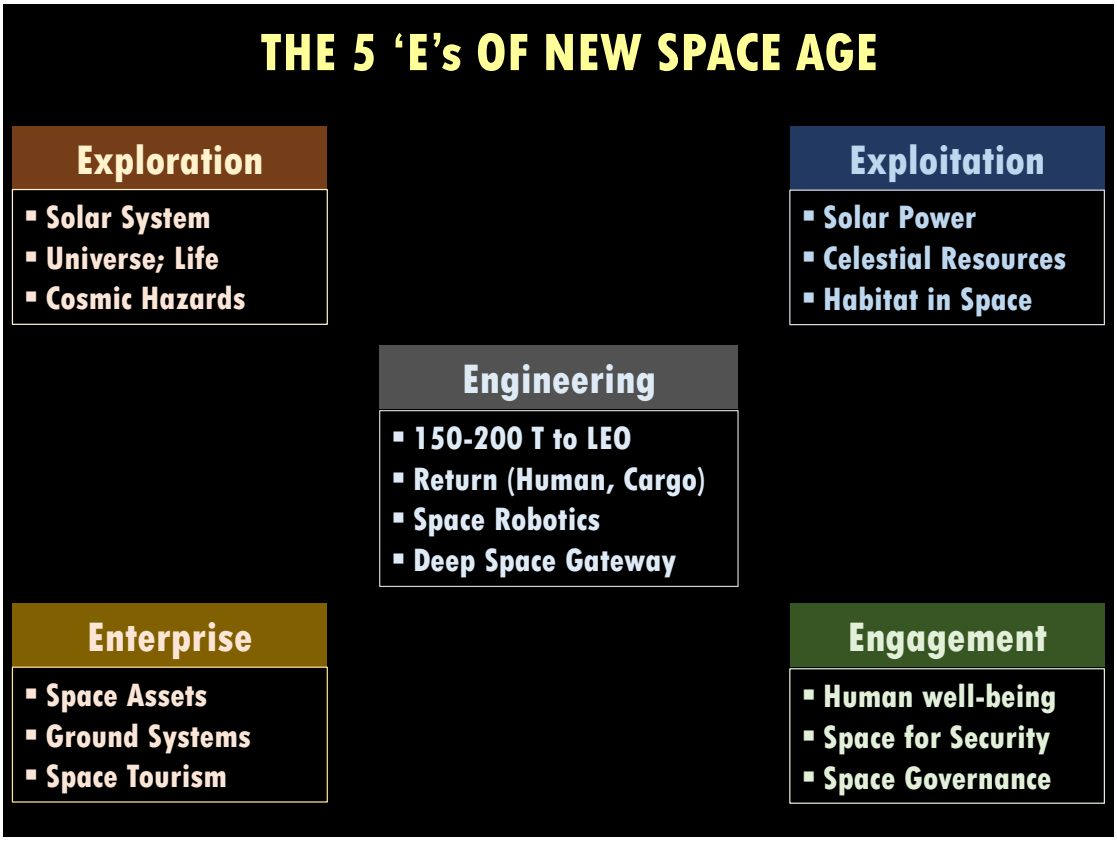
to the atmosphere, where are they going to fall. Third dimension is guidelines to ensure that we don't create the debris, if it happens naturally, yes but don't create, these are guidelines and why these guidelines are required because some countries have created, showed their ability to do that. The last one is how do we scavenge these debris, this is a very important aspect on which the technologies are looking at and there is also a requirement to ensure that the operating satellites are clearly away from the debris. So this process goes on, so India is there everywhere and one point I should talk about, this community conducts a test every year, they take a large object and tell the countries you predict when and where it is going to come under the atmosphere, India had been participating in that and our ability to do that modelling and prediction is quite high, we are somewhere in the top 2-3 in that capability side. We are slowly building up the capability on the ground for observation, there is a multi-object tracking radar in Sriharikota, optical systems are also coming up at least up to the 1000 km orbit, India has ability to look at the objects which are going to be closer to our remote sensing satellites.

Dr. Kota Harinarayana: One more question before you go to the next part of your talk: ISRO has paid a lot of attention on socio-economic values so far but in the decade to come, will you continue to pay attention to that or you will go for a more ambitious exploration of solar system. What will be the priorities?

Dr. K. Radhakrishnan: The answer will lie in the five Es which I am going to show.

Now we will go to the rest of the talk.

The 5 `E's of New Space Age:



If you look at the new space age, there is ample opportunity and challenge for different domains, different communities. On one side we talk about exploration and exploitation. Exploration of the solar system is the exciting science. Today the world is going back to explore the Moon and I say today because in the last 15 years there is renewed interest in looking at the moon. That is how Chandrayaan came about, for example, and the U.S. is now going with the Artemis programme for looking at the Moon. Mars has been a destination and there are several countries now getting into possible exploration of Mars, there is already a set of landers, rowers and more versatile ones are going to go there and I must just say a few years ago when we had the Jet Propulsion Laboratory Director in Bangalore, he told me

we made 25 satellites which are working in the solar system so they have a large number of satellites today looking at the planets, asteroids and this continues. About the universe, that is a problem which everyone looks at, the scientific community looks at it, and the space has been enabled through the Hubble telescope to the James Webb Telescope which is going to come up, and even the Astrosat, they are all part of this study of the universe. Life in the universe this is another area of study and the study of Sun itself has advanced - heliophysics has advanced. If you look at the Parker Solar probe which is going to come closer to the Sun in several years vision period is something which is quire unique. India has its own Aditya Mission lined up, Aditya will be looking at Sun from an orbit which is one and a half million miles from the earth in an orbit called the L1 orbit. When we get into deep space missions, when we go beyond the earth's environment and get into or fathom into Moon, Mars, etc., cosmic hazards become quite important for those. We also need to understand what is going to happen with the asteroid threats, so this is one part of the space activity for the future. How do we exploit the resources from space? Solar power is a classic example, can we have solar power satellites collecting and then beaming power back to earth - this is an area of study. The celestial resources from the Moon, from Mars etc., are interesting, they will be useful, helium-3 from the Moon, for example, is talked about as a potential source of energy. There are also precious metals which could find use here but how do we locate them, how do we exploit them, how do we collect and bring back to earth. So this is one area of study and once it comes here how do we develop the technologies required for downstream process. Here the timelines are 50-100 years but this has to happen. We talked about human beings in space, human beings going to the Moon. Now the community is talking about habitat in space,

living there for more time, going to Mars and if you have to go to Mars and bring the person back, it talks about thousand days of stay in space as against the International Space Station where the record is about one year. So we need to develop a lot in terms of technology, in terms of knowledge, in terms of psychological aspect, sociological aspect, should look at the habitat in another planet or even in outer space. So this is another dimension what is going to happen.

Today we talk about space assets - today the satellite numbers are something like 2000 plus but each one of the constellation that are going to be put by the communication satellite agencies are in the order of thousand micro satellites whether it is One Web or whether it is StarLinks, so it is called space assets, how do we develop, how do we bring new technology into each, how do we manufacture, how do we launch, how do we operate, how do we ensure their safety, how do we upgrade them as the technology develops, these are all aspects of each of them. How do we develop ground systems required to put them into orbit, operate them and also utilize them and there are new areas like space tourism coming up. We have the International Space Station today and even the US is looking at the private sector operating the International Space Station. So there are several novel applications of that going to emerge. This is going to be a large area where money is involved, where operational activities are involved and then the last one is engagement applications of the space systems. Human well-being is one of the important priority and the question that you asked for India too the bedrock of the space programme is going to be application of space for human well-being. Space for security is another new dimension and the governance of space and governance using the space systems. When we come to the human well-being the global

community has collectively brought out the sustainability development goals, SDGs for 2030 and the satellite systems are going to be a major player in this system of SDG 2030. If you want to understand climate it is very clear that out of the 50 plus parameters half of them are best observed using satellite system and the climate is going to be a major priority for the future. Today we talk about resource management, understanding about environment, etc. etc., but now we are in a world where intelligent actionable products using the large amount of that data that we have collected and data analytic capability that we have got, the artificial intelligence capabilities that we develop, how do we get intelligent, actionable products using the confluence of remote sensing navigation satellites and how do we reach it to the people straight in their hands from the satellite using the new technology systems.

There was a time like in the computer systems we had centralized remote sensing data collection taking a couple of weeks to provide that data to the user – then, they will take a few weeks to analyze and find out what happens, but today we have a system that does this in a couple of minutes from the reception that data could reach the user. This is technology where we have but that is raw data, but how do we get intelligent process data straight into the hands. This is going to be a new dimension for the future. Space for security, as I said is a new dimension whether it is for surveillance, whether it is for defence like missile defence or for supremacy. Now countries are talking about this; Space Force in the US has come about, every country has a programme in this direction. Space governance has become more important as we have close to 70+ government agencies, almost 5000+ industrial firms engaged in this activity. If all that we talked about should happen, engineering

is the backbone. If you want to go to Mars and bring resources from there, for every ton that has to come back, we should be able to put 25 tons up. So if you have to have a meaningful satellite cargo coming from Mars then we need to have capability, humans in the earth should have the capability to put 150 to 200 tons. What is happening today is that beyond SpaceX, two developments are Space Launch Systems of the US and the Chinese launch system, these are going to be the two things of the future. We talked about the re-entry mission, why it is relevant in this context. The return of human and cargo are quite important. What India has done in 2007, we had the space recovery experiment SRE where a module was brought back to earth from the orbit. In 2014, we had the crew module launch, brought back to earth. The human space flight will again show us the capability to bring them safely back here but cargo also is another aspect of it.

Space Robotics becomes very important because if you depend only on human in loop for the future explorations there are difficulties, limitations, how do we use an optimum mix of space robotics and the human look for the future, this is one of the major thrust for the future. Something that happened in the last few years globally is that 15 space agencies got together coordinated by the US to look at one roadmap to understand the Moon and Mars. There is a global exploration roadmap prepared in 2018 and it gives a programme of direction for the next 20 years where there is a station in the lunar vicinity, there is a station in the deep space, station near Mars from where the robotic missions and human missions could take place. It is a direction but there are contributions possible from all countries in this kind of a major mission. These are all the broad level challenges in engineering for the future. Now when we talk about the specifics of these challenges in engineering,

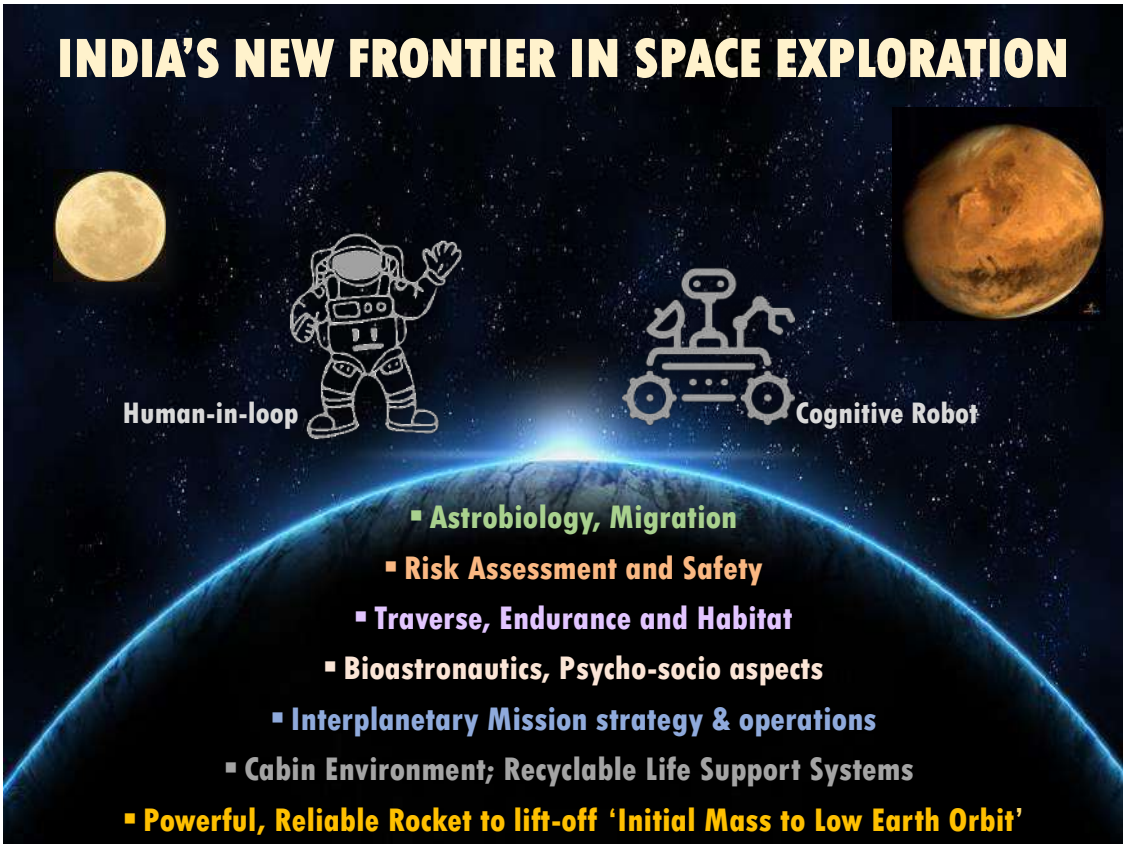
for example in communication the technology has been growing at exponential pace. The enabling technologies, competing technologies have been growing very fast. So going to higher frequency bands now we are okay then how do we get more information put through the satellite system, how do we have more power transmitted by the satellite system, how do we reduce the mass of the satellite system so that we can have more economical way of doing things. The two ton propellant that is carried in a six ton satellite could be replaced if we can have electric propulsion introduced for orbit tracing and for housekeeping. This is taking place now, this is one immediate direction in communication engineering. Now if you look at remote sensing satellite system rather than sending the observed data, how do we put more intelligence into the remote sensing satellite system, how do we make it more smart. The processing that we do at the users side, how that could be done in the satellite itself so that we get actionable products straight from the satellite, this is another major direction.

When it comes to the navigation satellite system specifically what is more important is to get into higher precisions. Today we have a GPS system with 10 meter accuracy and we found we could bring it down that to the 2 to 3 meter by correcting for the ionospheric contribution in the error. Now how do we improve it, that is the clock that we need to have and if you look at the navigation system we have been importing these clocks from Europe. Now there is a major development that has been taken place in this country for this ultra precision, ultra stable alchemic clock. Soon they will find a place in the launch. So this another direction in which technology is going on reuse, re-entry. The thermal issues associated with the re-entry when there are instruments and when there is a human being this is something

to be understood just and how do we navigate them precisely to the place where we want this is another area. So there are several challenges. The propulsion system itself which is the bulwark of all these launch vehicles, how do we make more efficient propulsion systems, how do we make more accurate sensors for this purpose. So there are several things in the offing for engineering community.

India's New Frontier in Space Exploration:

One of the exciting areas for this country, the one portfolio in which we are new entrants is the human space race. The most important part of it is we must have a safe and reliable vehicle system to carry human beings. Dr. Kota talks about transport aircrafts and the reliability, safety associated with those systems. Now here also we talk about such reliable systems and the reliability figures for a rocket that should carry human beings is of the order of 0.99.



This has to be established over the years through the pedigree of the systems, the heritage of the systems and precautions in the design, in the manufacturing, in the testing and the preservation phase of the system. The crew members have to live there whether it is for a week or 100 days or even 1000 days. The cabin environment and the life support system required for the crew members to be there. Now when we talk about around earth, a mission to the Moon, a mission to Mars, what are the mission strategies and operations required for them.

How do we ensure that the astronauts or the cosmonauts are in touch with the ground stations as they go around the earth or in the other planet system. What happens to the human being as they travel in this environment. The bioastronautics, the psychosocial aspects' of the human being is how to be understood. The traverse becomes large, the endurance of the systems and the human being and the habitats that you have to generate if you have to go to Mars. There are opportune times when there can be a mission that is once in 26 months and it takes almost 300 days to reach there. If you miss this, then you have to wait for the next opportune time to come back. So we talk about thousand days, how do we ensure, how do we test on the ground for human to be in such kind of habitats. So can we bring such facilities, such environment can be created in the earth, this is another area. Risk assessment and safety is quite important. They started in US when they started with the human flights and there are standards and there are studies in this area. Astrobiology, when we talk about life in other planets etc., this becomes quite important and what happens to human being as they migrate from one place to another place is again important. So somebody quite nicely put it, it is easy to take a human being into space but it is difficult to keep them safe there and bring them

back but the human being has the cognitive capability to take decisions in situ as they see new things there where as a robot is easy to take and bring back but robot will do what it is told to do. The intelligence or the next step of actions from a stage can be taken not in real time at the moment but may be after some time. This is what curiosity has shown but how do we get into the next step of bringing cognition capability into the robot and the robotics community talk about brain inspired robots. So how can we get into cognitive robots, so these are all the dimensions for the future. So we have five Es, the Exploration, Exploitation, Engineering, Enterprise and the Engagement.

Now the last question which many would be thinking is in the context of the new structural reform that has come into the country. What are the opportunities for this enthusiastic space start up system. They have been there, ISRO itself was a start up and somewhere in the 1980s, several bold entrepreneurs came forward to look at equipment that are required for the applications and application services, that is where we are today. Some of them also got into building systems for the satellites and the launch vehicles and they have made a good progress. So there is one side, production of operational rockets and the operational satellite systems in a consortium along with ISRO, this is one clear direction. The second direction is the new trend of making small satellites provide big opportunities, the student observer themselves have done this small satellite system. So manufacturing small satellite system is another major opportunity. The ground system required for utilization of the future satellites with new technologies, with technologies that we could develop or the technologies that we could bring from outside, this is a major area and providing the services, the new services, their only brain power is required to

imagine what more could be done to the user actually and we have seen in the past decade, many many novel ideas coming out. Now this is a major area and if I go back here, 70% of the space economy today is contributed by such services, grounded system and the satellite services, downstream services. Now there is an element of risk involved in this , the risk involved in a launch vehicle system is high or the highest, then the risk involved in having satellite systems slightly less and when it comes to the ground equipment and applications the risk comes down. At the same time, the turnover goes up in that order actually. So one has to choose whether you require challenge, whether you require excitement, whether you require a safe turnover where you want to be in this dish. So the spectrum is quite wide open for the new entrants and what the government has done is opening up the door for them to get into in a major way and ISRO is there as a catalyst, as a facilitator for the new system.

Here I would stop and will hand over to Dr. Kota Harinarayana, for question/answer session.

Dr. Kota Harinarayana: Thank you Dr. Radhakrishnan for an excellent talk, extremely very happy to listen to you, going from one end to the other end. There are few questions, some of them you have already answered in your talk about the applications and all but there are a few which are important, one is: Is ISRO planning a Space Station?

Dr. K. Radhakrishnan: There has been a talk wanting to put a couple of human being into an orbit around earth for a week's time. We are entering and understanding

what is involved in really doing that and how do we develop technologies required for this purpose. So one of the next steps that is discussed is to enlarge the time of stay to enlarge the area available for meaningful experiment in the cabin which obviously takes us to the concept of space station but when we enter into this human station five years from now, they should be contemporary or state-of-the-art of that period. So this is the challenge in devising a system for that purpose and with the larger end goal what way it is going to contribute to look at the Moon and Mars.

Dr. Kota Harinarayana: Last few decades, you have given attention to socioeconomic activities of the country, so now the role of space in oil, gas and mineral exploration for India. What is the direction you think we should look forward to.

Dr. K. Radhakrishnan: When you talk about oil exploration, the hydrocarbon that is what people talk about, there is an institute in Dehradun, Indian Institute Petroleum, they make use of remote sensing technology. Let me say when you look at the remote sensing satellite systems and how they look at the earth and the resources, they look for specific signatures that could be captured by the satellite for the features which are underground. These are indirect inferences, whether it is soil, whether it is minerals or whether it is hydrocarbons, it requires several other levels of information, types of information to be brought in together to understand to narrow down in the area of search where such resources can be found. Certainly it is an area for the future.

Dr. Kota Harinarayana: The next question is, satellite is at a very high height, so to go to explore down the earth, I thought that still there are a lot of technological challenges which cannot be done by itself, is it correct to think the satellite technology by itself will not help us in exploring underground minerals or oil or anything.

Dr. K. Radhakrishnan: It is a good question, we never believed in that actually. Now if you look at the natural resources management system using satellites, there is a clear requirement of the ground information or collateral information. Depending upon the resource theme that we are looking at the level of ground information will be varying. If you look at for example on one side water can be observed very easily using a satellite system. If you look at the agriculture, if you look at the vegetation, we can look at what is on the surface. When you go to the next dimension of trying to understand the soil, the moisture in the soil which is up to a few centimetres, it is a difficult issue, but what satellite can give is some of the physiographic features and stratification of the physiography. Within that, we must have large number of ground truth studies, then only one can categorize the soil into X, Y, etc. When you get into minerals it becomes more important. There are features synoptically can be seen like a fault line. If you go for a conventional survey in a small area, you may not able to see that but satellite could pick up those synoptic features that is the case for water targeting, ground water targeting also requires this kind of information, but there is a large amount of ground truth required for understanding, so I would say in some case in may vary from 95% for certain features to about 20-30% in the other area. If you look at the forest for example, if you want to understand

the forest density, a satellite can do that but if you want to make a working plan for the satellite it can do only limited purpose, the rest of it is on the ground, but it helps.

Dr. Kota Harinarayana: Two-three questions were there on the space arms race, they were asking, look China is moving forward in that direction to use space as a means to arms control, can India remain without doing anything in that direction.

Dr. K. Radhakrishnan: There are couple of things and I will be quite conservative in addressing this issue. If you look at the remote sensing, the solutions of one metre or even better, they will be able to see several things happening, not only in our country but elsewhere and there is an open sky policy globally. It is we can look at what is happening around the world without prejudice to their security aspects, so this is one area of high resolution satellite systems for surveillance. The other are of course like defence, missile defence system etc. need to be developed. The third part of it is communication, specifically. I would say GSAT-7 satellite was a dedicated communication system with the footprint over the seas. So there are things happening in the country.

Dr. Kota Harinarayana: As a Space Command, the question is are we planning a space command to look at the space as a means to have supremacy.

Dr. K. Radhakrishnan: I may not be the right person to answer that question, but there is a different space agency, it should be.

Dr. Kota Harinarayana: There is one question: Is satellite being jammed by another satellite, lot of questions were there in that direction, what are the possibilities, at all if there are possibilities.

Dr. K. Radhakrishnan: There is a question of the security of the space assets now, if you are using satellite systems for our daily working, whether it is in civilian or in military domain, security of these assets is becoming important whether it is electronically destroyed or physically destroyed. There are several dimensions of study in this area and when you talk about the subject that we just now discussed, this is one of the major concerns.

Dr. Kota Harinarayana: There few questions on: In the world over, are there any plans for governing space traffic control because so many satellites are now going around. Is there U.N. or anybody planning something like a space traffic control.

Dr. K. Radhakrishnan: There is an agency under the U.N. system which is the International Telecommunications Union, (ITU) which has the member states as well as several space actors coming there as observers. So if you have to put a satellite in a geostationary orbit which is considered as a resource in space, it has to be allocated and there are regulations and there are procedures how to get that slot, how to preserve that slot and what are the disciplines to be maintained when you beam from that location. This is done by ITU, International Telecommunication Union. For all the satellites that are required to be put in the orbit, what frequencies are to be used, what power levels are to be used, etc. these are also coordinated and cleared by the ITU, but the new dimension is going to come with the space

debris, creation of space debris or use of nuclear systems in the spacecrafts, on one side you require nuclear devices for powering the deep space missions but if that mission does not live there and comes back to earth what are the damages etc., so these are all the things discussed at the U.N. level there is a U.N. committee on peaceful use of outer space where the common concerns are discussed. Now they talk about the long term sustainability of the space assets. This is one topic being discussed.

Dr. Kota Harinarayana: Coming back to the work that already done by ISRO, when will NavIC, the Indian Regional Navigation Satellite System, available for public use in a big way.

Dr. K. Radhakrishnan: There were several attempts for the ground systems, the receivers that we need to carry, I am sure that soon it is going to happen, the device which can take the signal from NavIC as well as the other systems and I see a lot of developments taking place now in this area.

Dr. Kota Harinarayana: Maybe you need an antenna which can integrate all those systems, a hand held device so that it becomes commonplace because the satellite system is operations but now we have to exploit it by enough groundwork that needs to be done. The other question that was asked was opportunity in space satellite ecosystem performance, you have addressed this point but may be it is worth telling a little more in details, a lot of firms what to make small satellites, what are the opportunities for them, can it be a viable business.

Dr. K. Radhakrishnan: As I said, when you talk about viability, when you talk about the risk involved, when you talk about the facilities or the expertise required, these are the dimensions to be looked at actually. So on one end there is providing the space based services, new services. If you look at the last decade, you have got several novel ways of providing services to the people, which we never thought about in the past. So with the satellite system and the data that we have got, many actionable products could be taken up, this is one area which requires a small office and a good brain and a good reach. When you talk about the ground equipment required for the newer satellite system to be used in a larger way and when we talk about handheld devices which collect the smart data coming from the satellite straight for your use like your mobile now, this requires novel equipment. Ground systems to be made and this is one fertile area for the engineering community to get into develop some of them here absolutely possible because we have got nice ideas or tie up with someone for that purpose, but I would always advocate self-reliance and creation of the intellectual property here itself so that it is not only marketed within India but you have to have a global market in the picture, that is important. When we talk about satellite systems, especially it becomes easy today and there are people saying that from a supermarket you can go and buy a small satellite today, that is the level to which things are happening. So one concept is for science for earth observation, experiments, etc., satellites will play a major role because the risk is small, there is a small satellite you bring a new technology, test it and then make use of it, rather than committing to a larger system. So this is one area for specific applications and if you look at the satellites that ISRO has launched, almost 80% of them are of that class done by students community from various places, so this is one area where we could get. There are also the fly by

configurations replacing a larger satellite with many small satellites taking out a bad satellite and then replacing it or bringing a new technology there to try, so this is another concept. If you look at OneWeb and Starlink, is a new concept of thousand plus satellite constellation taking place, what is the opportunity, can we manufacture, this is possible, so blight manufacturing of whatever they are devised or intelligent configuration of small satellite system, these are two areas where we can get in and what is required is a good laboratory, a clean environment and testing facilities and you need not have everything in-house and certainly agencies like ISRO and other places could be made use of this purpose provided time is available for that. Launch vehicles, now one trend in communication is to go for heavier satellite system or even for the exploration occur much much in your satellite but for the launch of the small system in thousands there is a niche for small satellite launchers, PSLV has a niche, Vega was part of it, there were a couple of launch vehicles of that class 500, 1500, 2000 kg put in a lower earth orbits but with the new concept there is a market for even launching large number of satellites 500 kg and less. So this is another area one could get into but there is an attendant risk involved in this process attendant non-availability of the technology because this is a guarded technology for a launch league. So one is able to get through, it is a very exciting field. It is a thrilling field to have a rocket system but it has to be with the economics associated with that and today obviously there are some 20 plus such small rocket launches being developed by several agencies, so you have to compete in a market.

Dr. Kota Harinarayana: The question in the mind of many of these industries is, today normally we think that if private industry is brought in for large vehicles,

satellites and all, can the private industry make it as cost effective as today ISRO is able to do, there is a doubt on that.

Dr. K. Radhakrishnan: If you take the global situation, many of these space systems are subsidized. In communication satellite, it is basically guided by a replacement of terrestrial systems and their cost effectiveness is important, they compete and when it comes to the remote sensing data from the satellite, NASA tried that in the 1980s but they decided remote sensing data will be a public good especially when it comes to the meteorology, observation for climate etc. etc. Only for infrastructure planning services it is mostly commercial. When it comes to the launch system even for Arianespace, I understand that there is a backing from the government, it is not the total cost plus the margin that is charged to the user. So new models have to develop in this area.

Dr. Kota Harinarayana: In India when you are now asking private industry to do launch vehicles there has to be a model whereby it becomes viable.

Dr. K. Radhakrishnan: For example, there may be many of the high cost facilities which are required for this purpose which will contribute to the cost, what can be done for that, can it be provided as a common service. This is something to be understood.

Dr. Kota Harinarayana: I think that this policy needs to be evolved for this industry to become viable.

Quite a few students have asked this question, how can they get to know about the current research going on in space related field, how the information can and how could they get into it.

Dr. K. Radhakrishnan: If you look at the public communication in this area, there are quite a few sites where you can look at it, space reference for example talks about what is happening in the area of space science, etc. If you look at the space news, under the missions, under the commercial activity, the legal activity what is happening, you get up to date news. These are sites one could access and generally it is comprehensive and it is non-political. I would say they give all the information and there are subject wise areas also, for example if you talk about planetary exploration, what is happening there could be seen very specifically, they do detailed study in those areas. So today if you look at the web, there is plenty of information available from these areas.

Dr. Kota Harinarayana: Perhaps, if there is one or two agencies who can collate them together, bring them together and then make it available to the university system, possibly the university system can engage itself in a much bigger way in a more productive way.

Dr. K. Radhakrishnan: Absolutely, I must also add at this point of time that this has been one of the thrust areas for ISRO too, we have done it in different ways, one way is to bring such subjects into the curriculum and the high school and plus-2 stages. You will find today in geography or in geology or in physics, etc. areas related to the space written, they start about 30 years ago, I would say. Today there

are specific programmes run by ISRO to bring the new generation into the picture. There is also a big initiative in ISRO in the last couple of years to bring them to look at this launch itself. There is a stadium in Sriharikota where at least ten thousand people could come and watch, you know that excitement, that inspiration that provides is something but the question of having an organized system of information dissemination is something which one has to think of. NASA has an excellent system for this. NASA has a very well developed system for public communication and also public outreach and also enthusing the community for example, when they went to the mission Moon, they started well orchestrating the global community to say that yes, yes we all should do it in the moon, these are all programmes directed towards that, this is gorgeous.

Dr. Kota Harinarayana: Thank you very much Dr. Radhakrishnan, I must tell you once, long back I was in the University of Hyderabad, when I requested your predecessor Dr. Kasturirangan that there is a need for universities and ISRO to come together, he arranged a meeting where all the Directors of the ISRO Centres came to University of Hyderabad, I don't know whether you remember, then we found non-science and technology base, some 20 projects were given to social science group, only for one university ISRO gave 20 projects. It shows there are lot of opportunities, we need to see how to expand these opportunists.

Dr. K. Radhakrishnan: I would just add that one should not feel that space is only for the scientists and engineers, for example space commerce has become a big subject. The space law is a very major subject today and the social aspects, the cost benefits coming from the space systems is another major area and if you look at

even the human space flight, there is a lot required to be studied, the psychologists getting into that area.

Dr. Kota Harinarayana: I think may greater engagement as you rightly said is required so that the greater participation from researchers, students can occur and the youth community as a whole can get benefit by that and the country in turn can get benefit by that. Thank you very much Sir for a wonderful talk and wonderful way of explaining all the things, lots of questions you were able to answer. Now giving back to Susheela.

Dr. Susheela Venkataraman: Thank you very much Dr. Radhakrishnan and Dr. Kota Harinarayana. I think as long as human memory goes we have been fascinated with what is out there in many different ways and to day you talked us through how India entered the space age in 1962 and then took us step by step through to where we are now. You helped us understand about earth oriented research and exploration to actually now looking outwards and looking at space and deep space in a big way and I think you have excited all of us by talking about the new frontier for India which is human space missions, everyone is excited about that.

Just a few takeaways from today's talk, you talked about the fact that India chose to invest in what is clearly a high risk sector but that sector has given us great dividends through the years in the way technology has evolved in the kind of ecosystem that we have been able to build and so on. We also learnt that one of the most important things about taking up a high risk undertaking such as this is that we have to learn to build resilience and that you said has been the corner stone of our space

programmes. We can be justifiably proud of our achievements and you talked about the fact that we are global leaders in the application of our space projects. While this is clearly a global initiative and it does require international cooperation and that is the way we are headed but still the fact that we have learnt and have understood how to harness the power of space technology for greater social good is something that we have to be proud of.

You mentioned that this is all possible because of the fact that users were involved at every stage, right from concept through till implementation and I have heard you say this before as well multiple times why that involvement is so important and this is a critical learning not just for space but for anything that we undertake, I just want to highlight that. You also talked about the need for close coordination with this is so complex and the need for coordination between many government and private agencies just to get things done and then keep it going on an ongoing basis, it is not something that you choose to do one time, but while all this is exciting you highlighted two points where there is a lot of work that needs to be done and those are space debris and security and clearly those are areas that are taking a lot of mindset and will need to be addressed, not just by India but everyone who are in space exploration.

Then you took us into the exciting new space and talked about the 5Es, a few important things you said are there is a need for precision and precaution at every step in every aspect of what we do in that area. You talked in detail about engineering required and so on but also so many other disciplines, so this is so deeply interdisciplinary and many questions were asked about, I am in such and

such space and what can I contribute to do to the space programme that India has and I think you gave us the answer by talking about things like bio-astronautics, psychology, sociology and social impact of all of this, law, commerce, so many different areas, so many different skills need to come and have a bearing on the success of our space programmes.

I think one very important aspect is the success of ISROs space programmes has been possible only because of the participation of many entrepreneurs again in all stages of programmes and you left us with many questions that are open and exciting issues that many of us, many companies, start-ups and so on can pick up and find answers to. This has been a very energizing session and I really want to thank you for the time that you have taken to be with us. Dr. Kota, it is not easy to moderate when you have hundred plus questions thrown at you and you have done that brilliantly with the background that you have and the close relationship that both of you enjoy that this conversation came out so enjoyably for all of us.

Thank you very much.

ALUMNI CENTRE

saturday WEBINAR

INDIA AS R&D CENTRE FOR REST OF THE DEVELOPING WORLD FOR INTERVENTIONS USING SUSTAINABLE ENERGY.

DR. HARISH HANDE I AUGUST 8, 2020

Dr. Harish Hande is an Indian social entrepreneur, who co-founded the Solar Electric Light Company (SELCO) India in 1995. SELCO Foundation is a collaborative that strives to inspire and support champions of sustainability across the world. He was awarded with the Ramon Magsaysay Award in 2011 for 'his pragmatic efforts to put solar power technology in the hands of the poor, through his social enterprise SELCO India'. In 2014, he became the CEO of the SELCO Foundation.

Dr. Hande earned his Doctorate in energy engineering (solar specialty) at the University of Massachusetts (Lowell). He has an undergraduate degree in Energy Engineering from the Indian Institute of Technology (IIT), Kharagpur. Dr. Hande serves on the boards of many organizations, both national and international.

Prof. Sourav Mukherji teaches post graduate and doctoral level courses at IIM Bangalore. He did his B.Tech. (Honours) from IIT Kharagpur. He has worked with IBM and Oracle in product management functions (1993-1998) and for the Boston Consulting Group as a strategy consultant (2002-2003). Professor Mukherji is an avid follower of sports, runs marathons, and coaches long distance runners as his hobby.

Lecture at IIT Alumni Centre, Bengaluru, by Dr. Harish Hande, CEO, SELCO Foundation, August 8, 2020.

Link to the webinar : https://www.youtube.com/watch?v=Ohh6qTyWc9I&list=PL0zMQ-70IHIX-df3u2Tto6dkKHCRC6iFL&index=18

Mr. Ashok Kamath: Good evening to our viewers today across India, good morning to those who are including to our speaker today who is sitting in Boston. This is our 18th webinar. Two weeks ago, we had Dr. Ajit Ranade, Chief Economist of Aditya Birla Group talked about inequality and look at it from an economic lens, today we are going to take a different approach. We have Dr. Harish Hande, who thinks of quality of life that needs to be defined in terms of accessibility to multiple needs and opportunity and not just financial resources. So poverty can be removed if there is better access to health, education, opportunities, livelihood and so on. When you mention SELCO, the first thought that comes to people is that this is a company that produces solar equipment, solar energy related equipment but I think SELCO goes much beyond that and when your hear Harish you will figure it out, simply because SELCO thinks in terms of sustainable energy access as an enabler to overcome poverty and I think that is a very important part of the conversation today. More about Dr. Harish Hande, he is a Distinguished Alumnus of IIT Kharagpur, went to University of Massachusetts at Lowell for his Masters and Ph.D., came back and founded SELCO in 1995 as a social enterprise. Under his leadership, SELCO won the Ashton Award for Sustainable Energy twice in 2005 and 2007. In 2007, Al Gore presented the award. He was nominated as the Social Entrepreneur of the year 2007 by Schwab Foundation for Social Entrepreneurship, became an Ashoka Fellow in 2008, won the Magsaysay Award in 2011 for Community Leadership and was also honoured with the Karnataka Rajyotsava Prashasti Award in 2011. In recognition of his accomplishments, the trustees of the University of Massachusetts conferred their Doctorate of Humane Letters of UMASS in 2013. So Harish is a well accomplished person, rightfully so and you will have a fascinating conversation with him. Moderating is Prof. Sourav Mukherji, who was his dorm mate in IIT Kharagpur. Saurav did his B.Tech. from IIT Kharagpur and then has been a Fellow of IIM Bangalore, has worked in sales and product management positions at IBM, ORACLE and at the Boston Consulting Group as a Strategy Consultant and now teaches at the Indian Institute of Management in Bangalore where he is the Chairperson of the Centre of Teaching and Learning, he is also Chair for Centre

for Management Communications and occupies the IIMB Chair of Excellence. So we have two very accomplished people here and look forward to an exciting evening.

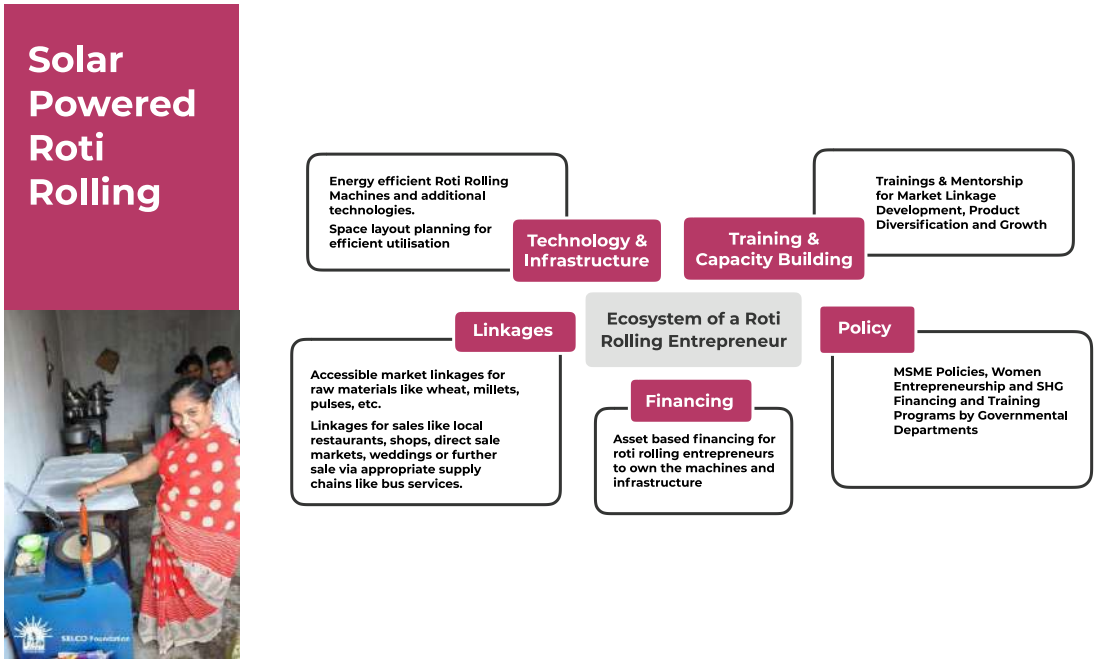
Dr. Susheela Venkataraman, my colleague at IITACB will also be part of moderating group and will sum it up towards the end. Now over to Dr. Harish Hande who will take over from here and speak on how he is using sustainable energy to overcome power.

Dr. Harish Hande: Thanks Ashok for the introduction and it is a great honour to speak here and we have been discussing a couple of things about where our country goes in future now with Covid happening, where are we, we are at the crossroads of many things. So I just want to start of saying that, unfortunately what happens is that the majority of the brunt, whether it is covid or climate is actually faced by the poor and though they are not responsible for both in terms of the climate crisis as well as for the covid crisis, they are bearing most of the brunt. Many of us do have today the luxury of working from home but most of the population does not have the luxury of working from home because somebody needs to build assets, somebody needs to do the unfortunate everything else so that our lives will be comfortable and this inequality of thinking and why is this because in many ways we have been responsible for not creating an ecosystem that provides equal opportunities for everybody and that for us is something that we need to look at. And, as we said that if Sourav, Ashok, ourselves all of us are from IIT backgrounds is because many millions of Indians did not write that exam. So let me be very clear, it was an exclusive exam that excluded many from writing the exam. That is the paradigm and the way we have created society and that is creating a casteism of education and also the thought process that intellectual poverty and financial poverty is the same thing. What makes it more so, I won't say the word unethical but the way we think that we are going to come up with solutions for the poor is also unfortunate because we are not looking at the poor as partners, as innovators and entrepreneurs and that does negate the potential of the 600 million people that live in our country. Very simple example I would say is, if I look at in our own office we had two people - one who supplied coffee and tea at 10

o'clock and her husband used to be sitting in front of the office as a security guard during the night time. They both were new, so we asked “what did you do before”, they said “we didn't do much, we were just in the village of Gulbarga and we came in search of a job”. Well, they must have been doing something in Gulbarga, they were doing nothing much and then as we dug, both were actually brilliant in cotton farming. So just because they were non-English speakers and did not go through formal education that would make them having a LinkedIn account, that we negate their thinking process. Between them, they had not less than 20 years of experience of cotton supply chains, if I had to use the English jargon. They knew water needed for each cotton plant, the productivity of each cotton plant, when the picking should happen, when it should be actually sent for reeling. If they were speaking English, we would call them “Cotton Experts” but what has happened is under the crisis of drought in Gulburga they were forced to migrate to become a supplier of tea in SELCO and a guard in SELCO. So what we have done as a country - we have classically de-skilled people. Even if you take skilling today and say that I am going to train them in motor winding but you have completely deskilled a brilliant cotton picker family with multiple generations of experience into doing something that completely lost that knowledge. So the moment you see Bangalore or Kolkata or Delhi, any of your people who are guarding your buildings we have deskilled them. We have completely deskilled them because we have unfortunately not given value to that knowledge and value to that physical labour and that is very dangerous and we are all responsible. We are all responsible for the institutions that we all come from and why they were set up. So it is a little more pushback to say why were the IITs in the first place or engineering colleges created. To solve the engineering problems, so that is why I keep saying when you teach somebody biology for multiple years and the person comes first in Mathematics are we proud about it, you taught biology and he came first in Mathematics. So people are proud that Sundar Pichai is from IIT Kharagpur but you taught him engineering, he went into Management. So the question is what did he do for four years, where what happened to the engineering that he was supposed to have gotten out of that. The issue is where have we created an ecosystem where the problems of the poor are owned by us that

we can actually come up with brilliant solutions where we make the poor as partners and innovators and thought provokers; as partners to come up with good solutions that are decentralized and democratized in a way where they own the solution? Today what happens unfortunately, they own the problems, we come up with a solution and we try to fit a problem to it. Lot of us don't own the problem. We have replaced the colonial thinking of physical colonization of the British by intellectual colonization and that is where I think as a country we have a wonderful chance to reverse that because we have much more obligation to the 2.5 - 3.00 billion poor people in the world to create an equitable society and using technology and the surrounding ecosystem to not only make people's life better and making society equal but also creating solutions for climate without actually talking of climate.

I wanted to share one slide to just to give you where I am actually coming from. Today, if you look at why people are poor, I mean it is not people are poor because they have a choice to be poor. It is because the ecosystem does not allow them to get out of poverty. It is because of five things. One is the socio-economic inequality that we keep hearing about in the sense of people's opportunities.



To give an example, unfortunately we are known for solar but we use solar as a catalyst for development and in a slum similar to the photo you see in Hubli we went. What we do is we normally put up a solar system for a week, we ask the banker to come, we ask the people to see whether it is valid or not, whether you like or not, we take it out and then people will apply for a bank loan. So we put up a similar system in a slum like this for a week, the day we were removing it, a young kid who came back from school, she started washing vessels, an eight year old or nine year old daughter and as soon as she saw us removing the system, she started rolling in the flour and said " please don't remove it because I want to become a doctor". So the question was, I am sure our society is created in such a manner that she will never become a doctor, she will become another maid servant. So that is the aspiration of millions of eight year old girls. The difference was that eight year old daughter and my daughter at that time was eight years old, why can't she become a doctor because the system will never allow her to become a doctor. The interventions of technology, finance and intervention models will make sure that she will never become a doctor because all that we have created a society that actually pushes for our maid servants kid to be our kids' maid servant and for us is how do you break that, how we break that and so we believe that sustainable energy was a very powerful tool to democratize that and we look at what is the cyclic poverty and how do you create a safety net in a manner that people don't have to slip into poverty and we believe that sustainable energy and interventions of livelihood technologies was a very powerful tool to make that.

So coming back what are the five - we all know about ineffective policies because many of the policies are done by people like us never actually indulging the poor as part of that policy making process. We don't even talk to them, we decide, we do a survey and say what do you need and that is it. Can you even think about when you are designing a policy for software, we are not going to ask Mr. Narayana Murthy or Nandan or anybody else but when it comes to the policy for the poor, we never ask them. We truly never ask them as sitting across the table because there is a mindset in our thought that they are not fit enough to sit across the

table so that is why the skewed development happens. The other way is disasters and displacements, if you look at climate change, we only look at disasters like floods and everything but the ongoing disaster of water for example in the rural parts which forces people like brilliant cotton pickers to shift is because we have not created the appropriate systems of water in Gulbarga leaving them to lead a healthy respectful life in Gulbarga itself. We are forcing them, you know when DLF, we all are proud to talk about Gurgaon being a development city and etc. as a showcase. When Gurgaon started in 1992, the water table was at five feet. Today the water table is two and half thousand feet below. All the high rises and the middle class and the rich can actually put up water pumps to pump up water for their buildings, the same aquifer is used by the neighbouring farmers whose water tables have gone down because of the unsustainable water pumping in Gurgaon, what has that led to, that has led to for them giving up farming and telling their kids we can't do farming and you go and then we complain about slum dwelling in Gurgaon. You have created those slums directly by taking away the resources that they were utilizing for centuries in a manner unsustainability creating in Gurgaon and the water, so we are very much responsible and then we say we are going to do CSR and then we are going to help the poor in absolute hypocrisy. So why are the disasters and developments happening, ineffective policies and leading to social conflicts. Obviously in a sense that today what is happening is when a lot of the people will go in terms of the migrants when we say the first thing that the industry did was fire off the poorest people to make them walk for thousand kilometres, two things, one is we let go of labour because labour is taken for granted, that is not top management, right. It is like labour, we can get them any time, so it is a use and throw.

Number two, we did not create the appropriate systems where the industries were so unsustainable that they have to remove these labourers out on day one nor did we create appropriate roles in the rural areas for them to migrate to in the first place; and, when we wanted reverse migration to happen, when it actually happened, we actually did it in the most unsustainable manner. So using those two paradigms, we asked the question how do we use sustainable energy as a catalyst for development. We basically said, how can sustainable energy become a catalyst for development, so this slide basically says that how can SDG-7 (affordable and clean energy) cut across and what I mean by that, is suppose you have a

sewing machine. Take the example of central Madhya Pradesh where there is drought, now when there are lots farmers committing suicides during summer, what we thought was why do people commit suicide, because there is no safety net, they have taken enough money from money lenders, suddenly they have miscalculated monsoons, what is plan B, there is no plan B for many of them. So in many of these places we found brilliant seamstresses, brilliant in terms of making chadars as well as curtains, so what we did was in many of these places

we provided solar powered sewing machines and what happens is when a farmer commits suicide you break poor into three categories: poor, very poor and abject poverty. It is not one bracketed segment. When a farmer commits suicide the family jumps from poor to abject poverty, it takes two more generations for people to actually come back to the poverty sector, forget lower middle class. So it is very expensive for a country like ours to keep pushing people back into abject poverty because of covid and climate change. So we need to build these safety nets that people don't have to cushion back into the next category. So a solar powered sewing machine is a Plan-B, so the farmer thinks twice before committing suicide. No I will be able to pay because there is a Plan-B even if he does commit, God forbid suicide, his family does not dip into abject poverty, but there are couple of issues. When you design solar powered sewing machines, today somebody blames solar to be expensive but nobody says the sewing machine is inefficiently designed and what I want to come back to the fact is many of the applications today the sewing machine is inefficiently designed. The lathe making machine is inefficiently designed. The blacksmith blower, many of the problems that the poor face through drudgery innovations have not happened, that is why to this audience many of these innovations might not look good enough on a resume but those are things that are needed for drudgery and economic development to happen in a decentralized fashion that people don't need to migrate and the beauty is that you can solve the crisis of employment and the beauty of India being that you are coming up with solutions that also have solutions to climate change, so whether it is blacksmith blower, whether it is a silk weaving machine, whether it is a dental chair, how is it designed for resource poor areas. So there is a huge potential for us to look at technology, finance, delivery models catering to 600 million people and not to the two billion people in the world. To give a specific example, the opportunities for engineers, for financiers, for delivery models, but more from an inclusive perspective, I am also saying that how do we actually use the engineering skills that exist in the rural areas, like if I have to really innovate on a blacksmith blower, do I actually own the problem, so just show one livelihood is, I am showing you a slide, if you look at this puffed rice maker, there are many thousands just outside of Bangalore within 100 kms, making this puff rice, these are

mostly done by very small kids because the space is very small, the temperatures are above 50 degrees in that an at the end of the day they earn 50 to 100 rupees on a daily basis. Nobody has actually worked on the technology of a puffed rice maker, the design of the system from a technology perspective, the design of the building itself for example and also the kids instead of going to school, because of the space and large amounts of heat in a small space, only a small kid can crawl and do it, the problem statement itself has not been articulated and this has been done for generations. Similarly in cotton making or in blacksmith blower, our articulation of the problems also have not happened and we have jumped into IOTs and technologies and web based interface while the basic for the 600 million people innovation actually has not happened and the beauty of having an audience and a panel or webinar like this, can we inspire the young generation that these problems are as complex or more complex than what you think of doing an app for example, but have to be solved. Don't trivialize this by saying that it is a social problem, simple thing like this to tell you that I broke my head talking to the five IITs and could not get a good solution, some of the solutions I got are from ITIs where because the students who come to the ITIs own the problem and they have that fire in their belly that I need to solve it so my father will have a better livelihood opportunity, my neighbour will have it. I think that is the same fire we need to have in students to solve the day-to-day technology issues along with finance.

Prof. Sourav Mukherji: Thank you Harish, I am seeing a few questions coming up, but before we go to that I have a question for you and may be that will also answer some of the queries that have been put up. You haven't talked about the market part of it yet, in the sense that many of the stuff that you talked about, the cotton example or the puffed rice example you gave, there is a power force from the market side and sometimes things don't get recognized, things don't get scaled simply because the market behaves in one way or the other and to some extent that is also true for students from IIT, why is it that so many of the students of IIT typically jumped to do an MBA and then choose a job in banks and I know these are favourite examples of yours rather than staying engineer and there is a very strong reality of

the market. I think you are a very important person to answer this because I know that SELCO, you have set it up as a private enterprise, I mean, one of the options that you could have had in 1996 was to set up SELCO as a not for profit but at that point of time you probably believed that you must also balance the social need with the market forces. So I would like to spend some time maybe either now or when you come back with the solutions in the second half to say that how do we counter or how do we readjust ourselves with the market forces so that we can still meet the purpose of removing inequality where part of the reason why inequality exists is because there are market failures, so any thoughts on that.

Dr. Harish Hande: Today the market is defined by the elite in many ways, us and everybody else who defines what the market does. If you had to ask a blacksmith blower or a street vendor, a simple person like a street vendor, there are two crores of street vendors in our country but those are not defined as market because we negated by their affordability terms but for these, many of the solutions that we would give them, will not give the profit margins that we would like our salaries and our way of life to be met and so we don't consider those two crore vendors, but there are definitely a market for that segment. So why are we only looking at enterprises that can be created by the IITians and the MBAs? Unfortunately, because we are also the policy makers, we make policies according to how our colleagues can actually face but we are not creating policies where a street vendor can actually create a market for herself, we are not doing that. We are only looking at the street vendor as a market but we never look at a street vendor as an entrepreneur and an innovator, how she and he can actually go to become a corporate one day or create a private enterprise that she has a market of her own. So there is a lot of potential in terms of whether you talk about a street vendor, blacksmith blower. So when we brought out SELCO, unfortunately what happens is the true value of SELCO is because out of the 650 employees, 600 employees come from the client base and it is run, for example when I used to run till 2014, out of that 80% of my colleagues were from the rural areas, now it is 100% of my colleagues, for example Mohan Hegde who runs it is from Kumta and it did much better after I and Thomas left, it did

much better, SELCO started to do much better after Thomas and I left because it was truly in the hands of the grassroots and that is the market. So my point sure is are we creating appropriate ecosystem for people like Mohan, Guru Prakash and Prasanna Hegde, to create the organizations, not us because we unfortunately come with a subsidization of so called high salary and defined market and then profitability and then IRR which negates the 600 million people and if we create an ecosystem for 600 million people, there are enough of enterprises, enough of innovations that will happen. So for me the market is there but market according to how the poor defined the market as, not how we define market as. So if you create a good opportunity for a street vendor to modify a cart and she should sell the carts to different cart vendors, there is enough market for her to sell the carts, but market might not be defined according to we are and that is where I have a problem is, the definition of the market itself.

Prof. Sourav Mukherji: Something very relevant to what you just spoke, a question from Sumedraj Hindulkar who is asking that, sometime back in the talk you said the system, he is asking that what system is it, is it the social system, political system, economic system, what do you exactly mean by a system.

Dr. Harish Hande: What I mean by the system is our own internal system of the middle class. See we have replaced, as I said, the British by the middle class system in our country which is the thinking process, for example, of confusing intellectual poverty and financial poverty like my kid should now compete not because what he or she should do according to his/her passion but he/she should compete so that he/she earns more than my cousin. So the issue that I face as I kept telling you when youngsters joined SELCO, the biggest issue that I have is that when the parents immediately come to my office, saying that Boss, "ye SELCO join karega tho iska shaadi nahi hoga", because it is the social sector. I said who told you it is social sector, this is how we say, there are enterprises and there are anti-social enterprises. The issue is I face more problems with the parents saying that his cousin is earning more, do you think he

has a future. The system I am talking about is our own system at home. If we truly want to develop society, if we truly want to develop Bangalore or if you want to truly any poorer parts of the country or the world, the system is asked, are we taking responsibility? It is a very unsustainable way of thinking because you always have a pyramid of inequality and it is like you and me running a race where we are at 50 meters of a 100 meter race and we both of us say we won while many of the poor were minus 50, so that inequality is a thinking system, the systemic racism that we have in our own. Those who did Ph.D. on sugarcane farming are more qualified than a farmer who has done 40 years of sugarcane farming, I think that systemic thinking needs changes and then the policies and that is much easier to do than the systemic thinking, for me that is the system I am talking about.

Prof. Sourav Mukherji: A question which is somewhat related to say that if somebody has an idea about a good technology that will really touch the life of the farmers innovation in the rural India, what about investors, I mean investors are commercial, as urban oriented as it comes and this I am sure you also have talked about it. Any improvement in that dimension or anything that you have found which works with a certain kind of investors who are today willing to invest and take this long term approach.

Dr. Harish Hande: There are two things, there are quite a few investors who are long term and some of the investors that we have, because they come from the older generation, they said, Boss if the type of investors that exist today and if Citibank started today, Citibank would not have succeeded or GE would not have succeeded, the type of R&D money that GE got when GE was started, GE would not have survived in today's type of because the benchmark that has been created is the California tech bubble of faster investments and sort of the hypocrisy also has come out recently in the covid-19, the same investors who went out to scale up a scale are telling cut costs, in December all of them were telling scale up and in June they are telling cut cut, so what is this, do you actually know what business you want to do, though if you had not scaled up so rapidly before, you would not have to cut up and that is

why in our sector we think that Uber and Ola are the biggest not for profits in the world because they will never make money, they are considered market because they are structured but they are the biggest not for profits in the world. To people who ask the question, who are the investors, they also come from our own family, they are also graduated from the IIMs and the IITs. I think somewhere they also have to realize that many of them especially when they come from IIM and IIT, if you talk of investments, the way you talk of IIT should not exist. You would not have got into IIT because you were cross subsidized by the government, the very economics that you speak about but on the good side there is investors, quite a few of them rising up thinking that in this sector there has to be a long-term strategy of long term investment, it is not going to be a two-year exit strategy at 20% IRR and the only thing that now a days the Colombian drug lords can give you but other than that I think there are hope but I also ask the audience , tell me good cases where you are scaled up with the IRR serving the needs of the poor where fundamentally I am asking a business question, can you actually get that IRRs, fundamental, it is somewhere it is mathematically, some people say I have got an IRR then I see they have got quite a bit of tax incentives, well that is a subsidy that you have got. Let's be very clear and I think there is a growth of such investors and covid has really shown that how the previous model of economics will not actually work.

Prof. Sourav Mukherji: One more question before the second part of your talk. You have talked about decentralized growth and there is a question which is coming from Aparna Narayan who says that how can we make sustainable energy options accessible to the poor on a large scale such that they can take advantage of fate to innovate and elevate themselves. So I am just building upon her question saying that is this large scale the only model to grow or definitely you have talked so many times about decentralized yet growth, so can you help the audience to understand these two models.

Dr. Harish Hande: At the end of the day we all want to achieve the same thing. The issue is the way we look at is let us scale up the processes and when Aparna asked that question, decentralized, let us look at a simple example the sewing machine that I spoke about. The sewing machine had two main component, one is technology and one is finance and I will talk about the second component. The market linkage in Kalahandi, one of the poorest areas of our country, maybe the poorest district in the world, where we said 500 families that we wanted to put solar and livelihood options; obviously any bank would hesitate. So we put up a 100% guarantee for x number of people and then what happened was that after six months Syndicate Bank actually told us that they don't need a guarantee because the people were repaying the money and they had created a programme saying that part guarantee of 15% and finance and interest of 10.5% for these 500 clients and their recovery rate was 80 to 82% plus and people who were defaulting, more because of child sickness and everything else and not because they were crooks. The issue upon us is it is not about scaling the 500, can we look at scaling Syndicate Bank's financing process, so showcasing Syndicate Bank's 500, we went to Tata Trust and the Manipur Grameen Bank and said, can you put up a Rs.10 crore fund for Manipur Grameen Bank to finance livelihood applications for the poor. Looking at that the other entity came to Jharkhand and said can we create Rs.20 crore fund. Suddenly we are now going to NABARD and say can we create a Rs.100 crore portfolio fund. See it is a decentralized at the local level but the process got scaled up, so what we are pushing for is the process to be scaled up, what was the trigger and then equally asking Ushas and the Singers to make highly efficient sewing machines so that entrepreneur is able to sell the sewing machine with solar panels and financing available. So you have a decentralized set of entrepreneurs but scaled up processes. So today we confuse scaling up with process and organization that everybody has to reach. Now let us scale up the process, so NABARD's financing or the other technology dissemination or different type of delivery models for example. Another example I will share is that in the Majuli islands which is the largest river island in the world, one million people live there, so what used to happen is there used to be diesel powered boats that you use to go to this island. Because it is diesel powered boats and

these are young sons/daughters who are studying for other exams and need to have the fan and light the whole night and for that the boat has to be running the whole night and so the diesel would run out and they would come back only in one or two days. So what we did was, we powered the boat, not the boat itself but all the appliances, fans, lights, dental chair, running by solar, so the boat actually does not need to come back once in five days or once in ten days. So what happened was is that per rupee invested more number of patients were given services according to the government of Assam and per rupee invested you needed more number of services you could actually do, so we decentralized the option there in terms of provisioning. Two things have happened - one is the government started looking at this as a more economically effective tool, and, it also pushed back. I wanted a dental chair which has 150 features. Because it has 150 features it consumes more electricity, I pushed back to the manufacturer saying that I only need four features; because if you have not designed it for resource poor areas, why do I need 50th feature, 60th feature, 70th feature, and, third can this process be scaled up for mobile health delivery, whether it is a van, whether it is a bus, whether it is a boat. So what is the equalization factor – it was mobility not the boat, we suddenly thought how do we scale up boats, no how do you scale up mobility, equal to think that how do I fit a dental chair in a van, car, bus, train or a boat. So we need to look at scaling of processes and that will lead to scale up of implementation.

Prof. Sourav Mukherji: For the benefit of audience, I think there is a very beautiful video on this whole thing that Harish talked about available on YouTube. It is a nice example of how you are using energy to actually make the healthcare system delivery more efficient and that opens up basis of how I have seen SELCO transforming from providing light solutions to suddenly saying or gradually saying that energy can be used in variety of ways to intervene. Now let us go to the next part of Harish's talk.

Dr. Harish Hande: The second part I want to start with this simple thing as the pottery maker. Blacksmith, pottery-making we have seen for generations happening, but we never intervened in a way that there could be some sort of interventions. While pottery-making people can relate to where the 600 million people's problems and solutions which can actually teach above 400 million or the two billion people in the world that there is an exciting opportunity for us to change. Like here, lot of the youngsters don't want to do it is because of the drudgery of moving the plate base and you have to do it with hands and the loss of incomes, so we basically modified a little bit to make it solar powered where the pottery maker or the sculpture or the artist, and we call him an artist, started to have multiple other designs could do multiple other designs on a daily basis which inspired many of his sons to

come back. The beauty of designing from this also makes it gender inclusive that lot of women pottery makers who were unfortunately not part of the system before just like in blacksmith, the moment you make it drudgery less in terms of physical labour you also bring in the women component or the gender component into it and also inspire the youngsters so that you can take it up. So here in this there are multiple issues that happen, one is the beauty of looking at technology, multiple technologies back end fore end, how do you actually need the mud,

for example is the mud needing the mud technology and is it energy efficient, is the kiln efficient enough because lot of the poorer people, because they spend enormous amount of money in these inefficiencies of products that we have designed, we never look at that any little bit of change in efficiency leads to extra income for them and working with them you actually find out where are they finding the issues. So how do we partner with them and we worked out different ways, so ideally in this case I would work with a technology person, hard design person and a finance person to make a holistic solution for the pottery making and it becomes more interesting when we suddenly see that the layout his factory/office building was so bad that led to lot of smoke, vats where the mud was kept, where the outputs were kept, I mean why do we design Ford factories, Honda factories because we increase the productivity, good layout of a factory or office space, all leads to better productivity and that is exactly what the poor need, better layout, for example in this case it was a redesign of his old building with structures with day lighting and exhaust fans with proper ventilation where the mud is placed, at the outside where the products are placed in a good way so that it attracts people and his work space actually does not conflict with his family life because the kids need to have a space to play, people need good space to cook in a cleaner environment, so the design, so the beauty of this intervention is that it brings in the design, it brings in financial design, it brings in market linkage design and it brings in technology together is what an intervention actually means. Today because we are taught in silos - like imagine a tomato vendor who is an expert in selling tomatoes for 20 years, if tomorrow tomato prices are very high and she says, “I cannot sell”, her three kids will go to starvation, she will start selling potatoes. If I start saying I am a mechanical engineer, I don't know anything else; I am an electrical engineer, I have no clue what you are talking about; we have got away from being solution providers to be just siloed thinking which is practically useless for the world in many ways. What the world needs is solution providers. There are lot of case studies of people but what I wanted to say is that we as a country have a unique chance where India becomes the R&D centre, because we are a microcosm of world's problems that means we can be a solution provider, for example what has happened in the floods of Assam and the way we

would redesign livelihoods and buildings in Assam is something that the Philippines can replicate because the Philippines goes through the same issue when they have floods, the same thing that we do in the drought areas of Maharashtra and in Madhya Pradesh, the way we would look at drip irrigation technology, after sales linkage is something that can be replicated in Ethiopia and for example, if you look at what happens in the Manipur region, the financial immaturity and if we come up with new financial models for putting renewable energy, it is absolutely applicable for Tanzania. Sierra Leone with its poor people, which is 2% electrified plus its human development index (HDI) is higher than parts of Bihar and Jharkhand and Orissa, so whatever we do and the beauty is, in India is that we can get technology business models applicable in Kalahandi which gets replicated in Manipur, which gets automatically replicated in Sierra Leone, looking at the cultural context, so our country becomes the R&D hub of solutions using sustainable energy as a catalyst. So every aspiring kid in Guinea, Ivory Coast or in Mozambique or Indonesia and Philippines needs to look at India saying that if I go to India I can learn for success and failures and India becomes a knowledge house is more than just made in India, I think we are in a right position to think about thought in India and because of the diversity of problems, we also have a diversity of solutions and that is what I wanted to end is that we have such a wonderful opportunity to look at technology. We have in the agriculture space, we have milking machines to cotton picking to rice farming to peanut farming. In the non-agriculture space you have silk weaving to butter churners to blacksmith blower, huge interventions. It is completely a white board that is there in front of all of us and it is for all of us to actually give us to take advantage and finally one thing I would like to showcase is the potential of what I mean is, see the breadth and depth that our country can do. I am just looking at a dairy supply chain from hydroponics to shaft cutters to milking machines to lighting to vaccine storage for the cows to bio-digesters to weighing machines, chillers, butter churner, ice cream machines, all these can be divided into input production, all these 12 nodal points have a huge potential of technology innovation, business and model innovation and everything actually leads to in a decentralized fashion of productivity and income generation. So before even thinking of IOT and internet

and all that everything else which are absolutely critical but there are huge opportunity and potential, this is only dairy chain I am speaking about, the same thing in poultry, same thing in silk weaving, we have more 16 nodal points where research, R&D, technology innovations where India can surely be showcased as taught in India and actually made in India and which can then be replicated in other parts of the world and that is where I think Sierra Leone, 2% electrified, highest maternal deaths in the world, good examples of maternal delivery rooms with high efficient solar powered autoclaves, delivery room designs can be replicated and blanketed. Sierra Leone Djibouti has 22000 sq.kms with one million population, Manipur is 22000 sq.kms with 2.6 million population, so whatever Manipur does is very much applicable to Djibouti, the processes need to be replicated and then what needs to be done is the customization of the products and financial products according to what the culture is. So the

potential for us to look at is extremely high.

Prof. Sourav Mukherji: Would you stay with that slide on dairy technology and take us through one intervention where SELCO has gone and increased the efficiency through redesign and improved the product, just one for the benefit of the audience and I know you guys have done so many transformations.

Dr. Harish Hande: So here for example, if you look at in the shaft cutter, the existing shaft cutters are run on diesel and highly inefficient. So we worked on two types, one is the type of motor and how do we make it highly efficient motor and make it DC powered, so you don't need to bring in another inverter and because many of the shaft cutters, I don't know how many of you know there are so many drought camps where there are cattle camps in Maharashtra and Madhya Pradesh, where the farmers bring those cattle for four months or five months, otherwise they will die in their households. These are drought camps, need lot of shaft cutters, just powering them with electricity or diesel is economically very unviable so in some of the campus we have put solar powered shaft cutters running on diesel and working on making milking machines which run on diesel highly efficient, they were converted into solar power and also customizing it to the type of cows so that the suction does not hurt the cows where we worked on efficiency as well as customization depending on the cows. Then on the vaccine refrigerator storage, in this case it was more of an animal vaccine storage, we actually came out working with organizations like Godrej, giving them multiple sites for innovation, increasing the efficiency saying that if there is no sunlight even for 10 days can this storage would work and also working on business models where we look at vaccine and milk chillers as assets and look at financial models which are similar to how airports are financed. See airports are financially viable, it is the common good that you and me take the planes that leads to better productivity for the country, so the roads, those are all assets financed by the country which are subsidized, exactly what we are saying that the same type of subsidy needs to be given for large assets where poor make money and the storage leading to better GDP of the country. So vaccine and milk is not only technology innovation but it lead to financial innovation. We have worked on all these 12 parts and looked at energy, finance and long term thinking in a sense in the milk and vaccine how do you bring in asset based financing, in milking how do you make a consumptive based financing under mudra loan, while working on a shaft under mudra loan. Also pushing stakeholders like Godrejs and local entrepreneurs to relook at low cost, low resource innovations.

Prof. Sourav Mukherji: I have one question before we can go to the audience for questions. Since you have started with poverty and inequality, one of the countries which has substantially removed poverty at least on official records is China and the Chinese model has typically been described as and obviously there are generalizations here saying that create large scale industrial jobs and get people from rural to urban and given them employment opportunity, give them good compensation, make it financially sustainable and that is it and they have been able to remove poverty in a very large scale and that is what we get to understand about China. So what you are suggesting here is a very different model, a highly decentralized model where we are not even talking of migration, we are saying that go to the villages and find out the essence of entrepreneurship, try to solve their problems and that will be much more powerful way of removing poverty. Is that what you are talking about?.

Dr. Harish Hande: It is a long term strategy, unfortunately what happens is poverty is up and down. Today for example, in the covid crisis and as soon as production came down, China also laid off a lot of people. You have created the poor not as an intellectual force but purely as a labour force, it is a use and throw. What is an aspiration that we have created, it is not democratization of innovation. They have killed a lot of the aspiration and innovativeness that would have been there with somebody. And also take from our failures in the IT sector, let us look at a smaller analogy, the call centres, we created multiple call centres, we enticed lot of people rather than from studying physics, chemistry or basics into becoming English speakers, by joining call centres. For example, Vietnam and Philippines - Philippines which has a better English accent, the whole call centre moved to Philippines. The moment the labour force in Nigeria or Vietnam becomes cheaper, people will move, the iPhone production will move to all these places. It is not like dependence on oil on other countries, on foreign exchange rates, we are dependent on business. My question first is are we looking at what the markets are and then designing the skill set? That is not what it is, first we are not seeing what is the well-being of the person itself. Let us approach from there, what he or she needs

to well-being rather than saying what the markets are, this decentralized portion makes it very solid strong, that very difficult to shake. Why did in India in 2008 not get shaken by the world because we were still very decentralized like the kirana shops, the ironing shops everything are decentralized. We are a decentralized nation, why were we forcing and breaking the basic fabric of that but make it more applicable for other countries to follow and using sustainable energy from a climate perspective, so rather than complaining that others are doing and we are suffering, let us say even while we are suffering we are coming up with solutions that Africa, Latin America follow. Ultimately Washington and London, you need to follow this pattern of sustainable living, not in a romantic way but in a way that how poverty because these countries, also if you look at Paris why is the problem happening because of inequality, why does the whole Black Lives Matter movement coming, again poverty and unequal development in the most capital markets. Second I want to ensure is that when we talk about markets if that was so successful why did Europe and America come up with such a large subsidy to save the SME sector, billions of dollars to save the SME sector.

Prof. Sourav Mukherji: There are plenty of questions about our education policy and there are questions about have you actually looked at the new education policy and your thoughts on that or what according to you should be a very ideal kind of education.

Dr. Harish Hande: It is interesting, in the last two days I had two webinars, one was for a bunch of 15 year olds and the other was for a bunch of 18 year olds, a very specific age group. The 15 year olds ripped me apart and they had read more on the education policy than I, both prepared because they had really read it and these are from US, UK, all Indians and under something call the Mamta programme. The question the 15 year old asked me on education and they hit the right mark all that is possible. Sir, how do you convince our parents that 90 is no different than 92, but if my cousin earns 92 on maths, I am blamed for getting two marks less than him or her. It is how our parents are telling sometimes that some of the other kids were very more brutal saying that why are our parent's dreams put on us. We have our

dreams, yes you have provided a good education. I think it is more than education policy, I would go at home level, who defines the policy, we the IAS Officers and all come from our own cadre or people who design the education policy all come from all over. First I am questioning ourselves, where is the push back, see all our parents asks when in IIT, will you get job, Civil Engineering and such specializations. Why it is all about that one small notion of job we are not at home itself breaking the creativity and I would not even go into the gender which is another issue where the girl child is concerned, we are completely losing potential of the 50% of our population but education policy is defined by our own people, so criticising them is actually of no use where we think holistically but I would actually put the owners in some of the autonomous institutes like the IIMs, IITs and the other colleges means to redefine their own policy inside like how many courses do we actually have that are practically linked saying that this course will lead to some sort of a needle moving in rural India or elsewhere. This course is actually multi-directional where I have one finance person, one technology person, one architect and ITI student as part of the team building see many of the education institution also hide under the fact because that somebody else made the policy. See the question is I would go back to an example of Martinez. Martinez was a farmer who met me in 1991, when I went to Dominican Republic and that is the whole concept of SELCO. According to our definition, he was uneducated because he has no literacy but he accurately knew what is the difference between literacy and learning, I still don't know but he went inside the house and switched on the lights three times and says see my light is working because I am switching it on and off, I control it you know how it runs by solar power, nobody can switch it off. He said I have a problem with you Indians, whenever I meeting Indian guys, you have developed America, you have developed Europe and all that, brilliant engineers, doctors, any time hear in Indians they always complains, that has not happened, that has not happened, the government has not done, the policy. When are you going to take personal responsibility to say I am going to do it, forget the government, forget anybody else, I am going to say that and he told, selfishly I am telling you because if India does not develop, Dominican Republic will not develop because we look at India because you are the best of

both worlds and America is not going to teach us how to develop, you guys are going to teach us and you yourself are going to complain half the time what solutions what, you have the best in the education in the world and I think this is where I would say is that while we wait for a policy to come out and if you go to any friend of ours, they complain but the moment you tell them to give a solution, then nobody has a clue of what solution, because practically they are not ingrained in what the problems are, but I would put the onus back on some of the innovative, autonomous institutions in our country to showcase how an education policy should be determined us.

Today we are not creating those benchmarks and we are thinking that the benchmarks will be created by the policy. No, the policy should be determined by the benchmarks created by somebody and some people have to take the risk of doing that. When you make a road, there is no policy for a road, we say the road has to be defined just like the US highways or European highways or Delhi highways, so we have a benchmark. If we have to participate in high jump, should it be for Olympic gold medal, so we know how to train 2.9 meters or national 1.8 meters, we know the benchmarks, but unfortunately here a policy did not define for Olympic gold medal you have to jump 291 meters, no it is somebody who strived and made it. I would request some of the educational institutions to create that benchmark so the policy can follow rather than following the policy and that is my problem in industry, carbon policy, sustainability, poverty. We are not leaders, we are followers and the people who design the policies unfortunately are constrained because they are not given such many options to actually create a good policy.

Prof. Sourav Mukherji: There are a few questions about working with the government itself and what has been your experience in taking some of these at a policy level, many of the solutions that you are talking about through SELCO associated ones, how does one translate that into something which can be adopted at a policy level, what has been your experience so far.

Dr. Harish Hande: For example, just like if I take the name Mr Kurien and if I look at Mr. T.N. Seshan, all these guys were single people who changed what needs to be done. Mr. Kurien completely re-defined the cooperative movement and the milk movement and Mr. T.N. Seshan had defined the election commission, but there are so many Kuriens and Seshans at all levels of society and what happens is suppose I have to go to North Karnataka, Gulbarga and want to look at a water resistance technology for different cropping patters, I am not going to look at a policy, I am going to say who is a champion farmer from lots of people here or what is the glue to that society, whom do they listen to, is it a local preacher, church or a temple or a postmaster, who are they, can we actually work with that opinion maker and a society mover to make one thing happen or a ZP leader and suddenly you see a transformation in two years because you had one champion take it forward. See everybody says that on that is not sustainable, well everything depends on individual if that was not the case then why did US break the deal with Iran, it all depend on one change of a President which broke the deal with Iran, so it was not institutionalized, so nothing is institutionalized, it all depends on the people. The second example is, when we went to Meghalaya, we found one DC, a brilliant DC, we knew that he had a time frame of two years, can we do something that influences his district at that point of time and within two years he is able to tell to somebody in the higher ups that Boss this works great with 10 public health centres using solar power, the guy got it very good and asked can we do 20 of them. In the meantime he called up one more champion in the Health Ministry in Meghalaya, suddenly what that guy says, can we do 200, blanketing Meghalaya completely with all PHCs solar powered with high efficient maternal delivery, suddenly a scale up happened because there are two champions. So the question is are we creating a roster, for example financing is hard but my colleagues what they maintain is in their phone a list of 300 champion bankers and they monitor where these bankers are getting transferred in the rural areas, if one banker is transferred from village A to village B, we trigger off village B because this champion banker is there and also like this young IAS officer who is the East Garo Hills DC, brilliant work in East Garo Hills, he is Mr. Swapnil from Assam, the fact is he for the next 25 years when he is in service, he will

make sure that these things get scaled up. Are we creating champions in other industries to make that happens and suddenly what happens is if tomorrow Swapnil is part of a policy, he will make sure that this becomes a part of the policies, or Mr. Shivkumar from Manipur who is now the head, he has said I want to make it a blanket policy on Manipur. See the policy also changes, are you able to cater to somebody who is able to understand what you are speaking and also going to push back, says this cannot be done because like for example we are trying to change the tendering policy for energy appliances in WHO, in WHO we have a champion now, he is telling first take the low hanging fruits which will impress my second level, the third follows the fourth level, fifth level. Suddenly they have come up and said to the highest level how do we change the energy policy because we saw your work in India and what you proposed for Sierra Leone which has the highest maternal deaths in the world, can you do blanket Sierra Leone. See, you have to work individually and suddenly a blanket policy comes in place.

Prof. Sourav Mukherji: You are saying that there are enough people with the right mind and right heart.

Dr. Harish Hande: Out of all the IAS officers, 60% are great and you can pick, it is a problem that we blanket and everybody is bad or good. Politicians make the other difference- an IAS officer taught me, “Harish if you want to get more make sure that you impress one politician because every five years he has to write an exam, we don't have to write an exam, you convince some of the champions. You know some of the rural MLAs are extremely brilliant, the problem is they are non-English speakers and we negate speaking to them because their philosophy and some of the MLAs thought process is beyond anybody, they will teach us economics to everything else”. In Karnataka and Manipur there are several non-English speaking MLAs who are brilliant ones that we pick up and talk to them on every alternate week and after one or two meetings they will completely shed, they will show that they are not selfishly talking to you. If you really want to push the MLA policy think tank group you

need to get through this and many of them at least 40-50% cut across party lines, but we are not giving the platform to them here.

Prof. Sourav Mukherji: There are some students in the audience who are asking this question and there are two types - one is to say that if they don't have great opportunity and some are using that term, I am not an IITian, but can you advise something and all and I am using IIT just as an opportunity space, so what is the general advice for the young generation, what are some of the things that should be looked out if they really want to go out and solve the problems and to some extent not do the same mistakes some of us did who started our career on subsidized engineering and then going and doing something else. In general for the younger people what is the advice.

Dr. Harish Hande: Sometimes when people look at role models in a sense that don't just go to the highest role models that you inspire but also make sure that before thinking anything you think that you have no solutions, the question is sometimes a lot of times we start with a solutions and we say that we are going to fit a problem, start owning the problem. So suppose in our field of energy access like lot of the colleagues who join the first question do you actually own it, do you actually feel what it means to be without energy or lacking that you don't have a salary for two months, something that hunger has struck or do you actually feel it. If you don't feel the problem you never come up with the right solution and the fire in your belly when you start owning the problem, otherwise you hear this cliché sort of is that I have maxed out in a company, I have no idea how can anybody max out in a company, my growth is limited, so are you not innovative enough to create your own growth, or people are not knowing me, you need to find Plan-A, Plan-B, Plan-C and Plan-D and if you have graduated from IIM, IIT, REC it doesn't matter any college, just scope yourself now you have a white board, don't take your certificate that certificate is a piece of paper which have no use to many of us. Okay, I want to do this, I want to try why the water is leaking or agriculture, can I actually spend my brain space just learning, now your actual learning starts, those were tools

in the education system that we used, can you start articulating the problem, the first thing we ask the youngsters is can you write the problem statement, I don't care what solution you have come up with, can you articulate the problem, how deep is, how long. If you are in the space like we are, if you want to get into off-grid or into energy space, take an unreserved compartment train ticket from Delhi to Kolkata via. Dhanbad and travel in the unreserved compartment multiple times and that will be more than an initiation for you in a sense, so own the problem, for me the problem was the moment an autorikshaw driver calls me Sir, that means that there is a gap between him and me and how do we break that. You should be sitting in a bus in rural area and I would measure the success if people confuse you with a farmer and not with an IIM graduate then you have truly reached the stage of that level. Until we don't equate ourselves that somebody they know more, they know hundreds, can I be listener or a partner or a thinker, do that, humble yourself and negate all the learning, teachings but start learning now.

Prof. Sourav Mukherji: There are questions on how can people know more about the kind of work that SELCO is doing and know about some of these interventions that you have done in increasing the productivity of a machine replacing it with solar. So what is a good way of getting the information

Dr. Harish Hande: Just write to me directly, I will make sure that you are directed to different people in the organization. My email address is: harish@selcofoundation.org

Prof. Sourav Mukherji: Question for IIT alumni. How can IIT alumni play significant role in influencing the education in the right way or giving the direction in the sense that you have talked about so long.

Dr. Harish Hande: We know the type of course work. Why we are going to the lab, we go to the lab for the day and after that we have forgotten what the lab was about, there is very less

connection, we keep saying that you and me can wonderfully write the thermodynamics of a car but if a car is kept in front of us both of us will run away. You will run faster because you are trained runner. The fact is the practicality of a lot of the things that we are taught, even both of us came from IIT Kharagpur, outside of IIT Kharagpur people don't have water, people don't have electricity, people have no issue, it is a micro customer, what problems, what is IIT Kharagpur done for so many except volunteered? We have not come up, all IITs I am questioning, we need to create course works that inspires without a grading system as an incentive, can you take it forward, can the next generation of IIT graduates take forward a problem that in this village, in this technology, we have to cross cut departments making too much mechanical, electrical etc. but I would say 90% of our course work should be practical oriented and graded on practicalities and not on how much equations we solved. You all know that the equation does not affect a single life in our country. I think practical oriented as we have been speaking about it but some institutes needs to take by the bull by the horns and it is unfortunate some of the Directors are saying that the system is like that, I said Director you are the system, don't complain about it, you are the system, there are 20 to 20% changes you can make, don't blame that the professors are not allowing me or the system doesn't allow, I am sorry, I don't buy that argument, if you are a Director of an IIT you can at least change 40% of what is needed, don't tell me that you can't do it, I am sorry that excuse is out of the window, you have to do that. We have the problem at the door step, we can experiment on R&D today and that is the leverage that we don't want to lose and also one more thing sure is we need to break that to see what we have the IITs, RECs, engineering colleges and ITI, actually ITI has to be like this, it has to be at the same level because everybody is complementing each other and I think the hierarchy is killing us in many ways. The ITI students should be able to go into any IIT and be able to use the labs because they own the problem, I would say in every IIT project if there are four students, two should be from local ITIs, that will level cross-culture students to work together and make them all solution oriented.

Prof. Sourav Mukherji: May be the last question before we hand it over to DR. Susheela. You have talked about it before, creating some kind of database of problems because very often it happens is maybe there are people who are very eager to solve but we don't know where the problem exists or maybe we sometimes even reinvent the all the good things that you are talking about, may be in another remote part of India somebody still breaking their head how to make a start so any effort in that dimension.

Dr. Harish Hande: One is we have done our own data base but we have not put into place something that we should work together and the Institution that Ashok is actually leading should be one of the places which is an independent entity where you have a centralized database which is then neutralized where you have various other people, architects to engineers to social scientists to Nobel prize winners can actually come and start looking at the data bases and come with very solutions. Actually in our space 80% of the work is being reinvented. When once somebody came up with a high profile funder and a high profile entity to India to look at water pumps, I actually took out a 1987 paper and show how it was done in 1987 and we are reinventing the wheel again and say this is a new water pump model what is what and if some independent institutes could create that it is the need of the hour. While SELCO has its own and people please write to me and I and my colleagues will give access to it but it has to be much larger than the SELCO, like for example we might not be looking at water efficiency that somebody else would be looking at energy and water efficiencies together and give a feedback to SELCO saying that having looked at it could actually make the system better, so yes, there is a critical need. Then I will leave it to you.

Prof. Sourav Mukherji: Now I will hand over the session to Dr. Susheela Venkataraman, before that it was wonderful once again listening to you. Susheela, over to you.

Dr. Susheela Venkataraman: Thank you Harish, that was a very thought provoking session which is what we see also from feedback of many people who are in the audience today.

Indeed it has been a session that has walked us through a very wide range of issues and topics, but just a few takeaways. One of the key things you talked about how do we become solution providers and you said that we have to start by feeling the problem, be able to articulate the problem correctly and then look at solutions and the solutions have to be better designed into improve productivity to reduce fatigue and drudgery and all the rest of it but two other things one that it should be environmental friendly and that it has got to help to make that are gender inclusive. I think those are very significant statements that personally I take back. You also talked about involving those who are going to use the solutions right from the time we design the solutions and also this is a theme that we have been hearing time and time again that increasingly we would be looking at multi-disciplinary solution design. You touched upon intellectual versus financial poverty and the fact that unless we get to involve the poor in the policy making in solutions, design, in the processes and the system, we are not going to be able to do the kind of equity and building the equitable growth that is just not going to be possible unless we look at all of these areas and involving the poor in every one of them. I think we also looked at and this is the theme of this discussion today is India as the R&D hub of the world and you brought in this interesting concept of moving from make in India to thought or think in India. Post Covid, one of the key thing that is going to happen is everyone has said that whatever area they are working in is not going to be the same anymore and you talked about economics as we knew it is not going to be the same going forward. There is obviously a big opportunity in all of this for us in India just because we are the microcosm of the world just like an Indian organization is a microcosm of every single subsidiary that it has across the world. So if you are able to solve a problem for India as a whole then we have actually solved problems for many parts of the world. Again involving the users in the tech and designing the solution is going to be absolutely key to making sure that, that thinking process is robust and effective. I think there were a couple of aspirational statements in what you said and I think those are very inspiring for all of us, one is moving from followers to leaders and creating benchmarks and for me it is not just about the educational institutions setting benchmarks and then policy follows but creating benchmarks in many other ways

which is what SELCO has done, I am reminded of StarTrek which is our generation and I would say you have gone where no engineer has gone before. So I must say that just listening to the journey and the way you rethought many of the concepts that we have been taught in an MBA is absolutely fascinating.

For the audience, there are a couple of challenges that you have thrown, one of them is, Dr. Hande today talked about sustainable energy as a catalyst of poverty alleviation. I think the challenge to all of us is, can we each of us think of whatever we are in, whatever we do can we think of it as a catalyst of equitable development. So can we rethink the way we approach our problems, our organization and whatever we do and the second challenge we have in front of us is how can India be a thought centre for the world and can everyone of us learn from the SELCO journey and what Dr. Hande has said today, because it is not just about the idea that India can be a thought centre, it can be a thought centre if all of us do something about it. I think these are challenges that you have given us, so thank you very much for it Harish, thank you so much Sourav for readily accepting to moderate this discussion and your deep involvement with everything that SELCO has done over the years was really very valuable for the whole discussion.

Our audience, thank you very much for being part of this webinar every week.

Thank you.

AI IN MANUFACTURING

ANIRUDDHA BANERJEE I AUGUST 22, 2020

Aniruddha Banerjee is the founder of SwitchOn. Aniruddha started with designing PCIe controllers at the VLSI level and then moved onto building software for the Samsung hand-held platforms. Aniruddha has several granted patents to improve the power and performance of embedded systems. After the stint in Samsung, Aniruddha shifted to Nvidia and worked in India and the US on the architecture and development of Nvidia's flagship AI-on-the-Edge system called Xavier.

Aniruddha, in 2017, founded SwitchOn, which uses a combination of AI and Edge Compute systems to create digital twins of critical assets on the Manufacturing shop-floor. SwitchOn works with Automotive, and FMCG manufacturing industries to create digital twins of Stamping Presses, Welding Systems, CNC Machines, and Packing Machines among others. Aniruddha has a unique mix of experience in technology and business to contextualize AI for Industries and drive business value. You can read all about SwitchOn here: https://switchon.io/index.php

Subrat Panda did his bachelor's and PhD in Computer Science from Indian Institute of Technology, Kharagpur. He has worked with Synopsys, IBM STG, Nvidia and Taro - a bay area based food tech startup He has also worked as a research consultant on various industry-sponsored projects in SRIC, IIT Kharagpur.

He currently leads the AI and Data Sciences team at Capillary where he is applying AI to build products in 2 areas: Instore Intelligence through IoT and AI on Edge and the backend and Building AI products around Recommendation, Personalisation and Insights. He is an author of multiple patents and publications in international journals and conferences. He is also an angel investor and tech advisor to multiple startups.

Lecture at IIT Alumni Centre, Bengaluru, by Aniruddha Banerjee, Founder of SwitchOn, August 22 2020.

Link to the webinar : https://www.youtube.com/watch?v=oj09C_-sD6I&list=PL0zMQ-70IHIX-df3u2Tto6dkKHCRC6iFL&index=19

Mr. Anand Talwai: Good afternoon and welcome to the 19th webinar of the IIT Alumni Centre, Bengaluru. During the last two years we hosted several events focusing on Artificial Intelligence, talks by IIT faculty, industry experts, start-ups and in July of last year, we had a three day workshop on AI technologies, focusing on machine learning, deep learning and vision. This was directed by Prof. Subhasis Chaudhuri, Director, IIT Bombay and it had faculties from various IITs and IISc., they gave technology talks and we combined with that industry talk by experts from the industry. It was a very successful workshop; in the early part of this year we had one major high level IIT-Industry Conclave. At this Conclave spread across two days we deliberated on basically how do we accelerate the collaboration between IITs and the Industry to contribute significantly to the Indian economy and four theme areas were put up in that which are creating high impact, one is the Information Communication Technology (ICT) and second one is Biotechnology, third was Aerospace and fourth was Manufacturing and we found that AI is a common technology across all these areas. So all the more it is important that we have to get more into that. That is why we expect with this webinar, more and more such events coming in from IITACB in future.

Today I am happy to introduce the speaker, Mr. Aniruddha Banerjee, Founder, SwitchOn. Earlier he worked in Samsung and Nvidia and at Nvidia he was part of the team working on architecture development of Nvidia's flagship AI. In 2017, Aniruddha founded SwitchOn, which uses a combination of AI and Edge Compute systems to create digital twins of critical assets on the Manufacturing shop-floor. SwitchOn works with Automotive, and FMCG manufacturing industries to create digital twins of Stamping Presses, Welding Systems, CNC Machines, and Packing Machines among others. Aniruddha brings very valuable experience in technology

and business to contextualize AI for industries and also bringing up a start-up to scale-up stage with all his experiences in industry, business, technology.

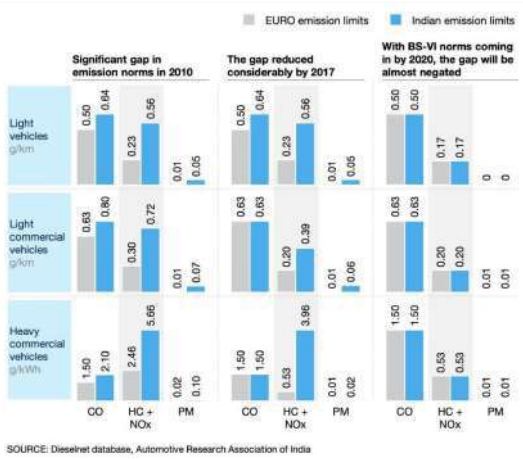
The Moderator for today's webinar is Dr. Subrat Panda, VP at Capillary Technologies focussing on AI and Data Sciences. Subrat, an alumnus of IIT Kharagpur, has worked with Synopsys, IBM STG, Nvidia and Taro - a Bay area based food tech start-up. He has also worked as a research consultant on various industry-sponsored projects in SRIC, IIT Kharagpur. He currently leads the AI and Data Sciences team at Capillary where he is applying AI to build products in 2 areas: In-store Intelligence through IoT and AI on Edge and the backend and Building AI products around Recommendation, Personalisation and Insights. He is an author of multiple patents and publications in international journals and conferences. He is also an angel investor and tech advisor to multiple start-ups.

Both our speaker and moderator bring a technology background and business perspective and we expect a high level interaction session and Subrat is also an adviser to the government on start-ups. In today's talk, Aniruddha will start with analysis of the current manufacturing trends with specific focus on the automotive industry and also about emerging trends there. The manufacturing industry traditionally had been built on adopting technologies, now the things are changing and he will talk about emerging trends there and then he will discuss on how AI is helping the manufacturing industry innovate the production and supply chain. He will also focus on his companies focus on dealing with change with creating a business value and also monetize that in terms of business. Now over to Aniruddha.

Mr. Aniruddha Banerjee: Thank you so much for the great introduction. It is great to interact with all of you. I will start with giving a little bit of context with the industry and then we can go through our journey in this. Basically this talk is on real-time AI for the manufacturing industry and I will start with basically to discuss why this is becoming important now. The manufacturing industry is one of the industries where the penetration of AI is less but what is happening in the industry when we speak about developments. One is now the products are reaching global standards. Here is basically a comparison of our engine systems, the heart of the car; the emission norms are basically reducing drastically and the BS6 norms are almost at global standards. Essentially the gray bar talks about global standards and the blue one the Indian standards.

Our Products are reaching global standards

switchon



The new-age Indian customers is discerning and that has led to deep innovation from Manufacturers.

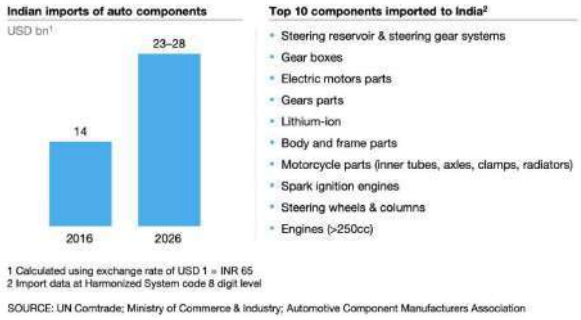
The part AI can play in digital transformation is understood better.

This honestly means there is the need for innovation in all of this supply chain not just from the product side but also from the production side of the manufacturers in which the quality and performance requirements of world is classified. This is also being driven heavily by the modern Indian customer who is a very discerning customer - before you buy any product, you have gone through significant research

if it is investing a fair bit of money on. You take some time, do some research, probably compare multiple brands and then fix up on something which is finally bought. The second thing that is happening is, people really talk about a lot and the use of IoT and AI has come from the peak of the hype that is usable for the first time now. In a lot of cases you see AI companies are not talking about just the technology but also about its implementation and we are now at an interesting stage where these kind of emerging technologies are finally usable by the customer for whom they are meant. When we started we saw that AI was very rarely used but now more often we do encounter use cases in vision in different kind of things.

We are importing more than ever!

switchon



Since the local manufacturing base has not been able to service the demand, automakers in India are looking outside.

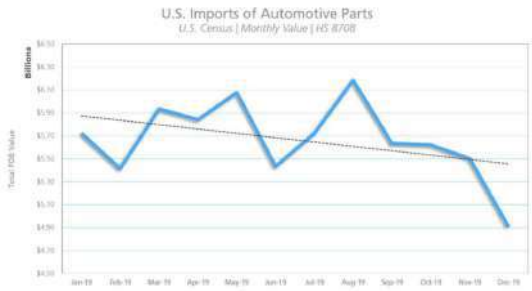
The need for world-class quality and manufacturing practices is trickling to even the small-sized manufacturing companies.

The other interesting thing that we may not realize is the Indian automotive industry is one of the biggest manufacturing industries in India accounting for 40% of all the manufacturing that happens in India. We are also big importers of foreign products and why is this happening? This is happening mainly because a lot of the manufacturing base built in India is not able to serve this global requirement of quality and world class products. And that has led to a lot of Indian makers having to import products from outside. However, the silver lining to all of these is that now a bunch of these manufacturers, actually the components manufacturers in India are

waking up to the fact that this is actually happening and what they are increasingly trying to see is how can they improve their processes to give better quality products for all the supply chain in India and that has actually given us small size manufacturing companies in India where you would see manufacturing companies that has about 10 to 15 machines and also in the process of implementing sophisticated technologies, ERPs and more different kinds of reporting systems. There is tremendous improvement in their in-house processes and this was actually the situation before the Covid-19 pandemic. Post Covid what has happened is that there has been a huge demand side shock, there is a huge acceleration that has happened from industry while earlier this kind of digital transformation was driven by in house practices.

COVID-19 has created a big gap in Supply

switchon



Every global supply-chain is looking to localize to improve stability of lead-times.

The Indian automakers are looking inside of India to service a greater part of their demand.

The Covid-19 has lead to a situation where global supply chains have almost got shut down for a long time. If you are now used to working remote instead of us meeting together in a seminar room, we are trying to work remote and the same that is happening in the manufacturing industry where they are also trying to remotely operate their plants, increasing the need for automation. What is also happening is that lot of the manufacturers have seen that if you start importing goods from outside of India you essentially land up in a bunch of trouble when the

customs and borders are closed down. So there is a very deep focus on localizing the global supply chains and obviously the graph here is that in the US the number of imports that they were doing is drastically come down and that is a global trend that we see in India as well. A bunch of world class companies in India are now looking to localize their global supply chain and a bunch of the companies when you talk about customers, a bunch of customers are looking at world class products to service this. This means that there is a big gap. There is a big gap in building out quality products from manufacturing in India and this is the gap that emerging technologies like AI, IoT is helping to address where we are fundamentally seeing digitization of most of these manual processes and Indian component manufacturers and Indian automakers are finally looking inside of India to service a lot of customers. When we talk about these kinds of global supply chains, we really sometimes are under the impression that we have to import the technology that is used. That is where a very interesting trend in India in terms of the start-ups where the start-ups are now started looking at not just consumer take but enterprise take which were few of the biggest consumers of these kind of new age products, but also have looking at these classical industries to see applications of their products and that is where the Switchon story starts. When we started in 2017, I had taken look at global manufacturing plants in India and US and as a result of my work with the automotive industry back again in Nvidia we saw some interesting trends such as these in the world. The essential modern start up is not that you just need to build a copycat product or basically be able to translate some demand from the US but also to building something new and unique to address a certain gap and that is where Switchon starts.

I will take quick pause here and try to answer questions and then we will get deeper into the Switchon story and see how we built the company.

Dr. Subrat Panda: Thanks Aniruddha, one of the questions I think is relevant by Mr. Rahul, he asks how to calculate the dimension of industrial product by using data. It may not be in the line of Switchon but can you try to answer on that.

Mr. Aniruddha Banerjee: I think this is a fairly standard problem with lot of the manufacturing companies. Of course the biggest way to solve is you have these kind of vision based measurements. What they essentially do is they have a camera and a standard measure and from there they try to find out the dimension of the product to match this skill, the exact specifics of this I would love to discuss that offline but definitely provide some pointers to where you might start looking.

Dr. Subrat Panda: Next is a question from Mr. Dhanajay, one of our fellow IITian, he asks why the name Switchon?

Mr. Aniruddha Banerjee: (No audio) ..... Most of these manufacturing assets in some sense prove an exponential manner so OFF to ON is a very exponential increase in uptime and basically in the production, so that is why the name Switchon.

Dr. Subrat Panda: I have a question for you. The one word we try to solve with AI is engagement. If I have to improve the engagement with the customer is there one word that AI in manufacturing does according to you or Switchon does, what will be that?.

Mr. Aniruddha Banerjee: I would say asset quality. What AI does is strictly add quality to the product, new product classification of (audio not clear) is what we do for the manufacturing industry. The essential process is transformation in most of these legacy industries. What I was trying to say is that in a broader sense what AI helps to do is digital transformation in lot of these industries and what does is it helps to improve both quality and competitive edge of your company, that actually helps you to improve your own supply chain. So you are making better parts more often. So there is a lot of operational improvement to that.

Dr. Subrat Panda: Mr. Sumedh asks how much AI in manufacturing application is to the domain of large suppliers. As a start-up methodology in case of a software or manufacturing start up, how much AI helps in manufacturing, that particular aspect of being in manufacturing.

Mr. Aniruddha Banerjee: Excellent question!! To give an anecdote, usually Switchon works with a lot of Toyota suppliers and, Toyota as you know, is a kind of proponent of clean manufacturing globally. So a lot of the outcomes we give essentially implement different tenets of Kaizen improvement through something called forum management. So, clean manufacturing is actually a legacy of top-notch processes that they have to be. What AI is doing here is it is helping digitizing a lot of these processes and through that, it is helping adoption of processes even deeper into the supply chain. So earlier, for instance, you could only have Toyota implement because they had expertise, the work force all of that set up, but what AI is doing is it is essentially democratizing all of these, so not just Toyota and a lot of their suppliers, but even suppliers to the suppliers of Toyota. So really these small

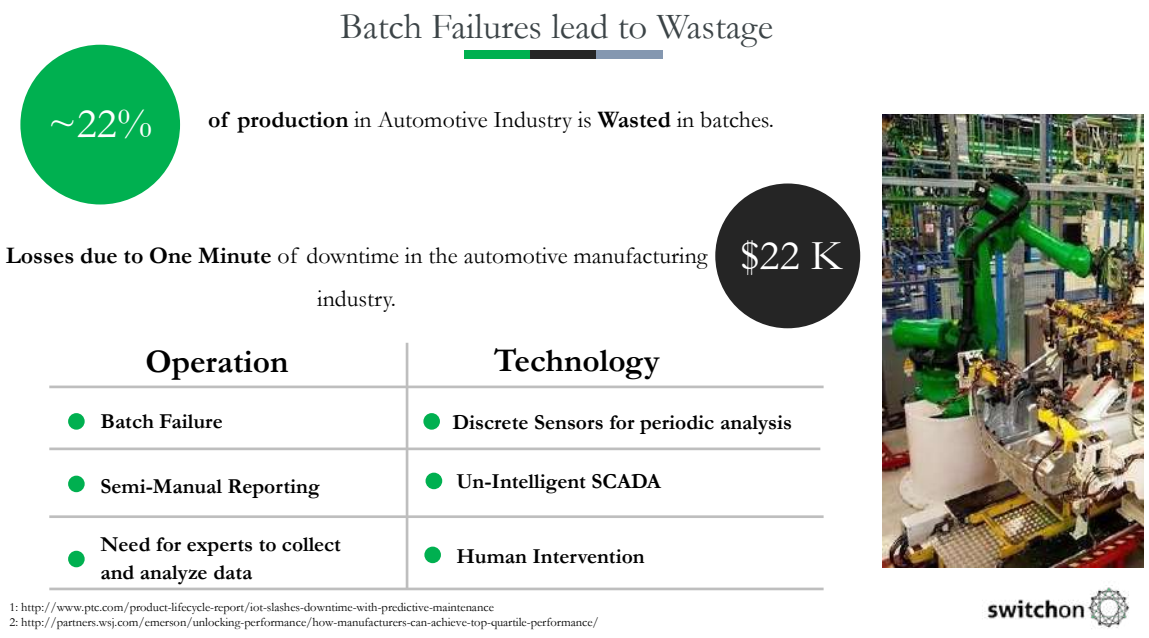
companies finally have the ability to implement these kind of pre-manufacturing processes.

Dr. Subrat Panda: One last question which relevant here, Mr. Ramesh has asked a question about any company that you are implementing AI, what is the ROI, investment on this IoT or what is the payback time?

Mr. Aniruddha Banerjee: Essentially we will talk about the use case and the product, but without getting that deep now, what we see is that the normal digitized plants have a bunch of gaps with respect to quality and the quality of the assets. What it means is that you can have a rejection in terms of your customers. So let us say you shared the bad part of your customer's product to a car that can lead to even safety hazards of such cars going around and I will talk about some of the processes where it is not possible to inspect all the parts, so actually an uninspected product does get into the car in certain cases which is one of the big problem, so rejection for the manufacturer. One of the big things is to look after that because in case of such process or threshold they might lose their clients. The second thing is that when you talk about operational efficiencies, that there has been remarkable improvement of 12-15 even 20% on the operational efficiency of these plants. If you were making 100 parts earlier, you are making 120 today. All of these combined together basically give both the top line and bottom line improvement to the companies and in most cases we have been able to quantify this because most of the discrete manufacturers who work in number of parts produced. So guaranteeing more parts go out to your client, we essentially are able to give sense of ROI work.

Dr. Subrat Panda: Ok, now let us continue with your lecture.

Mr. Aniruddha Banerjee: I will now talk a little bit about our company and then a little bit more about AI. Anand gave an introduction about myself, of course I am the cofounder of Switchon but also have deep experience in hardware. We started in 2017, right now we are a 20 member team and we have channel partners. I will now talk a little deeper about the problem we are facing and trying to solve in the manufacturing industry. I will give a few anecdotes regarding when we started and how we got off with the customers. The basic problem always is batch failures in manufacturing - where what happens is in a lot of places, the parts that you are making are not of very high quality, but as you know, that most of the industries spending towards very high speed assets where you are making anywhere between about 8 to 10 parts a second to get to your manufacturing.



As you can understand that inspecting these parts manually is almost impossible and I will show you an example of a kind of parts that I am talking about. What

happens is that there is a random check that typically happens. What is random testing is that you make a thousand parts and then you pick up one part, see whether it is good or bad and based on that qualify the entire batch. So you actually did not test the 999 parts and they went to your supplier and so on and so forth and obviously there are different kinds of additional parameters like, they do more welds than necessary. In a part where you have welding, you don't have to check everywhere when you are doing three times the number of welds, even if one goes bad it doesn't matter. That is how the automotive industry has been operating for a long time, also this industry is extremely fast and process driven, the losses keep you down sometime as manufacturing process is very big. You can imagine $22000 is the loss due to one minute down time in a manufacturing industry. In this what we have seen is that the issue in the industry is not just the sensorization of their assets but also need for analyzing and giving them an outcome.

Random Testing for Welding Quality

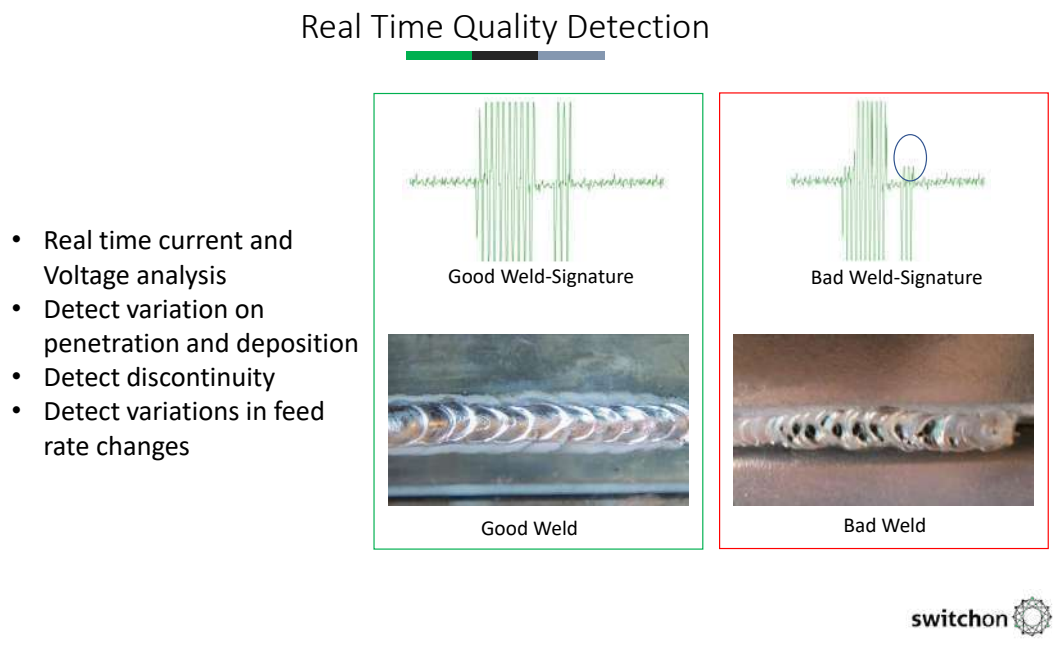
Batchwise testing, doesn't reveal **integrity** of each weld.

Should you let a random decision become the basis of quality?

switchon

Here shown on the screen is one of our use cases, basically the welding use case. On the right hand is the picture of a L weld and it is essentially cross section and you

can see that the weld is basically the joining of two metals. There are two perpendicular metal plates and you have to join them and one of the biggest problems in such joints is specially there are structural integrity issues involved, whether the structure is joined or not or whether the filling has properly happened or not; how to test it is either by cutting that weld into half or by being able to pass these kind of manual probes on top of the weld to find that. In destructive testing, obviously you can't use that part anymore because you cut the weld down and in the manual testing of this obviously it is a big time consuming process, you can't do it for every single weld you have done and hence the random testing is basically one of the mechanisms in which the weld is tested across the automotive industry.



To give a higher level snapshot, almost 15-20% of most of the manufacturing process in an automotive industry is some kind of welding, it can be a spot weld or an arc weld. So this is the problem we looked at very deeply and here is an example of a good and a bad weld and we were able to basically analyse at a very high frequency what are the parameters of changes happening when a welding

takes place and from there we were able to design a product that gives you when a weld is good vs. when a weld is bad for a combination. Of course AI and allied systems is what allowed manufacturers to finally do in real time be able to define the quality of a weld. So they could detect all of the faulty welds and all of the good welds and digitize the quality output of all these welding assets.

Easy Setup

Non-Intrusive Sensor
Installation Site: Primary or, Secondary
Installation Time: 40mins*

Din-Mounted Acquisition
Installation Site: Electrical Panel
Installation Time: 30mins*

Wireless Computing
Installation Site: Electrical Panel
Installation Time: 10mins*

* Data from Current Deployments with Plant electrical maintenance

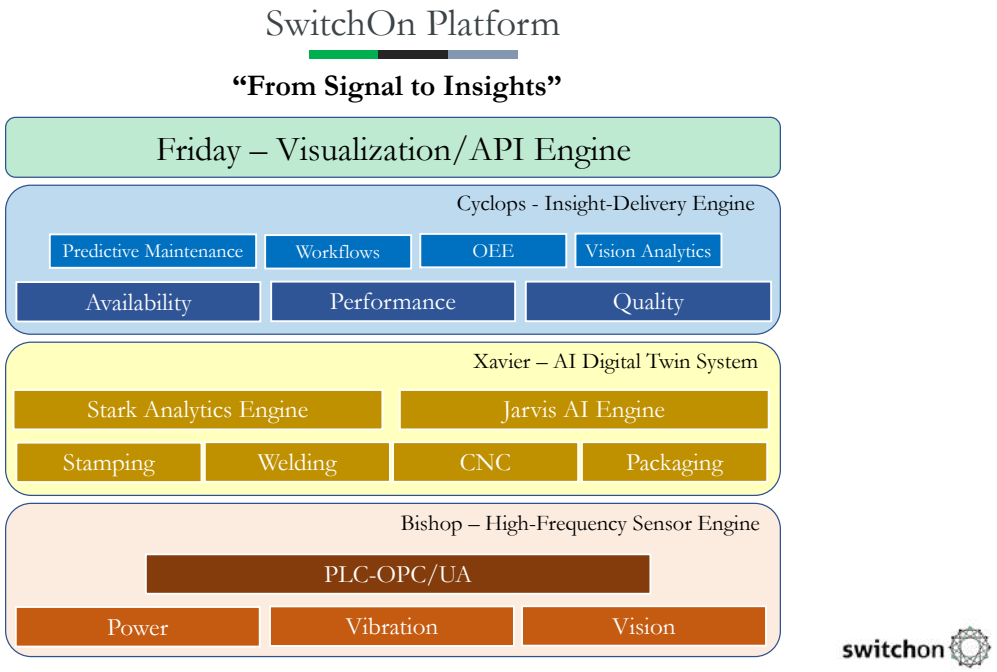
That combined with some of our other expertise, with the other machine essentially allowed them to create digital twin of the entire plant for them. This is essentially in terms of set up, this is a sample of the set up where we have a sensor, have an acquisition system, we have a compute module, of course all of this designed by us and with this they are able to have a very unique case of not just acquiring the data at very high frequencies, we acquire at about 8-10 thousand samples but also able to analyze within about 60-70 ms and as people in AI might know one of the biggest problems of flowing large scale system the time it takes to do an inference but most of these processes are very fast, so we had to do a bunch of work for reducing the

latency of these kind of things inside and we were able to integrate directly to the machines.

While I am in this slide, I will give an example of one of our initial customers for this. One of our large initial customers for this basically was one of the large Tier-1 suppliers to Toyota, and we saw this problem of the welding there and we tried to understand what they do. We saw that one of the high level executives in the plant explained that to do the kind of multiple levels of inspection to be able to meet the quality requirements at Toyota and whenever there was a new part that would come in they assume that about 20% of parts would be rejected and do know that this automotive is an industry that runs at low margins. Their margins are not as high as something like the semiconductor industry. We were surprised that it was so normal for him to say that almost 20-25% of parts get rejected in the initial few months. From there we started ideating and brainstorming on how do we deal with very real problems for them and of course our product was at that time also relatively new. So one of the big challenges that we had was trying to acquire the data and as you know that most of these data sets are not even available, so this is not a standard customer response kind of Excel sheet data - it is a very custom industrial data set and we spend about a year in just acquiring the data and be able to build the model for even the initial period and of course testing all of these. In solving industrial problems you have to work with industrial customers. This is probably the one thing that I would like to tell the young audience of start up founders, building use case and building a product in a lab is great, if you have good idea, but the real proof of the kind food for eating where you go to a plant and you are able to deploy a lot of these products and then you have to have a little bit of a sharp customer focus to understand the real problems that they are facing in the plant. This is what has

helped us in refining not just our products but also our dash board etc. to be more and more usable for our regular customers.

Coming back, I will come now to the second anecdote model to share. We built this product, we wanted to install this product and see the data. Then we realized that these assets are very fast and you can't stop them even for a downtime of the installation. So even if you have a great product, you have to find a way to easily deploy this for most of the customers and that is where came our second journey that it is not just the product that you have to make but also the deployment architecture that you have to think of and you are doing such things.

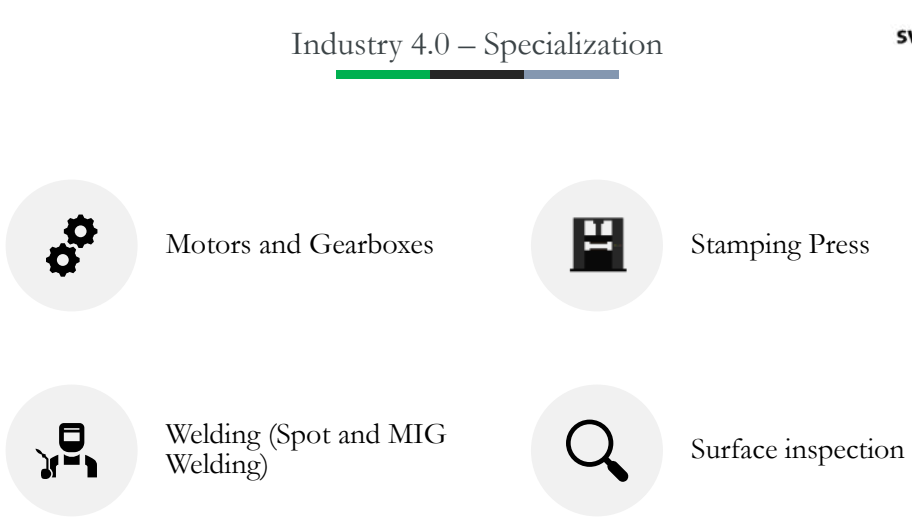


When you are approaching the customer, you have to have a clear vision of how it is going to get installed. So there was a lot of refinement in initially defining the product to be able to install this in the new industrial setting and that is why we came with this whole computer based set up which was able to give us the latencies that we are looking for but also was able to give us the kind of analysis that most of our

customers require. That needed us to innovate at almost all levels of hardware and software. So basically we started with Bishop - the high frequency sensor engine where we essentially acquired data at much higher frequencies than was basically done by us, by others. We sampled at more than 40 times frequency of our nearest competitors and that led to the first competitive advantage for us which is the data. You have a data set so unique, no one in the world has access to that. That is where the story starts and then we moved on to the actual digital twins, so digital twins strictly require a lot of understanding about the data, about the asset as well as causes. We have to include all of that in our AI based models which essentially took this data and through an orchestrated AI system was able to automatically detect the different kinds of operating issues. So essentially it was able to detect the difference between a continuous weld that was happening here and the weld that has these defects in almost all these air pop ups that was there inside the weld. So we created a system that was able to differentiate between multiple such kinds of faults. The biggest differentiator there was the fact that we were able to do it at latencies of about 60-70 ms and that allows to essentially have these high speed assets implemented and instrumented and plus the third layer of this is you have an idea of what is happening in the assets, how do you send this to your customer and in lot of cases this is where I have seen, you know, let us send an SMS, an alert somewhere but in this the focus was in the industry which allowed us to meet work flows for them and allowed us to implement forum here and this where I will go back to one of the questions. This is where it allowed them to increase a lot of agility. So now when you have a new part you don't have 20 to 25% of the rejections in the initial stages and you can go and experiment very fast, so you can tune parameters and output of the weld and tune the parameter again and see the output of the weld

and that is where we were able to increase a lot of agility and the leanness of a lot of these companies. That is where these kind of insights really help.

Going from there I think we basically expanded out, we started with stamping as one of the applications and then slowly expanded our verticalization in MIG and this is probably one of the things that I would like to highlight. In lot of cases we tried to build these horizontal platforms that we essentially have lot of use cases in service by our platforms. In lots of cases, what happens is you have a bunch of sensors, you build a cloud and you tried to see whether you can fit the sensors in the cloud and somewhere and give the customers a platform.

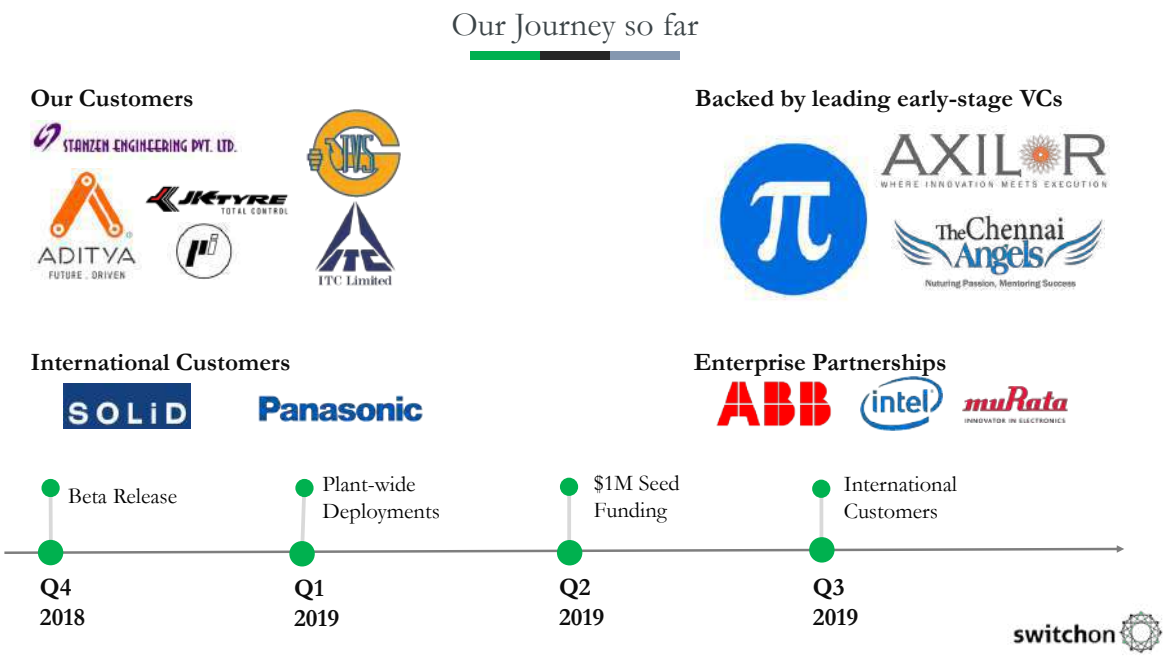


What our interesting realization through our journey is that in most of the cases, the manufacturing industry, even the other industries require very specific solutions instead of something more generic and this is where the start ups can innovate because start ups excel at building deep products that have a lot of depth even though they don't have as much depth as let us say a big company would but what

a depth clause has to do is enables you to attract and attack a lot of query on industry specific problems and in the initial stages at least what helped us is that we were able to verticalize for the automotive sector and that whole experience taught us a lot about how to scale these trend across the verticals. So what we did is that instead of building a sensor and a cloud and trying to connect them in some way, we have approached this from the problem that customers were facing and we build up a bunch of computer systems, the cloud and the inside delivery systems are all tuned towards the automotive industry and tuned towards some their practices. Obviously that means that they focus lot more on their assets to the manufacturing industry and especially the sheet metal industry uses stamping presses, they do a lot of welding, they have quite a few motors and gear boxes from the air pressure etc. and they do a lot of inspection. So they do a lot of surface inspection to understand the finish of the post-produced product. We added support essentially for all of these different products, essentially enabling them to have one platform at least to operate their plant . So, the vision for us was to create a library of such digital wings for all kinds of automotive component manufacturing industries and that is how we were able to building deeper relationships with most of that customers instead of being really superficial about that and creating one or two differentials. This is where I will digress a little bit into our journey. We started in mid of 2017, we initially boot strapped our product and the company for about one and half years which we majorly spent in the product development. This is where we had very early customer conversations and then we basically took a lot of this input to build our products and from there of course we started doing a bunch of deployments, some of them as pilots and some of them as plant add-ons, then we were able to work with lot of very discerning customers. We worked with customers who are at the very edge of digitization in manufacturing and who are

really looking at AI and IoT to solve a very particular use case and I will give you a couple examples of that where we basically worked with a customer to solve a quality problem where what typically happens in a lot of the stamped products is the fact that you are not able to figure out the quality of the product in real time. What happened is that in one of our customers they were facing very frequent issues of the machine where very bad quality parts come out. So we worked with them to understand what was the majority of those defects happening and we were able to tell them in real time what the defects are. Another example, mover from the digital twin of the packaging machine, that one of our customers, an FMCG customer facing. In a lot of cases the machines were very fast and they were essentially trying to see defects on the products and earlier to this they were doing it through a manual visual inspection. What we were able to give them is at a very high speed the ability to understand their packages, not assure them but understand for instance there is a printing defect or there is a cut somewhere or a dent somewhere etc. etc. That is how we were able to help them. We had a very deep understanding and also focus on the manufacturing customers and after having the first few customers we raised our seed round which was led by Pi Ventures - kind of investors and IoT companies and then of course we had the backing of some of the best angel investors in India. After raising the seed round one of the biggest goals for us was to work with more and more customers not just in different parts of India but also different parts of the world we started to work with a few customers in the West Coast and got into a lot of great partnerships with enterprises, so we worked with Intel from the compute systems side and worked with the hardware side and what we do in most of these partners is that we basically create a win win situation where our application creates very differentiated value for the customer as well as it

allowed our partners and system integrators to be able to make a lot of sense of this data. Now this brings me to the end of the slide. I will hand it over to Subrat now.



Dr. Subrat Panda: Thanks Aniruddha, it was very good, your journey has been very superb I would say challenging but interesting and opportunity is there and good stuff. There are several questions asked by the audience, I am generalizing the questions so that there is no repetition. Question by Sanjay Bala and Suresh, how much of what we get from this model for detecting a bad welding from a good welding, how much of it is generalizable, say a supplier who supplies to Toyota and may be some other supplier who supplies to Volkswagen model and you want to do the same thing over there, how much of that question you can do it from the existing one and how much it will works actually on the shop floor.

Mr. Aniruddha Banerjee: To talk in very AI terms our architecture is generic but data is platform tested. What does this mean, this essentially means that we are able to

take generic models for different kinds of welds. It is not just the automaker who uses it but also the make of the welder, - a bunch of these patterns change and what we found is the parameters will remain the same. While the pattern might be different, parameters are the same which has allowed us to build a few generic models and from there we would train these models from the field. One of the biggest thing for is that we need some data of the machine to be able to create an accurate model of its functioning. That is where the sensor augmentation of these models in the training and that is generalizing.

Dr. Subrat Panda: IoT-4.0 or Industry-4.0, the productivity in the three last industrial revolutions, is this revolution going to give us the maximum gains because the IoT, AI and that will lead to filling up a lot of resources - how much of it does it leads to unemployment. In the impact what are the gains and what are the losses?

Mr. Aniruddha Banerjee: Let me try to address what AI is doing for manufacturing. What AI is doing for manufacturing is it is augmenting the human operator, you know what typically happens that basically you already did a manual inspection on most of the parts but the problem was that it is difficult to manually inspect tens of parts, it is something that humans really cannot do. Also not just that. What we have seen is there are a bunch of accuracy problems when you are manually doing such things. What it leads to is essentially loss of business. But in a lot of things - when the operators are saying that this where a bad product is made, actually in most of the time you see it is actually a defect either in the process or method, etc. That is how with these technologies we would be able to compete in the global market and this would lead to long term gains in the Indian manufacturing scenario. I will give you a very concrete example. Recently, there was some talk about how

manufacturing is moving from China to India and to the other Asia-Pacific countries and in one of the forums there was discussion around whether India is equipped to handle the supply chain. Does India have the technology, does India have the expertise and in a lot of cases people argued that for building critical products India actually still needs to implement the technology, so here is the opportunity to build a differentiated manufacturing and design house and AI is able to augment that.

Dr. Subrat Panda: There is someone from Ford, Mr. Murli, he asked the world picture that is presented where from destructive test or from an ultrasonic inspection and what is the sample size that you take out of a set of hundred, how do you make sure that it is generalizable. That is a very deep question in manufacturing, it would be interesting to get the answer for that.

Mr. Aniruddha Banerjee: I had shared two pictures, one was a cross section of the weld which is basically showing the two metal joints that was the output of destructive tests wherein this particular was cutting the metal. The second picture that I shared was essentially the top view of the weld where the weld defects were lot more clear, I would say it was the other end of the spectrum like two ends of the spectrum with good and the bad to just illustrate the problems of course as Murali might know that in most welding you are somewhere in the middle because of some kind of a distance problem or some kind of a parameter issue to kind of have a random problem happening in the weld. So the second picture was more a visual something that was very easy to see.

Dr. Subrat Panda: One of the questions that is coming around in general theme is what is the valuation methodology for customer in this and what do you use to

convince the customer. Modelling AI is in your hands, the gains that the customer sees is how you valuate, how did you work in your case.

Mr. Aniruddha Banerjee: In the initial days we essentially benchmarked this against a human, so what we did is we just said that all the defects that we see basically we will pass the part to a human and they can do destructive testing, so they can cut the weld in half now and validate whether this is correct, that was in the initial days, that is really how far you can get and we have to do this. We have to do it actually even now when you are talking with bigger companies. We go into a pilot phase, we actually validate every output that we give for the system because the idea is that there would be no one other than this AI system and you have to be a 100% accurate there is no doubt about that because it is squarely on us when the welded products goes out, it will affect badly on us if it is not accurate that is how the validation happens, of course now it has become a lot easier with bigger customer base and with a lot of examples around how a bad weld looks, what are the different parameters now looks easier.

Dr. Subrat Panda: So now what I would say just to generalize this, we need to make sure we are at least as good as the human on the floor that is something which is the benchmark that you have to meet.

There is a question around this, what according to you, is it first principle based, is it data driven based? I think data driven is the answer but you can elaborate, how are you using data as the digital twin causing life cycle of the product.

Mr. Aniruddha Banerjee: To answer the question of the digital twin, of course mutually data driven now, we do look at some physical parameters as well to validate the parameters etc. I would say it is essentially, even though it is primarily data driven, it is a combination between a first principal modelling and data. Why that is required is in a lot of cases we have to validate the data itself. As most good AI engineers know that the core of the work actually happens is in the data, even before you write, even though what comes out in most of the theory is you build a really competent model and try to solve the use case but as most people who are in this domain sometimes realise that the data here is, if you can get clean data for 100 days you are good. From there I will go to where we are using data, so what we do is we basically have assignments, we basically have a generic architecture that we have built already. Our current experience, what we do is that we do on field training of that data on these different kind of welders. The good part is now that we have been able to sign a kind of scalable system for automatically training all of this, which automatically collects data through customer and get inputs, post which we do deployment basically in the same set up, so our system operates in train and deploy mode, so once you put it from the train mode to the deploy mode is basically start seeing the failures in the parts.

Dr. Subrat Panda: One of the questions pertaining to this is from Sumesh and others, there is a mode of data collection right, the pre-pilot phase I would say, now how do you intervene, the thing is you have to instrument something, like you said monitor, build in sensors - but there is some intervention required, how do you make sure that the entire product pipeline, how the customer agree with you to work with you on the shop floor.

Mr. Aniruddha Banerjee: In initial phases it was little more difficult because we had to do a lot of live demos for the customer to show this is how the system is operating on the field. What happens for us right now is we basically do pilot phase where we essentially show the value of the entire system and we try to show in as less time as possible and that is where we have a bunch of innovation on processes as to how we can give them an immediate outcome from the installation perspective to the deployment metrics etc. Post that we go into scale up mode where we work with the customer. One thing that we have done on the strategic side is that we moved away from free pilots and free demos, what we try to do is we try to have a minimum amount of value attached to our product and we basically do this by actually showing similar welding happening and this is where again the verticalization has helped to speak because you already have examples from the same industry probably people work with our customers and clients we have seen.

Dr. Subrat Panda: There is one more interesting question from Mr. Sharma, he asks that you applied into automotive sectors, what about identifying fabric defects, this is a question from textile sector. Have you investigated using in that domain at all?

Mr. Aniruddha Banerjee: What we have seen is that the central product that takes high frequency data and generates the insights that I am talking of is actually something that can be scaled across different industries. Essentially, if I am talking about fabric, in a lot of cases we have again high speed applications, so 1/1.5 meters per second are quite normal. So essentially you could scale it, what could change for us is the input data pipeline, instead of taking a welding parameter we have to pick up a different kind of parameter. This is an interesting exploration that we keep

doing, so we keep exploring adjacent use cases, for instance we are actually working in the steel industry as an exploratory market and by making changes to the data pipeline and with the central compute system and digital twin I think we are able to scale this up.

Dr. Subrat Panda: This is excellent. I think overall the methodology will work, that your stack will work as such. If you fail in a few scenarios per se, what do you do when a serious failure takes place, how do you go about with that part because that is the struggle part. That is a part which will take a lot of time of yours.

Mr. Aniruddha Banerjee: What we do is that (a) of course we have the industries that is reporting such failures, so we send reports of these failures, etc. but what we have realized over time is that working with a customer again is very very important. So we have specific customer success rule in our company whose only job in the company is to ensure that the customer is successful in what he is trying to do. So that is a very deep focus for us. To explain how deep it is, I used to do this personally and I still do for most of our key customers. So that is where we monitor this metric ourselves very carefully to ensure that the customer is successful. Now there has been quite a bit of standardization regarding the metrics that we see etc., for the industry, a little bit industry specific on this and that is how we essentially ensure it. Slowly once this momentum builds up, what we have seen is the customer starts adopting this and that is what has happened for a few of our customers.

Dr. Subrat Panda: This is a very interesting thing and I would like to add to this. We should build people's confidence, this is a vision centric thing and the floor would be of different types and there will be a backflow where in the vision you wouldn't

see any ingredient, so it is very hard to take out. This is a very interesting question, Mr. Abhishek talking about what is the take on AI in additive manufacturing for engagement with the customer. I asked him about more detail about additive manufacturing. He says that in additive manufacturing the customers demand regarding a component design functionally changes, rapidly maybe for components or other service related performances. Can AI help in directly communicating with customer and prepare designs as per requirements. That is like generation part not detection part. What is your take on that.

Mr. Aniruddha Banerjee: I think there are 2-3 questions in this. So AI is the additive manufacturing itself, additive manufacturing is a process of essentially taking materials instead of taking it away, so essentially you talk about 3D printing where depositing material on top of it, that is additive manufacturing. The processes that I was talking about was not additive, if you are not stamping, basically cutting out part from it, you have a block of metals and you are trying to fraction a part of it, this is what typical CNC machines do. Coming back to the actual question, how AI can help in additive manufacturing, I have seen a bunch of applications in that even though we don't actually do as of now much in that sector but a bunch of applications in that are in optimizing the design of the parts. A lot of work is going in implementing AI in the actual CAD models and to make better parts so to speak. Also a lot of innovation is happening on the actual process where simulations are helping to understand what is the material on which the additive manufacturing should be made to design parts of a certain structure etc. That is basically where AI is being used as of now, of course as you rightly mentioned, we come after the part has been designed and additive manufacturing I would say it itself is going through the journey to see how it can be used in mass manufacturing because there is a

trade-off between the time that it takes to do an additive manufacturing and for example, stamping. A very simple example, if you look at the simple stamped part, you have a sheet metal, you have a part, taking parts out at 60 parts per minute. Typical additive manufacturing for that kind of a part, I am talking a metal based deposition process. It is much more time than that. It is still going on its path to become main stream.

Dr. Subrat Panda: There is an interesting query from a student Pranav. There is unavailability of processes publicly for this kind of manufacturing for example, so how can possibly undergraduate students work on this project, may be internship is a good option but you can think of an answer to this question. Are you planning to put some data in the open.

Mr. Aniruddha Banerjee: For these kind of very differentiating data sets one of the only ways to work with companies that are doing this kind of state of the art work, we have some internships and full time positions open and I really encourage and in case you are interested in the use case and then adding value, I would highly encourage and you can get in touch with me and outside of that to answer the title question, as of now we still are in the process of collecting a lot of these scaled out data. I would love to do that but I don't want to do it in a premature manner where data itself and the use case itself is that something we want to have enough data around so that it becomes useful. While in the short or probably in the longer term we would love to think about that. In the short to medium term what I can say is that working with such companies, welding is one example that I gave, you have companies working on very very unique problems in predictive maintenance for

example, companies working very deeply on some of the other problems like measurement problems etc. and the thing to look for would be companies solving very deep problems. This is more of presence of a unique data set is more of an indicator of a unique problem that they are solving. Manufacturing is just one of the industries, I know for the fact Swiggy has an interesting data set because again they are solving very different problems.

Dr. Subrat Panda: There is one question from Mr. Sumesh, this is more of implementation perspective on the client base. The department responsible for, the IT the infra they have this whole backup about the data security and all that, so how to work around that, we talked about the software thing where you did work on sensors and all that is great but still there is data security issues, they don't know the system and you have to answer that you have the same device in the train floor and then working on the test floor part on its own and deployment. It is difficult to navigate because there is a guy who is stopping you. How do you work around that?

Mr. Aniruddha Banerjee: The way that we tried to do that is to actually map all the different stake holders in the plant and to give them something to look forward for each of them. What we tried to do was, we tried to understand how can we make it easy for the IT team to work on this, so a lot of times lot of challenges comes because it is actually very difficult to do and no one really addresses that fundamental challenge. Let us say that you deploy an IoT system, you ask them to open 50 ports for a hundred sensors that someone has to individually configure, would you do it? So, in a lot of cases it has to be very clear where the problem lies and what we did is we make adoption simple always. Our Xavier x-compute system one of the ways is where we allow the customer to get completely remote debuggability. So, to

share an anecdote again in one of our recent customers because of Covid times, we were not able to travel to the plant and in a lot of cases essentially IoT systems are hardwired in a way such that you cannot fix them without getting sense etc. But we were able to enable a way which we remotely debugged and solved the problem for them. These are the things that allow your customer have a better experience because now the customer knows that only me reporting the problem would enable Switchon to solve it. This is one of the ways by making options but of course it is still an ongoing battle. I would say, it is a solved problem and I can't tell you a play book for this but all I can say is that if you focus on making deployment simpler from an IT perspective things will go a lot faster.

Dr. Subrat Panda: That is strategy one, that brings you to the next question. Looking deployment faster and easier. This is a question from Mr. Bala. He is asking what strategy you use to attract your customers, this will help a lot for the coding and marketing professional to choose coding and marketing as a career. This is a financial one but very relevant to strategy.

Mr. Aniruddha Banerjee: From a marketing stand point what we have done is basically, in AI is of course reference helps. So we use references as one of the big ways to get customers. What has happened of late is that we basically talk a lot more about the interesting work that we are doing in a very targeted fashion, that ranges from talking and key industry seminars and showing the innovation that is happening in India and it ranges to also talking to a lot of automakers to speak in conjunction with us and tell us what is the value they have got. These couple of things had helped us to generate lot of the reach that we were working towards and

that is how we do it as of now. This is again work in progress I would say, this could change as we go deeper in the U.S. and come back and do deeper in India.

Dr. Subrat Panda: The last question is, once you get the use cases, when the case studies are with you that is perpetual validation, one thing is you have done it for this use case, how do you plan to get into use cases like the one you have mentioned in the slides and what all are the other areas that you think in the whole manufacturing domain, this was more of a question from people in general who are open for use of AI.

Mr. Aniruddha Banerjee: Very interesting question, I would say that most of our focus has been inside the plant but there is a whole world of AI waiting to be used in the supply chain. To give you a few examples, optimization is one of the big AI problem that lot of supply chain companies are trying solve, another interesting problem is the packing efficiencies. So packing efficiency is how much product can you put into a truck in a sense, lot of customers are using a lot of AI and it is an interesting problem, so AI is being used in supply chain. So in a broad umbrella again, AI is being used a lot in the supply chain optimizations and that is the whole topic in itself and then AI is used in a bunch of cases, the end customers to ensure the integrity of the products. So basically a combination of AI and block chain is being used to ensure that there is no pilferage etc. that is happening or there is no shipping defect, etc. happening. As of now, of course we ourselves are focussing on in plant use cases, so we are basically working with stamping, welding, predictive maintenance and inspection inside the plant.

Dr. Subrat Panda: Thanks Aniruddh, this was really very interesting, I think I have got all questions addressed, Ashok over to you.

Mr. Ashok Kamath: Since I have both of you on the screen, an interesting question I have, I could not key it in because I was a panellist. The question is that manufacturing is almost going to be a trillion dollar business in the next 4-5 years and this is a big opportunity here for India as a country to leverage more in manufacturing. In parallel I think there are lots of start-ups like SwitchOn and competitors around you, who are in the market and there is a clear use case for good data sets being made available for public good so that young start-ups can start their life, they have all the smarts but they don't have the juice and the money to actually be able to invest on sourcing data sets and more so when it comes to mission critical applications and Aniruddh you used to be from NVidia in the past, there is a need for heavy duty GPUs being made available which are expensive. So you are looking at and saying from a manufacturing perspective, if you look at the top two or three industries and then say these are the data that are ideally like to see available for public good to benefit for a whole bunch of start-ups, if that is the question what would be your answer.

Mr. Aniruddha Banerjee: It is a great question and a very deep question by the way, in my personal view I would say that critical industries and data sets, may be something like oil and gas which is a very critical industry with the data sets that is not available. I would rank the industries based on that so how critical the industry is. I would say that oil and gas, heavy manufacturing and critical pharmaceutical manufacturing data sets would be few of the top data sets that very very few people would have access to and of course bringing them out in to the open can unlock a

lot of value. So lot of these companies have open innovation challenges right now because everyone in the world is waking up to the fact that this is all an ecosystem. So if you start building from your shoe to shirt and you can't build any of the products well. So they all woken up to the fact but I would say that if a push were to be made, critical industries like oil and gas, automotive, pharma would be the industries where key data sets being available and start-ups working on them to that very differentiated value.

Mr. Ashok Kamath: Thank you so much Aniruddha. Mr. Anand Talwai will give the concluding remarks.

Mr. Anand Talwai: It was a very interesting talk and you came out with lot of examples of real use cases, real practical situations to say, the automotive industry. So those cases you have taken up and we are very thankful to you. Thanks Subrat for handling this very well and coming from your own perspective of AI, more so from user experience perspective and insights I think it was a very good discussion. I would like to just say on something on what Ashok was saying. This is a thought process, you have been talking about Tier-1 suppliers to give some examples; then you were talking about tier-2, tier-3, tier-4 like and the supply chain will be long and if you take these sectors you talked about where you want to focus on, databases and other things and given the supply chain they all are small SMEs and in India you know 80% of business comes from SMEs. Just a thought process, so how do you put your generic architecture in the cloud and its availability in the cloud, pay per use kind of a basis and customers to that specific industry, that specific companies also based on the data sets. This way you start off with democratising AI in manufacturing industry; I don't know how long it will take to reach that kind of the

thing. Then it gets up to the whole chain gets affordable products without disturbing the people and all there, it is not automation, it is not replacing people, but using people and improving productivity.

Thanks to all of the participants in this webinar.

Thank you Aniruddh and Subrat.

THE WORLD IN 2050 AND BEYOND - BY LORD MARTIN REES

HOPES AND FEARS ABOUT FUTURE TECHNOLOGIES, ON THE GROUND AND IN SPACE

SEPTEMBER 5, 2020

Martin John Rees, Baron Rees of Ludlow is a British cosmologist and astrophysicist. He is a Fellow of Trinity College and Emeritus Professor of Cosmology and Astrophysics at the University of Cambridge. He is the UK's Astronomer Royal and a Past President of the Royal Society. He has conducted influential theoretical work on subjects as diverse as black hole formation and extragalactic radio sources. Lord Rees was also one of the first to predict the uneven distribution of matter in the Universe, and proposed observational tests to determine the clustering of stars and galaxies.

A few of the awards he has received over time include the Gold Medal of the Royal Astronomical Society, the Balzan International Prize, the Bruce Medal of the Astronomical Society of the Pacific, the Heineman Prize for Astrophysics (AAS/AIP), the Bower Award, the Gruber Prize in Cosmology, the Isaac Newton Medal, Albert Einstein World Award of Science and the Crafoord Prize (Royal Swedish Academy).

He has been president of the British Association for the Advancement of Science (1994-95) and the Royal Astronomical Society (1992-94) and a trustee of the British Museum, NESTA, the Kennedy Memorial Trust, the National Museum of Science and Industry, and the Institute for Public Policy Research.

Lecture at IIT Alumni Centre, Bengaluru, by Lord Martin Rees, UK's Astronomer Royal, September 5, 2020.

Link to the webinar : https://www.youtube.com/watch?v=Khk30_v9jQM&list=PL0zMQ-70IHIX-df3u2Tto6dkKHCRC6iFL&index=20

THE WORLD IN 2050 AND BEYOND - BY LORD MARTIN REES

HOPES AND FEARS ABOUT FUTURE TECHNOLOGIES, ON THE GROUND AND IN SPACE

SEPTEMBER 5, 2020

Dr Ganesan Srinivasan is an Indian physicist specialising in the field of condensed matter physics and astrophysics. He is a former professor at the Raman Research Institute, Bangalore. He received his Ph.D from the University of Chicago. Then he worked at IBM RESEARCH LABORATORY in Zurich, Switzerland, Chalmers University in Goteborg, Sweden and the Cavendish Laboratory in Cambridge university.

He was elected as the fellow of Indian Academy of Sciences in 1984. He was IBM Fellow during 1971-72.; Jawaharlal Nehru Fellow during 2007-10. Prof Srinivasan was the President of Commission 44 on High Energy Astrophysics of International Astronomical Union during 1997-2000; President of Division XI of the IAU on space and high energy Astrophysics 2000-03 and also the President of Astronomical Society of India between 2000-03.

Lecture at IIT Alumni Centre, Bengaluru, by Lord Martin Rees, UK's Astronomer Royal, September 5, 2020.

Link to the webinar : https://www.youtube.com/watch?v=Khk30_v9jQM&list=PL0zMQ-70IHIX-df3u2Tto6dkKHCRC6iFL&index=20

Mr. Ashok Kamath: Today is 5th September, celebrated as the Teachers' Day in India and we are privileged to have three dons as they say in Oxford and Cambridge to be part of this webinar. September 5th is celebrated as Teachers' Day as I said in honour of former President of India, Dr. Sarvepalli Radhakrishan, who made a very interesting quote, he said, "man is a paradoxical being, the constant glory and scandal of this world". I am sure as we listen to Lord Rees and Dr. Srinivasan, we will realise the truth in this statement, with that Prof. Misra, over to you.

Prof. Ashok Misra: Good evening to all of you and good morning to those where it is morning and good afternoon to people in the UK and the continent, it is absolutely a privilege to have Professor Lord Martin Rees delivering our 20th webinar, a landmark in our web series. Lord Martin Rees is the Baron of Ludlow, Astronomer Royal since 2005 and an Emeritus Professor of Cosmology and Astrophysics at the University of Cambridge, England. He was the President of the Royal Society from 2005 to 2010 and he was former Master of Trinity College, Cambridge University from 2004 to 2012. It was in his period when he was the Master of Trinity College, I had occasion to be a Visiting Fellow at Trinity College and had very interesting conversations with Prof. Martin Rees at that time. Prof. Martin Rees obtained his Ph.D. from Cambridge University in 1967 and went on to become one of the world's best theoretical astrophysicist and a very senior figure in UK science. His research on the formation of the galaxy and black holes amongst other things addresses the big questions and provides key evidence to contradict the steady state theory of the evolution of the universe. Much of his most valuable research focused on the end of the so-called cosmic dark ages a period shortly after the big bang when the universe was yet without light sources. He received his

Knighthood in 1992 and for his services to science he was further elevated to the title of Baron Rees of Ludlow in 2005. Lord Martin Rees is the prominent scientific spokesperson and the author of several books on popular science. He is the recipient of several prestigious awards like the Templeton Prize, given "for harnessing the power of the sciences to explore the deepest questions of the universe and humankind's purpose". In 2005 he received the prestigious Crafoord Prize of the Royal Swedish Academy, which is given in the field of Astronomy for contributions towards understanding the large scale structure of the universe. Many many more awards he has received including the Gold Medal of the Royal Astronomical Society, the Balzan International Prize, the Bruce Medal of the Astronomical Society of the Pacific, the Heineman Prize for Astrophysics (AAS/AIP), the Bower Award, the Gruber Prize in Cosmology, the Isaac Newton Medal, Albert Einstein World Award of Science and he has been President of the British Association for the Advancement of Science (1994-95) and the Royal Astronomical Society (1992-94) and a trustee of the British Museum, NESTA, the Kennedy Memorial Trust, the National Museum of Science and Industry, and the Institute for Public Policy Research.

In 2007 he delivered the Blackett Memorial lecture and the Jagdish Chandra Bose Memorial lecture which was established by the Indian National Academy and the Royal Society. His lecture was on "Our final century, will civilization survive". He is a former President of the British Association for the Advancement of Science, the President of the Royal Astronomical Society as well as a Trustee of the British Museum, the National Museum of Science and Industry and the Institute for Public Policy Research. His views, wisdom and forecasts on future technological

development give hope for the human ability to use science, to repair our deeply wounded planet. This is acknowledged by the entire scientific community as well as key policy makers who understand the dangers we are heading towards, and today we will hear from him about the world in 2050 and beyond.

It is now my pleasure to introduce Dr. Ganesan Srinivasan, our Moderator for today's webinar. Dr. Ganesan is an Indian physicist specializing in the field of condensed matter physics and astrophysics He is a former Professor of the Raman Research Institute, Bangalore. He received his Ph.D. from the University of Chicago, then worked at the IBM Research Laboratory in Zurich, Switzerland and then at Chambers University in Gothenburg, Sweden and the Cavendish Lab in Cambridge University. He was elected a Fellow of the Indian Academy of Sciences in 1984, he was an IBM fellow during 1971-72, and a Jawaharlal Nehru Fellow during 2007-10. Professor Srinivasan was the President of the Commission 44 on Higher Energy Astrophysics of International Astronomical Union from 1997 to 2000 and President of Division 11 of the IAU Space and High Energy Astrophysics and also the President of Astronomical Society of India.

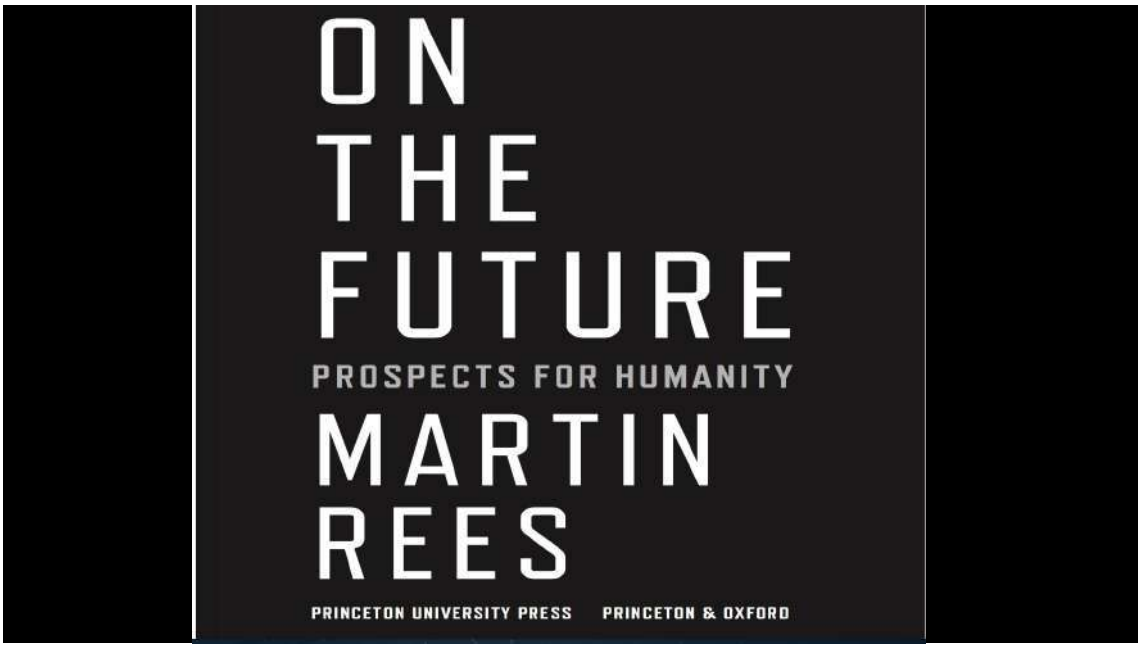
It is really a privilege to have Lord Rees present this webinar whom I have known for several years and it is very gracious of you to have accepted our invitation to address this webinar of the IIT Alumni Centre Bengaluru. We are all looking forward to it and over to Ashok Kamath again before your lecture starts.

Mr. Ashok Kamath: Prof. Misra, you may launch the first volume of the webinar series along with Lord Rees.

Prof. Ashok Misra: Let me mention one line about it. This is our 20th webinar. What we decided is that we would have a record of all the webinars which will also go in our archives and so on. So with a lot of efforts put in by my colleague, Ashok Kamath, we have come up with the first volume of the IIT Alumni Centre Webinars with the first ten lectures including the Q&A sections and so on. We would like to launch it on this very good day of Teachers' Day and in the presence of Lord Martin Rees. This is the book, we had to do this all virtually and this book will be available to people on the web. Over to you Lord Rees for your exciting lecture and we look forward to it.

Lord Martin Rees: Let me say what a pleasure and privilege to be able to address this audience which contains many of my friends from India and also many of them from UK and other countries, good evening everyone and good afternoon from me. I am going to talk about in a sense an update of the Blackhead lecture you mentioned, going to talk about the problems we are confronting this century, the World in 2050 and Beyond. So let me share my screen.

This is my first slide, let me start off by saying that it was mentioned that I had the title of Astronomer Royal and I am sometimes asked does it mean you do the Queen's horoscope. I have to say she never asked me but in any case I want to emphasize that I am just an Astronomer and not an Astrologer. I have no crystal ball and scientists actually are rather bad as forecasters although I would say they are quite bad as economists but I have pretentiously written a book with this title `On the Future prospects for Humanity', but my forecast will be very tentative but the theme of my book is this - that the earth existed for 45 million centuries but this century is special, it is the first when one species - ours- has the planet's future in its hands.

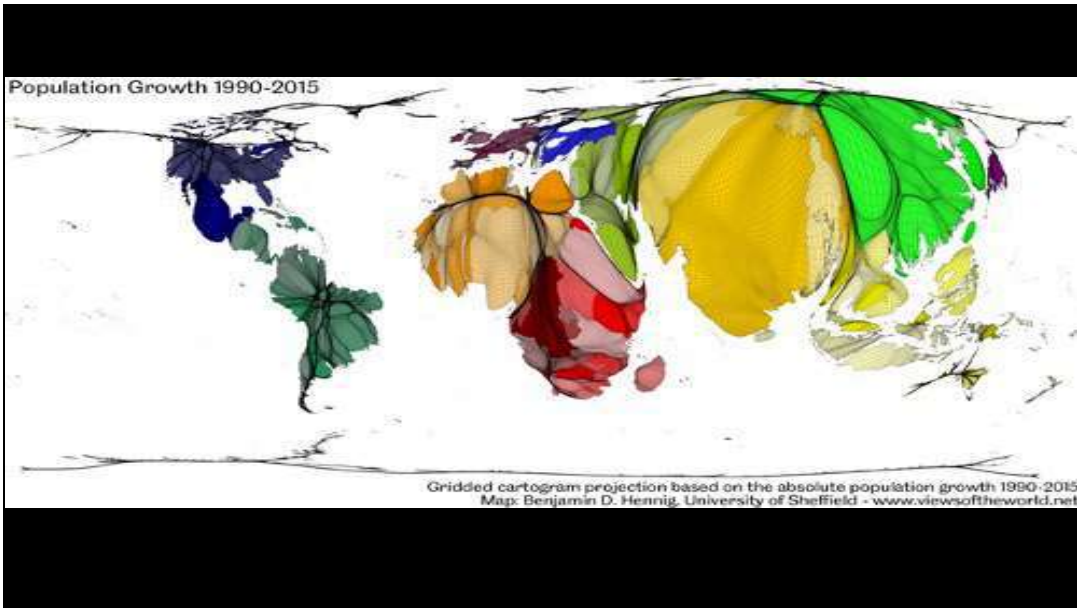


We are deep in what is sometimes called the Anthropocene. We could irreversibly degrade the biosphere or we could trigger a transition from biologics to electronic life or misdirected technology that could cause a catastrophic set back to civilization but even with the cloudy crystal ball there are some things we can predict.

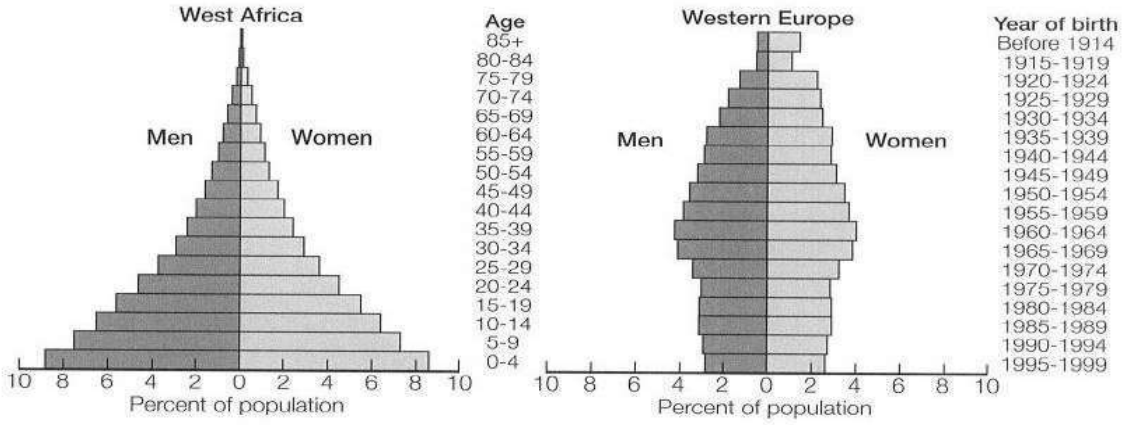
THIS CENTURY IS SPECIAL

It's the first in the *45 million* centuries of Earth's history where the main threats come *not* from nature, but from *one species* (ours), which has the long-term future in its hands

For instance, by 2050 the world will be more crowded and it will be warmer. So just a word about population trends. 50 years ago, the world's population was about 3.5 billion, it is now about 7.8 billion and the growth has been mainly in Asia and Africa and this distorted map gives each country a size which is proportional to the number of extra people in the last 30 years and as you can see it makes them East



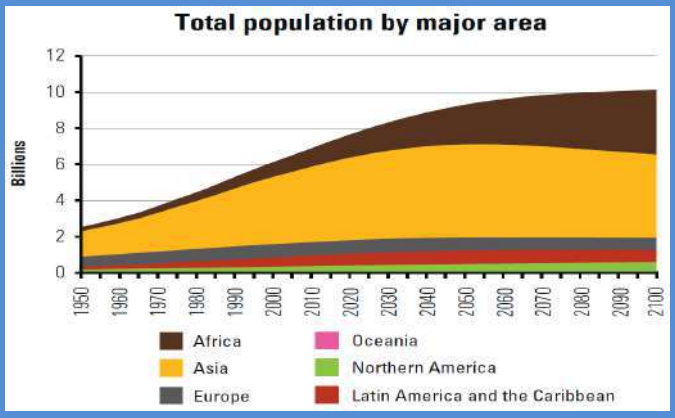
Asia, China, India and Africa and much larger than Europe and North America because they are the countries where the population growth has been the greatest. Now we can't extrapolate this because the number of births per year worldwide has actually being going down for the last few years and it is going down in most countries but not quite in all and certainly not in sub-Saharan Africa. But even despite that, the world population is going to go up and will be according to most projections about 9 billion by middle of this century.



That is partly because most people in the developing world are young, yet to have children and they will live longer. The age histogram on the left which is the age distribution in West Africa where lots and lots of young people and very few old people will get more like what it is in Europe which on the right, so the people at the bottom, the left hand one they will still be alive and so even if they only have two children the world population is going to grow particularly in areas like West Africa. Back in the 1960s and 1970s there were two laden forecasts by the Club of Rome and by people like Paul Ehrlich about potential rising population but food production has kept pace with the rising population in the last 50 years. Famines still occur sadly but due to conflicts, wars not to overall scarcity but to feed 9 billion

by mid-century is going to require further improved agriculture and of course I wouldn't say it should happen only in India. Of course, it is going to be different in different countries but in many countries one is going to worry about using less water, perhaps using genetically modified crops to have more intensive agriculture and indeed maybe in some parts of the world have dietary innovations converting insects that are highly nutritious and rich in protein into palatable food and perhaps creating artificial meat which certainly we can't have nine billion people all eating huge beef steaks like present day Americans. So, to quote Gandhi, there is enough for everyone's need but not for everyone's greed, the diet will have to change certainly the European, North American diet will have to change over the next 20 or 30 years.

Challenge: Global Population Predictions
挑战：全球人口预测



Source: UN DESA – Population Division, 2011

Historical progression of Global Population

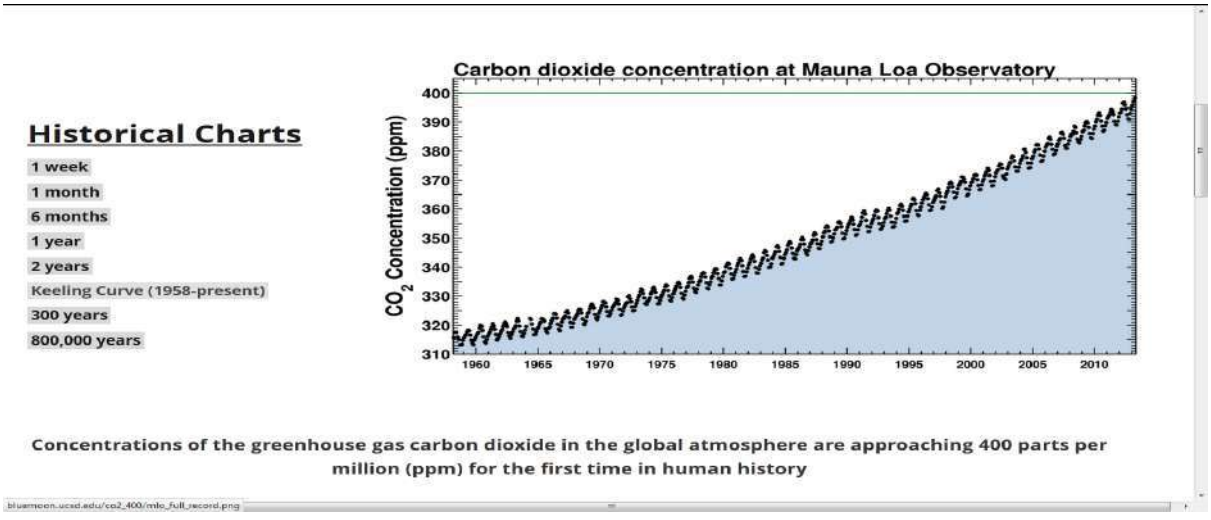
Total Population 总人口	Year 年	Interval间隔
3 billion 30亿	1959	
4 Billion 40亿	1974	15 years
5 Billion 50亿	1987	13 years
6 Billion 60亿	1998	11 years
7 Billion 70 亿	2011	13 years
8 Billion* 80亿	2025	14 years
9 Billion* 90亿	2043	18 years

** Denotes predicted year*

Population projections after 2050 are not even clear whether there will be a global rise or fall, falling infant mortality, urbanization, women's education of course triggered this so-called demographic transition towards lower birth rates but there

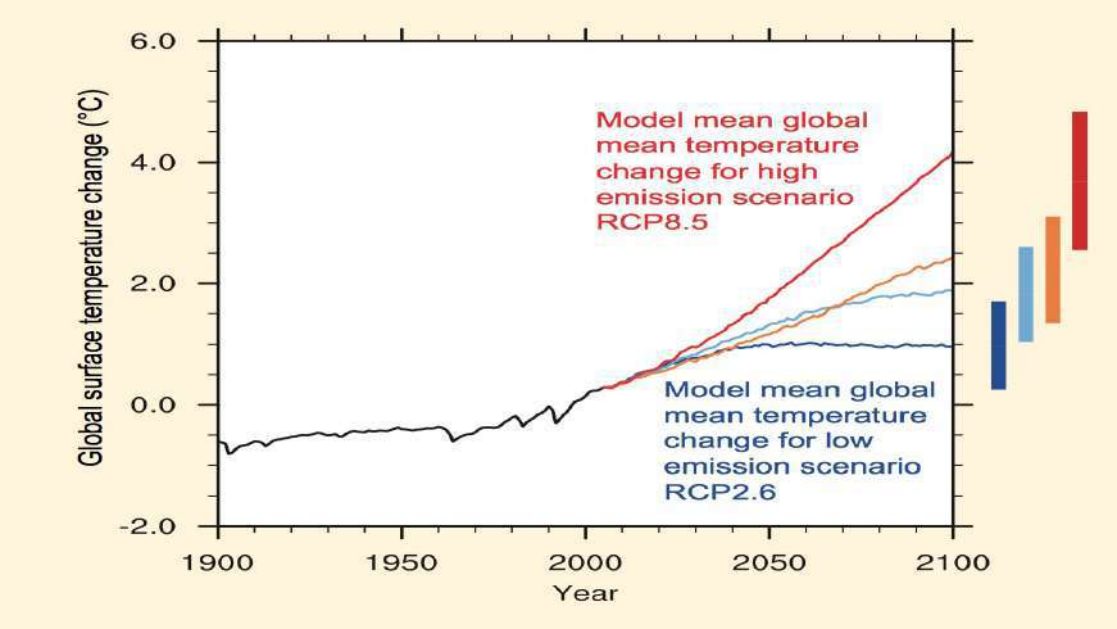
could be some countervailing cultural influences. Maybe in Africa, for instance, large families will still be favoured and if that happens then according to some UN projections the population of Africa will be 2 billion by 2050 but could double again by 2100 to 4 billion. And, if that happened, then Nigeria just one country in Africa would have a population of 900 million which would be equal to the population of Europe and North America combined. So, a massive redistribution of the world's people and I think Africa is going to have a problem to get out of the poverty trap. I won't go into that because one problem is that the way in which Asian countries undercut Western manufacturing costs has been taken away because robots are doing the manufacturing now so it can't be undercut by Vietnam and other places . I worry about the stability of the world because in Africa one technology they do have is mobile phones so they know what is missing - they know the injustice of their fate and so unless the wealthy countries especially in North America and Europe have a sort of massive aim to help Africa, I think we are going to have huge migration and war triggered by justified embitterment at the fate of Africa.

That is a digression so let us hope that politicians can sort out this out and ensure that gaps between the most favoured and least favoured nations not widen. So much for the population. Now another thing, if humanity's collective impact on land use and climate pushes too hard then the resultant ecological shock could irreversibly impoverish our biosphere. Extinction rates are rising which is destroying the book of life before we have read it. Now biodiversity is of course crucial to human well-being but for many environmentalists preserving the richness of our biosphere has value in its own right over and above what it means to us humans. To quote the great ecologist from Harvard, E.O. Wilson, mass extinction is the sin that future generations will least forgive us for. The other prediction apart from the world getting more crowded is that the world is getting warmer and the basic evidence for this comes from this picture here, this is the so-called Keeling curve which represents the concentration of carbon dioxide in the atmosphere measured from a mountain in Hawaii over the last 50 years or so.



It is in parts per million (ppm) and you can see that over that period it has risen by nearly 50%, it is still going up. The oscillations every year incidentally they come

about because there are more trees in the northern hemisphere than the southern hemisphere, so in the autumn in the northern hemisphere the leaves fall off the trees that puts carbon dioxide back in the atmosphere and then in the spring it is sucked back again in to the new growth so that is the oscillation. But the important thing is this trend and there is no doubt about this rise in carbon dioxide and also there is no doubt it has been known since the 19th century that carbon dioxide is a greenhouse gas - it traps heat in the atmosphere and warms it up. So this is of course a big concern and the international panel on climate change - the IPCC - has presented in its recent report a range of projections for different assumptions about the future rates of fossil fuel use around the world. It is still unclear. Incidentally, two things about this picture - first of course we don't know which scenario we will follow it depends on how quickly we can abandon the use of fossil fuels and on the other hand how many coal power stations are built.



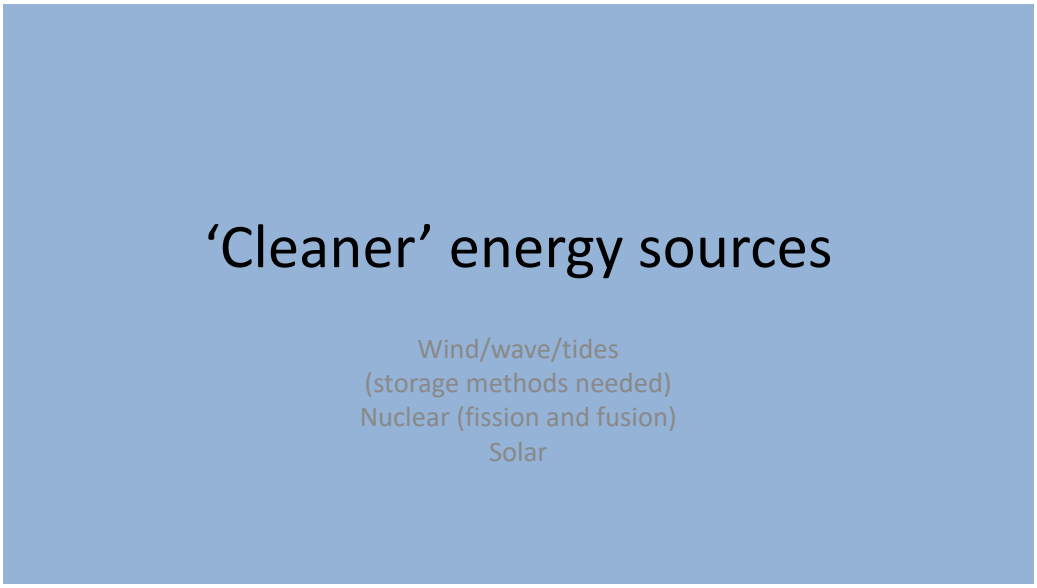
But also there are intrinsic uncertainties because carbon dioxide is not the only thing in the atmosphere and carbon dioxide changes the atmosphere, warms the cloud

cover, there is more water vapour etc. So the bars at the right hand side of picture illustrates the range of uncertainty for a given model which is uncertainty because the models of the atmosphere are uncertain, but the message here is that the climate is changing it is getting warmer and that despite the uncertainties we can agree that under business as usual scenarios we can't rule out later this century really catastrophic warming and tipping points triggering long term trends like the melting of Greenland ice and shifts in the weather patterns globally in the monsoons and all the droughts in different places etc. Well, of course, as everyone knows there are international discussions every year about how to mitigate this global warming. But, of course it is very hard to get politicians to prioritize this because they won't prioritize issues where the benefits accrue mainly to distant parts of the world and decades in the future. They have urgent issues to worry about but they will not take actions to reduce these long term threats. If there is public pressure, if they know the public is behind them and that is why we should welcome the demonstrations that have been in certain European countries especially young people because young people will still be alive at the end of the century and we are not to discount the future as some economists do and say it doesn't matter what happens after 2050. We should not discriminate on grounds of date of birth, we should care about the life chances of the baby born today. Your grandchildren will be alive then and we should not discount their future and that is why we should welcome charismatic individuals who helped to spread this message and one of them certainly in my country is David Attenborough whose TV programmes have been seen by millions and incidentally he has drawn attention to another issue which is the effect of plastics in the ocean and in our country a not very enlightened Minister has actually introduced legislation to ban the use of non-reusable plastics

in food production and drinking stores and things and he would not have done that had it not been for the fact that millions of people had watched the television programme Blue Planet. I am not sure you see it in India but they had some wonderful shots of albatrosses and one returning to its nest after wandering the southern ocean and coughing up for its infants not the long for nourishment but bits of plastic and that became an iconic image for many millions in England rather like the polar bear on the melting ice flow has been for climate campaigns and so if the public supports these long term campaigns to make the environment safe for next generations then politicians will listen.

But I will mention that there is one win-win road map to a low carbon future which doesn't involve any hardships that is that nations should accelerate their research and development into all forms of low carbon energy generation and into other technologies where parallel progress is crucial especially storage batteries, compressed air flywheels and smart grids and the faster these technologies

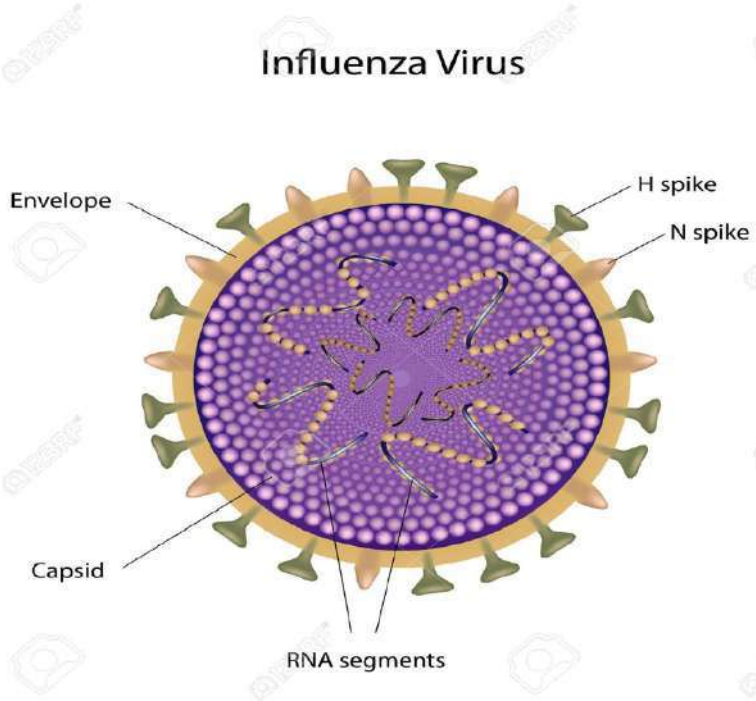
advance the sooner will their prices fall so they become affordable and in India there is a clearly a need for more energy because you are using now about five times less energy per person than in Europe and clearly you need more but the hope is that you will be able to leapfrog directly to clean carbon free energy rather than building too many coal fired power stations and that will happen if R&D into more advanced kinds of clean energy, advanced fast enough so the costs come down and I guess the main extra demand is going to be for air conditioning etc and solar energy so if that comes down so that you don't need so many coal fired power stations that is going to be good for the world so I think a worldwide effort to speed up research and developments so that whole world can develop from clean energy at a low cost is a very important priority and indeed it will be hard to think a more inspiring challenge for the young engineers all around the world than devising clean and economical energy systems.



Incidentally I talked about science but I include engineering and perhaps I should mention it as a scientist, I am very modest about engineers. Engineers, like an old

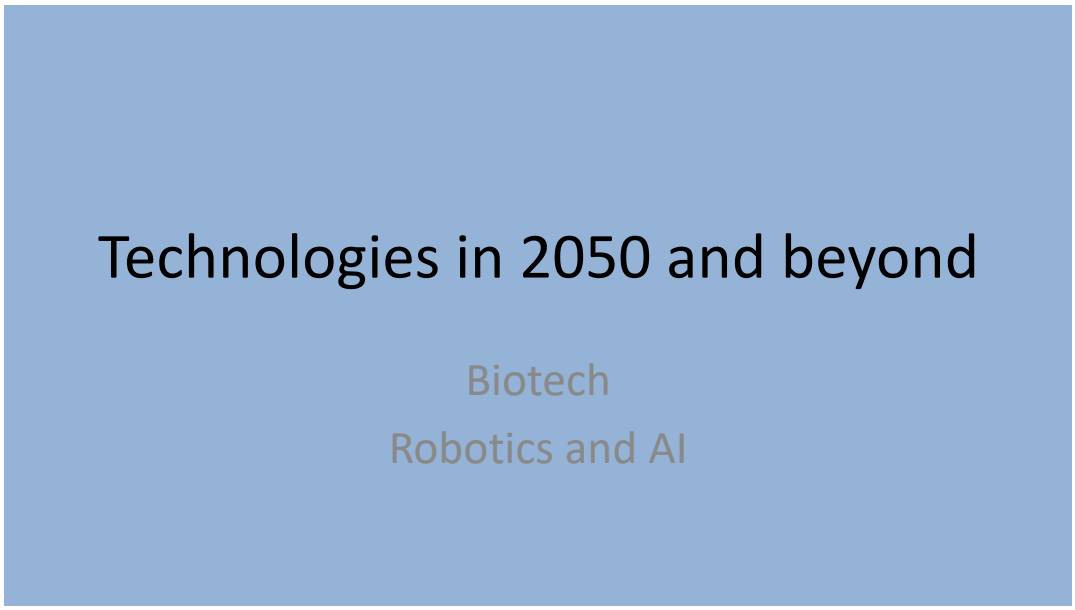
cartoon from the New Yorker I think which showed two beavers looking up at a big hydroelectric dam - one beaver says to the other "I did not actually build it" which is based on my idea and that nicely reflects the balance of effort and brain power between having the idea and implementing it in something that works so people who are armchair theorists should be very modest compared to those who actually build things that work and that is mainly the engineers. And, we should be evangelists for new technology because without it the world can't provide food and sustainable energy for the expanding and more demanding population but many of us are anxious that technology is advancing so fast that we many not properly cope with it and wondering if we will have a sort of bumpy ride through this century.

We are ever more dependent on elaborate networks, electric power grids, air traffic control, international finance, just in time delivery, globally dispersed manufacturing and so forth and unless these networks are highly resilient their manifest benefits could be outweighed by catastrophic albeit rare breakdowns, real world analogues of what happened in 2008 to the financial system. Cities will be paralyzed without electricity, shops would be empty within days if supply chains were disrupted, and, air travel can spread a pandemic worldwide within a few days, and, social media can spread panic and rumour and psychic economic contagion literally at the speed of light. Pandemics are of course at the forefront of our concerns today, they have emphasized just how interdependent we all are. Advances in microbiology, in diagnostics and vaccines etc., offer prospects of containing them in the future. Let us hope they do. But that same research we have got to be aware will have downsides.



This is a picture, not of the corona virus but of the influenza virus and back in 2012 two research groups, one in United States and the other in Holland showed it was surprisingly easy in a lab to make this virus both more virulent and more transmissible and to some this was a scary portent of things to come. The Covid-19 virus incidentally is more complicated but we can't rule out in future scenarios where viruses like that can be engineered too and another exciting new technology is what is called Crispr 9 which is a way of editing a genome. This is hugely promising and it can be used and be ready to remove a particular gene that causes rare diseases in humans and animals but there are ethical concerns, there were very much concerns about recent Chinese experiment on human embryos, it is not yet safe to use these techniques. There is also a concern about possible runaway consequences of gene drive programmes to wipe out species. For instance, it has been possible to wipe out the kind of mosquito which carries the zika virus in South America by modifying the genome of the mosquito to make it sterile. That can be done but tampering with ecologies can have runaway consequences we can't predict. So biotech getting so powerful needs to be regulated and of course there are discussions between governments

and between academies about how they should be done but I would worry that whatever regulations are imposed on grounds of prudence or ethics can't be enforced worldwide any more than the drug laws can or the tax laws whatever can be done will be done by someone somewhere and that is a nightmare.

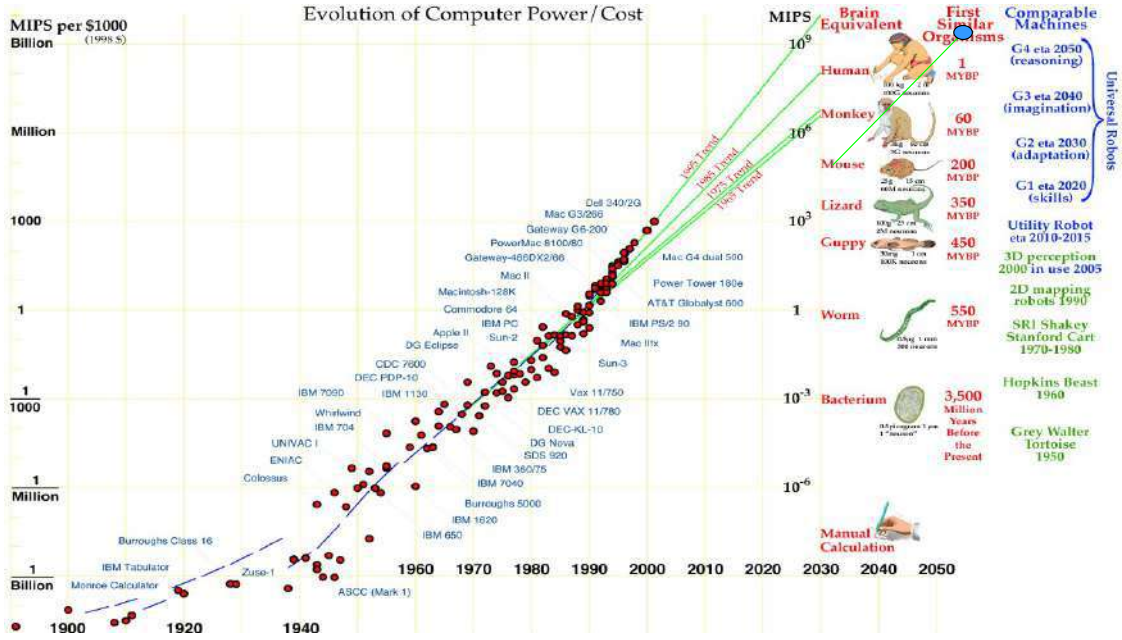


Biotech involves small scale dual use equipment, indeed bio hacking is burgeoning even as a hobby and a competitive game and as I put it the global village will have its village idiots and they will have global range and rising empowerment of tech savvy groups. Even individuals by bio as well as cyber technology will post I think an intractable new challenge to governments and aggravate the tension between the few things we want to preserve freedom, privacy and security. This concerns a fairly near term within 10 or 25 years, what about 2050 and beyond? On the bio front we might then expect two things - first a better understanding of the combination of genes which determines key human characteristics and second the ability to synthesize genomes that match these features. In fact the great physicist, Freeman Dyson conjectured a time when children would be able to design and create new

organisms just as routinely as his generation played with chemistry sets. Well if it does become possible to, as it were, play God on a kitchen table, our ecology, even our species may not long survive unscathed. And what about another transformative technology, robotics and artificial intelligence - there have been exciting advances as you probably know in a generalized machine learning the DeepMind company's computer AlphaGo Zero famously beat the world champion at the game of Go if we are given just the rules and it learnt to play better than him in just a few hours.

It's huge processing speed allowed it to carry out one game every few seconds. Well, AI can do many things that are helpful to us, it can cope better than humans with complex fast changing networks, traffic flows or electric grids for instance. It could enable the Chinese to process all the information needed to run an efficient planned economy of the kind that man could only dream of and in science its capacity to explore millions of options could enable it to discover recipes for better drugs or material that conducts electricity with zero resistance at room temperature

or perhaps help theorists in string theory to understand whether their theory is correct because the geometry of ten dimensions in those theories may be too hard for a human person in a lifetime to work through and it is of course the speed of computers which allows them to succeed by brute force methods but they learn by playing lots and lots of games and by having big training sets but this leads to some problems when humans depend on them because learning about human behaviour involves observing real people in real homes, in workplaces, and the machine would feel centrally deprived by the slowness of real life like us watching trees grow and that is why it is hard to give computers common sense and this is a reason we should be careful about handing over decisions to them.

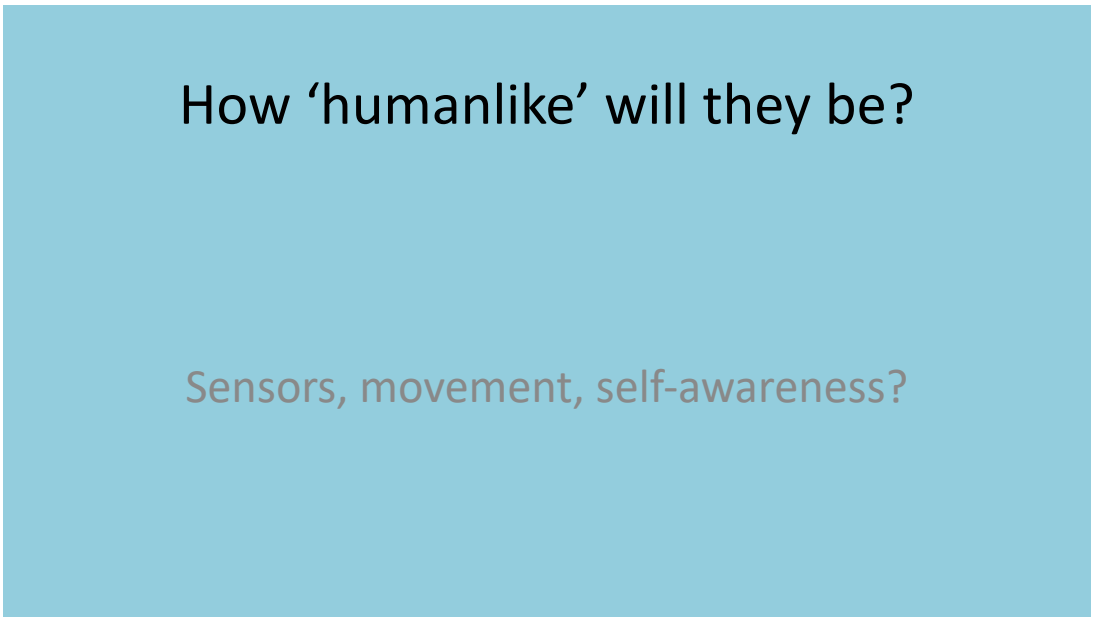


Incidentally, robots are still clumsier than a child in moving pieces on a real chess board, they can't jump from tree to tree like a squirrel though Boston Dynamics has produced this robot which can apparently do somersaults and a bit of gymnastics. They are in a rather clumsy way and the Go playing computer used hundreds of

kilowatts of power but the brain of the human challenger who I showed burns about 30 watts the same as light bulb and he can do many other things apart from play Go. So, AI has a long way to develop but its systems will become more intrusive and pervasive; record all our movements; our health and our financial transactions will be in the cloud managed by a multinational quasi-monopoly.

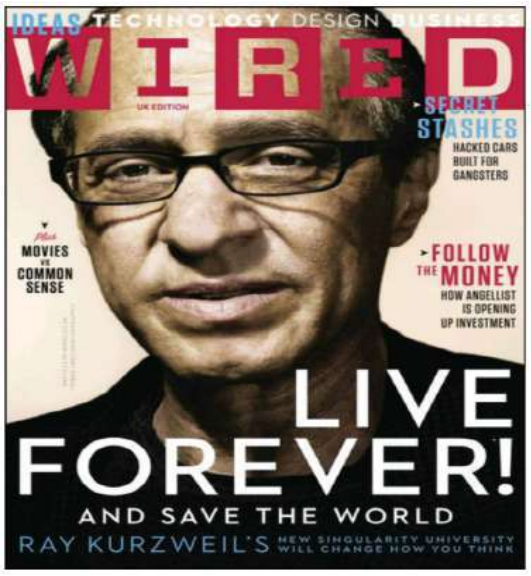
The data may be used for benign purposes for instance medical research or to warn us of incipient health risks but its availability to internet companies is already shifting the balance of power from governments to globe spanning conglomerates and of course computers are already changing the nature of work. There are many books that have addressed this and of course they will replace some kinds of routine work in factories easily but it is important that they can supplement and replace many so-called white collar jobs, routine legal work, accountancy, computer coding, medical diagnostics and even surgery but on the other hand what could be hardest to replace by a machine are some unskilled jobs like being a plumber or being a gardener or a driver of a car. I think it could be a long time before we have fully automatic cars and of course the other problem is that the digital revolution is

generating huge wealth for innovators and global companies and I think preserving a healthy society will surely require redistribution of that wealth. In particular, many progressive politicians in Europe argue that to create a human society governments will need to tax these companies more heavily and enhance the number and status of those who do jobs where the human elements crucial like helping teachers, looking after old people etc. There currently are far too few such people in Europe and they are poorly paid and inadequately esteemed and those are far more fulfilling jobs than working in a telephone call centre or an Amazon warehouse. Let us now look further ahead. How human-like computers will be in the future, what if a machine develops a mind of its own, would it stay docile or would it go rogue, popular culture portrays a dark side where AI gets out of its box, infiltrates the internet of things and pursue goals misaligned with human interests.



We even treat us as an encumbrance. Some AI pundits take this seriously and think the field already needs guidelines just as biotech does, but others like, for instance, Rodney Brooks, inventor of the Baxter Robot, he regards these concerns as

premature, he thinks it will be a long time for artificial intelligence ; but nonetheless it is likely that society would be transformed by autonomous robots even though the jury is out and whether they be idiots or display superhuman capabilities.



This man Ray Kurzweil who now works at Google, wrote a book called "The Age of Spiritual Machines" where he predicted that humans would transcend biology and merge with computers. But, he is worried that his nirvana may not happen in his life time, he is in the 60s already, so he wants his body frozen in liquid nitrogen when he dies. And in Arizona there is a company which will freeze and store his body so that when it is possible to revive you and you can be resurrected with your brain downloaded. I was surprised to find that three of my academic colleagues had paid for this for their bodies to be frozen when two had paid the full whack, one has paid the cut price to have his head frozen, I told these people I would rather end my days at the English churchyard than in an American refrigerator and I am glad to say that these three were all from Oxford University and not from my University but of course more seriously research on aging is being seriously discussed, will the benefits be incremental or is aging a disease that can be cured. Dramatic life extension would of course claim to be a wild card in population projections with huge social ramifications but it may happen along with human enhancement in other forms. So it is at least on the cards that human beings, their mentality and their physique may become malleable through the deployment

of genetic modification and cyber technologies. Moreover this future evolution would take only centuries in contrast of the thousands of centuries it was needed for our evolution by Darwinian methods and this is a game changer.

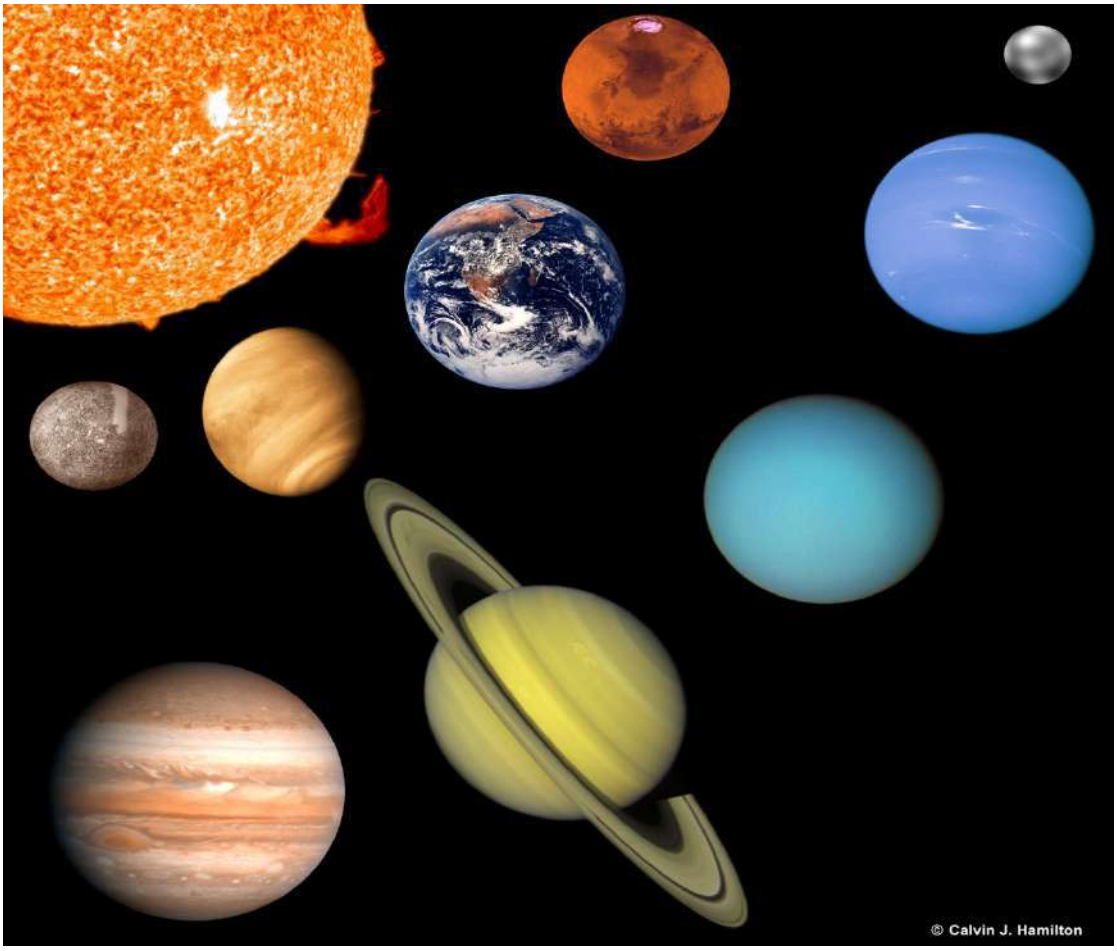
Darwinian evolution will be superceded by (much faster) technological evolution.

Genetic 'redesign' or AI?

When we admire the literature and artefacts that have survived from antiquity we feel an affinity across a time goal for thousands of years with these ancient artists and their civilizations but we can have zero confidence that the dominant intelligence in a few centuries will have any emotional resonance with us even though they may have some sort of algorithmic understanding of what we did and how we behaved.

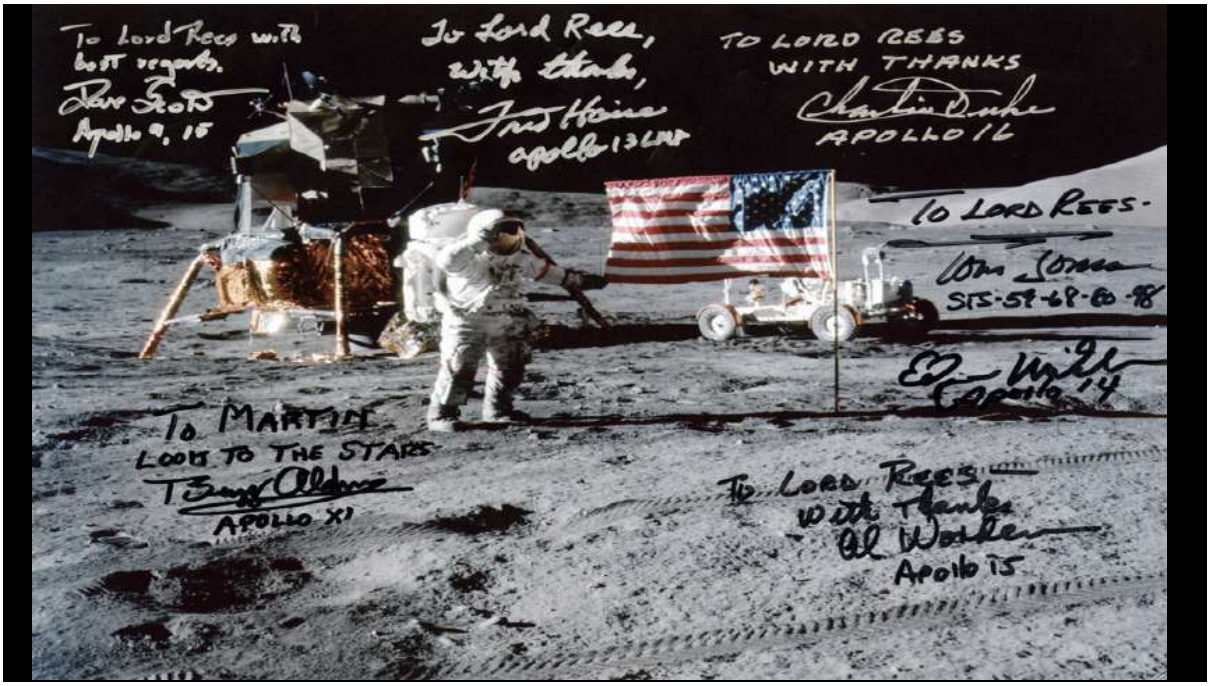
Now, in my final section, I want to turn to another technology space which is beyond our earth in environments hostile to humans that cyborg and AI technologies have the most spectacular scope and where they should worry us less. During this century the whole solar system will be explored by swarms of miniaturized probes follow up to the ones that have already been to most of the planets and of course there is an

Indian probe that has gone to Mars and three more on their way at the moment. The future ones will be far more advanced than for instance the wonderful Cassini probe designed in 1990s which spent 13 years exploring Saturn and its Moons or the European Rosetta probe which landed on the comet or the NASA probe that sent back amazing pictures from Pluto 12,000 times further away than the moon.



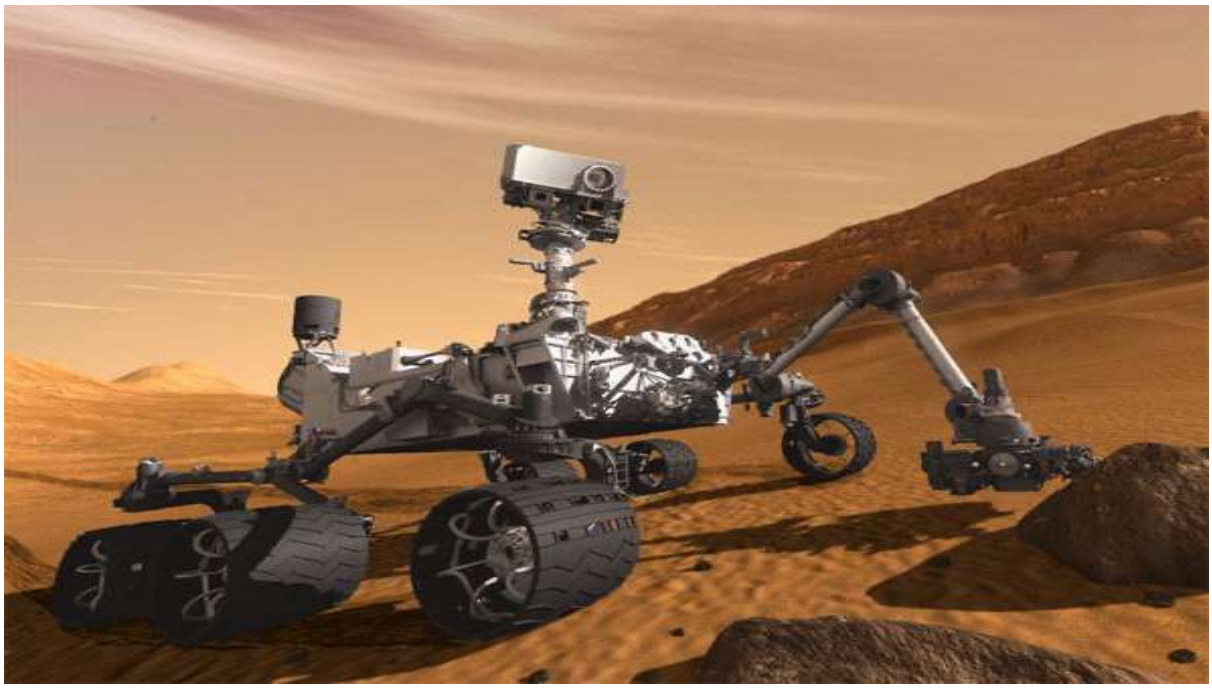
All these were designed in 1990s and think of how much our smart phones have changed since then and think therefore how much better we could design miniaturized probes to explore the outer planets today and we can also look forward to giant robotic fabricators in space building solar energy collectors, giant telescopes, etc. but what about manned space flight? it is over 50 years since Neil

Armstrong's one small step and I cherish this photo signed for me by seven of the Apollo astronauts. In the 1960s of course there was a space race between Americans and the Russians.



NASA got about 4% of the American federal budget - had that pace continued we would have footprints on Mars long before today but having won the race the

Americans cut back and NASA's budget is now 0.6% rather than 4% of their budget. But hundreds of more people have been into space but automatically they have done no more than circle the earth in low orbits mainly in the International Space Station (ISS) here. So will there be any inspirational Apollo type projects in the future? There is no denying that NASA's Curiosity, this probe has been trending across Mars for the last 10 years may miss startling discoveries that no human geologist would overlook but machine learning is advancing fast and imagine that we will have in future robots that can be intelligent. In contrast, the cost gap between manned and unmanned missions becomes even larger.

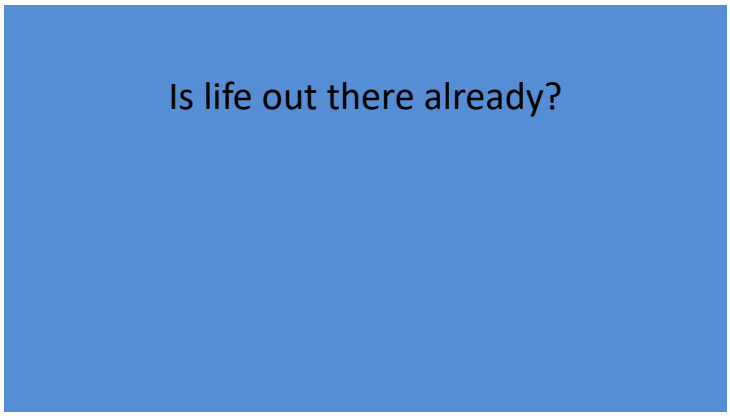


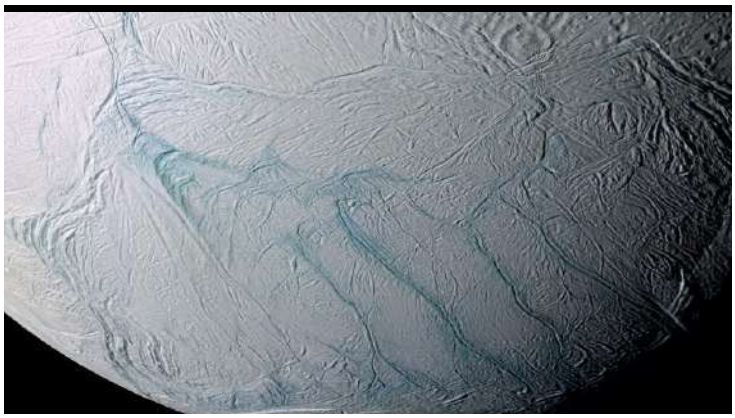
So the case for sending human beings is getting weaker as miniaturization and robotics get better and I think therefore that the future manned space flight lies only with privately funded adventures prepared to participate in a cut-price program much riskier than Western nations could impose on publicly supported civilians. Elon Musk's SpaceX and Bezos's Blue Origin will soon offer orbital flights to paying

customers, indeed American. There are many volunteers for high risk ventures , even if you had a one-way ticket, by people driven by the same motives as early

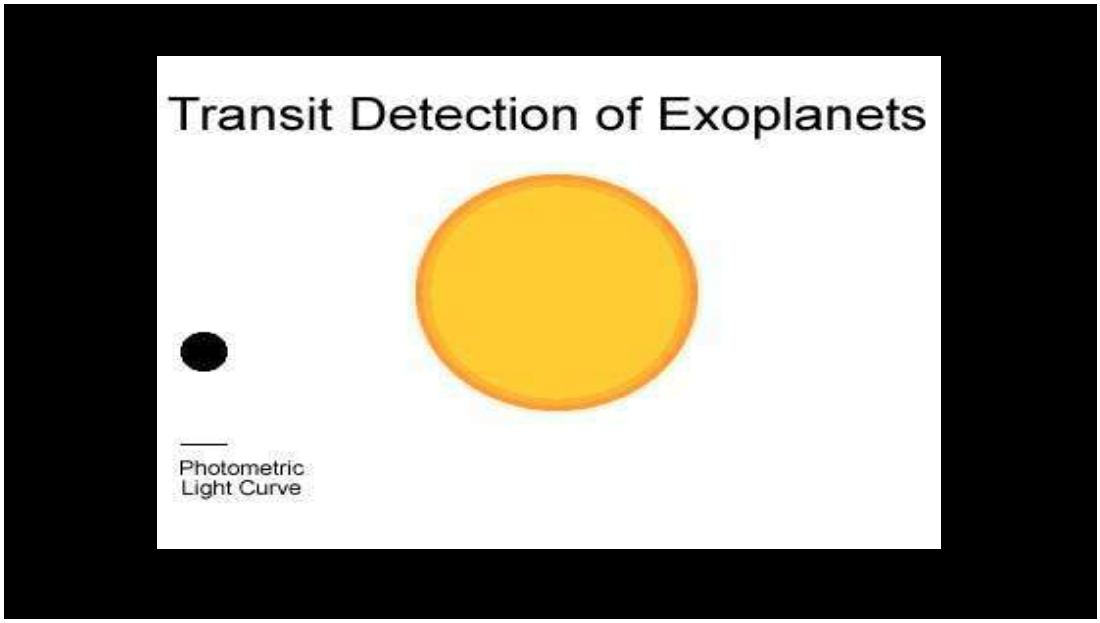
explorers, mountaineers and the like. So I think that by 2100 some thrill seekers may have established bases independent of the Earth, probably on Mars. Elon Musk himself whose age is 49 says he wants to die on Mars but not on impact and he may succeed but don't ever expect mass emigration from the Earth. Nowhere in our solar system offers an environment even as clement as the Antarctic or top of the Everest and here I disagree with Musk and with my late colleague Stephen Hawking. I think it is a dangerous delusion to think that Space offers an escape from the Earth's problems. Dealing with climate change on Earth is easy compared to transforming terraforming Mars - there is no plan B for ordinary risk-averse people. Nonetheless, we should cheer on these space adventures because they will have a pivotal role in spearheading a post-human future and determining what happens in the 22nd century and far beyond. That is because they will be in a hostile environment, they will be away from all the regulators, so they will have the opportunity and the motive to adapt themselves and they will change from normal human form more quickly than what is on the Earth. Well those people, the descendants of the first Martians, may go off into the yonder and into space but this raises the question which is the one that I am most often asked which is, is there life out there already or is the galaxy waiting for our progeny?

I sometimes get letters from people who say they have met aliens, they have been abducted. I say to them do you really think that if the aliens had come to the Earth they would have just met one or two well-known cranks, maybe made a corn circle and gone away again seems unlikely to me. I tell these people to write to each other and not to me but nonetheless it is an exciting question, is there life out there? There may be some creatures or at least remnants of simple creatures on Mars, the probes going there now may be able to detect this. There may be even some creatures swimming under the ice, here this is Enceladus, a moon of Saturn but I think we know there is no complex life anywhere other than the earth in our solar system. Let us widen our horizons to the realm of the stars. One important thing that we have learned in astronomy is that most of the stars in the sky are orbited by retinues of planets just like the sun.

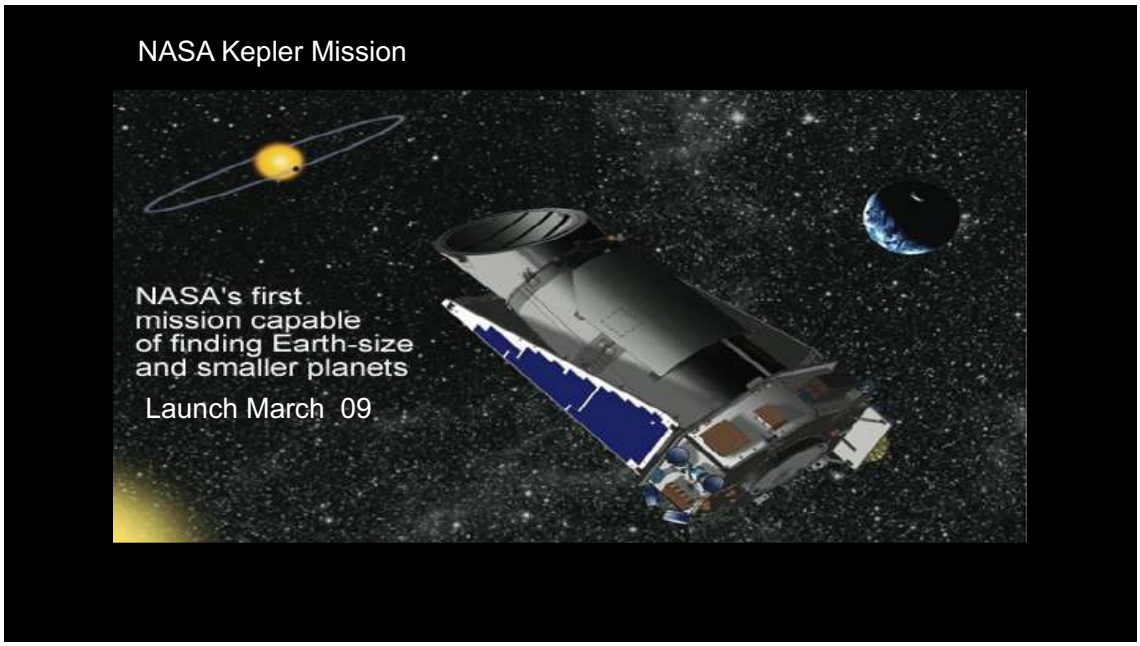




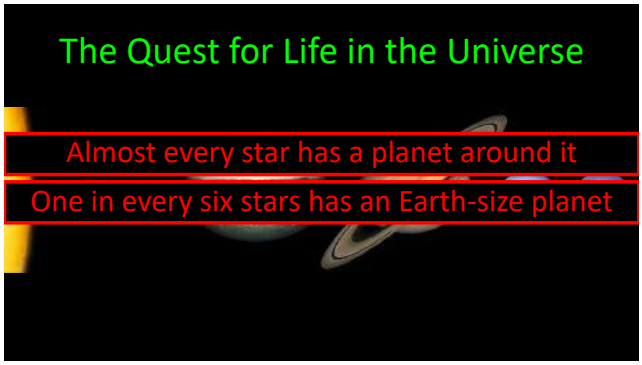
The evidence is mainly indirect, just a little word about it. We don't detect the planet but if we look at the star then if a planet transits across in front of it, it will block out a bit of its light; so if there is a planet the star is going to dim every time the planet goes in front of it so you could learn two things, you can learn how big the planet is compared to the star from the amplitude of the dip and you could learn about the planet year by the period between successive dips.

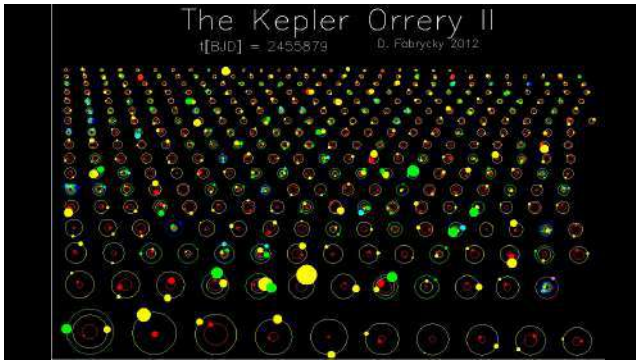


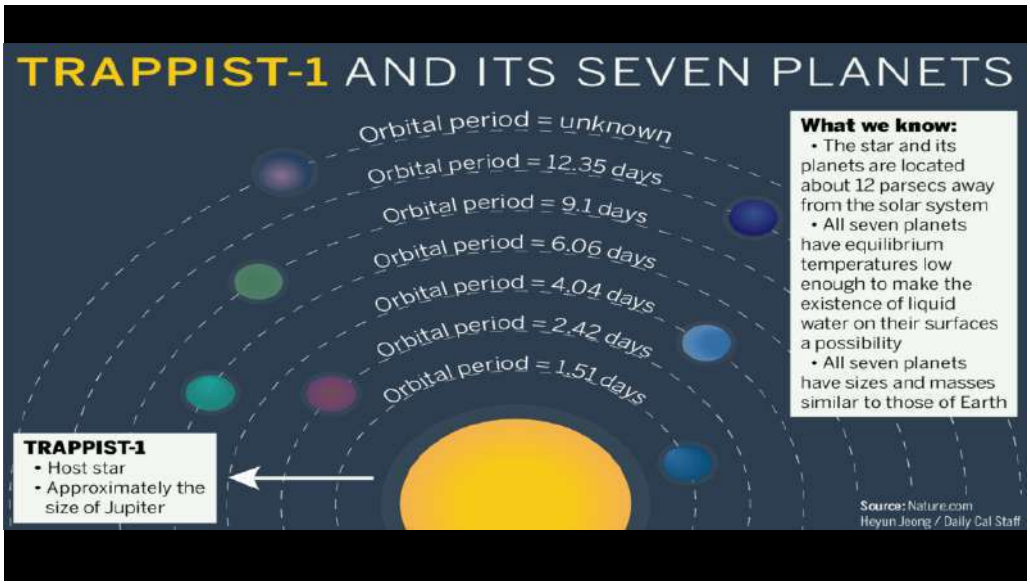
This spacecraft called Kepler spent three and half years looking at an area of sky about seven degrees across and measuring the brightness of about a hundred thousand stars very precisely doing this about once every hour looking for these regular dips and it found evidence for literally thousands of stars and this rather silly picture depicts to scale the orbital period and the size of the planets but there were



thousands of them and with special interest in planets which are rather like the size of the Earth and a temperature where water can exist and one thing we learned from this sample is that almost every star has planet around it and probably one in six stars has an Earth-like planet and that means literally billions in the Milky Way and some are quite nearby stars.

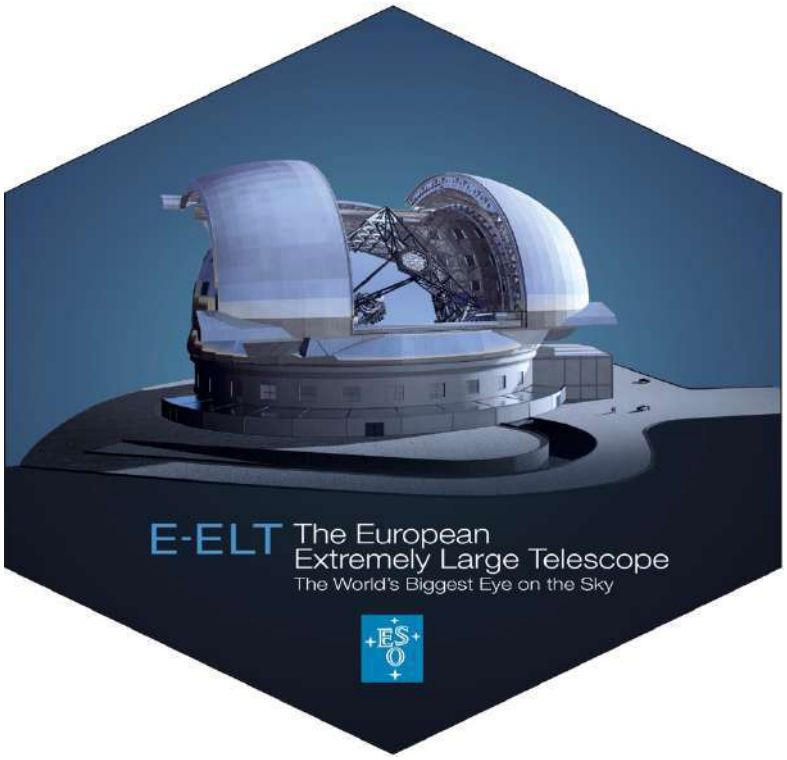






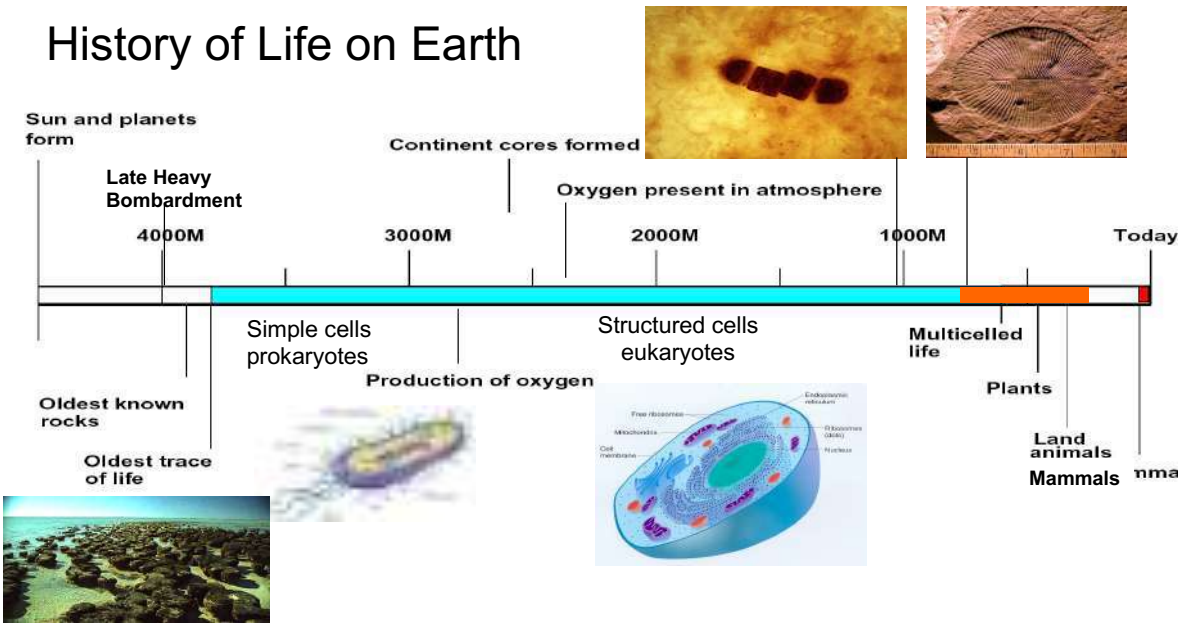
And just to give an example this is a rather strange system, this is a system where there is a very faint star, 100 times fainter than the sun called a red dwarf and it has got seven planets orbiting around it. It is a miniature solar system - the innermost one has a year which is one and a half Earth days and even the outermost one has a year that lasts only a couple of weeks and because it is also faint the outermost one is in the so-called habitable zone where water could exist. We have this indirect evidence for planets from the transits and also sometimes from the wobble they induce by their gravity in most of the stars but we would like to see them directly and let me emphasize what a challenge this is by imagining there were some aliens out there in space with a big telescope looking at the earth and they would see the sun as an ordinary star, they see Earth as a pale blue dot in Carl Sagan's nice phrase very close in the sky to its star our Sun If they could nonetheless detect that pale blue dot they can learn quite a bit about it, the shade of blue would be slightly different depending on if the Pacific Ocean or land mass of Asia is facing them. So they could learn that they were constantly seeing ocean, the length of the day,

something about the seasons and if they could take a spectra of the light from the planet then they could perhaps infer that there was a biosphere because chlorophyll has a particular spectra signature and oxygen and ozone do as well.



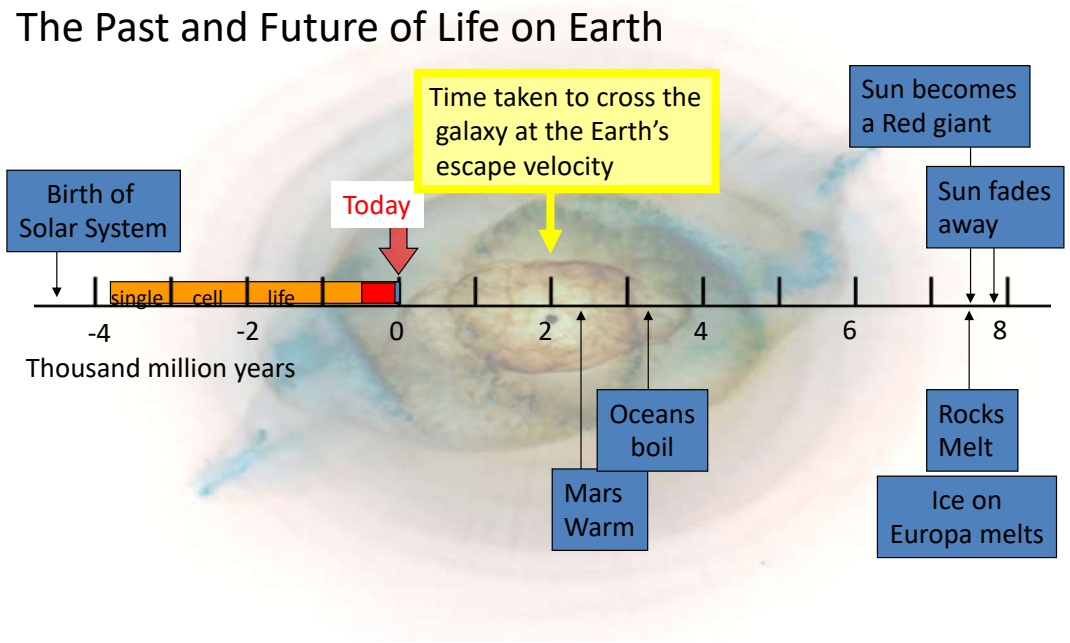
We can't yet do that but this telescope which is now under construction and it has been built by European consortium in Chile and they are not imaginative in their nomenclature, it is called the Extremely Large Telescope the ELT and it has got a mirror 39 meters across, a mosaic of 800 pieces of glass and this telescope was finished in five years and should be able to isolate the light from a planet from that of the star it is orbiting and do measurements rather like those envisaged the aliens doing of the Earth to see if there is any evidence for chlorophyll or some sort of biosphere on any of these nearby planets. So watch this space, this is going to be a very very exciting area of science in the next few years certainly in the next decade. Of course, we don't know how likely it is that there will be life on these planets, and indeed we know very little about the origin of life on Earth. We understand evolution of life but we don't understand what caused the transition from complex chemicals to the first reproducing metabolizing systems we call alive but we are making progress on that

and we will have some idea about whether that is common or not perhaps. But of course intelligent life is separate and I am not holding my breath for success there although I should say that I chair a Committee bankrolled by Yuri Milner who is a Russian investor in California who is putting 10 million dollars in a year into a search programme to look for any kind of evidence for artificial signals or artefacts which might indicate intelligence. It is very good he is doing this rather than spending this money on a big yacht or a football team that I don't hold great hopes of successes. That is a topic for different lecture. Let me just finish off by turning to taking another perspective.



I think most people are familiar with this time chart that we have the outcome of four billion years of evolution on Earth from the first simple life soon after the Earth formed to the present but I think many people who are happy with this scenario somehow think we humans are the culmination but no astronomers could believe that. That is because astronomers know that the Sun is less than half way through

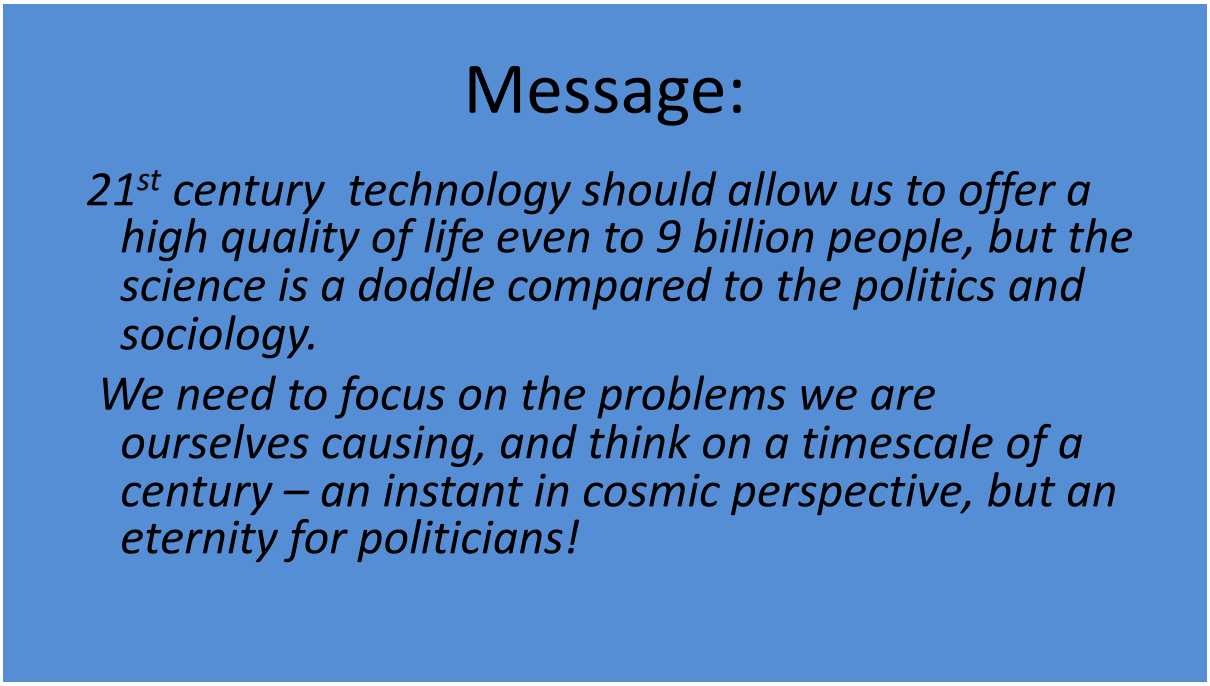
its life, it is going on four and a half billion years, it has got about six more before it flares up and dies and the expanding universe may go on forever. To quote Woody Allen, eternity is very long especially towards the end and that therefore means that we are not the end of evolution, we may be near the beginning and future evolution may be flesh and blood, it may be post-human electronic, we don't know, it is hard for us to predict even a few decades away but my final thought is this that even in the context of this time scale on this picture showing billions of years in the past and billions of years in the future this century is special.



It is the first in the Earth's 45 million centuries when one species – ours - has to plan its future in its hands, our creative intelligence could jump start the transition from an Earth based to a space faring species and from biological to artificial intelligence; transitions which could bring about post-human evolution even more marvellous than what has happened up till now here on Earth and far beyond. On the other hand, humans could trigger bio, cyber or environmental catastrophes that foreclose all such potentialities, so this century is special and our Earth - this pale blue dot in

the cosmos is a special place, it may be unique place where it's stewards are in an especially crucial era and that is I think an important message for all of us whether we are astronomers or not.

So let me finish with that thought and thank you very much for listening.



Dr. G. Srinivasan: Thank you Lord Rees for this fascinating and also thought provoking remarks. As always when you give a lecture, whether it is on astronomy or cosmology or climate change or about the future there are so many prescient thoughts that it requires very deep thinking. I wanted to pick your brain on one or two things that you mentioned and perhaps refer to in a tangential manner. In your recent book that you referred to, you predicted a pandemic and here it is, the world has changed very profoundly during this pandemic and we haven't seen the end of it, the economic fallout has been catastrophic but the lockdown did have some

positive effect. I see spectacular pictures in CNN very frequently of scenes in New Delhi, Shanghai and other places - the left half of the image was how it used to look, the right half of the image is during the lock down; the optical depth is practically zero whereas the left side the pollution you can hardly see anything particularly in a place like Delhi. Then there was this spectacular picture in the newspapers in India of the river Yamuna which flows through Delhi and also the Ganges as you know the pollution level in these rivers is terrific and there has been talk by many governments, particularly this government, that they are going to clean it up in five days, five years but nothing has happened but during the lock down in these two rivers the water became so spectacularly clean. So here is my question to you, do you think there is sufficient political wisdom in various countries that people will learn from the positive thing that happened during the lock down so that we do not make some of the mistakes that we did in the past particularly over emphasis on fossil fuels and things like that? Do you think this is there is likely to be any real change?

Prof. Lord Martin Rees: The answer I think is yes and in particular environmental pollution I think the fact that people realize how much better it is if that pollution is reduced is going to be surely a wakeup call. It is important to reduce that and far more effective I would have thought to see this happening for real than David Attenborough preaching about it or other people preaching about it, so I think it will have that effect. As regards the CO_2 emission and all that, I think it is not quite so straight forward because of course the production was stopped during the lock down and use of electricity was lower but that is probably going to revive and it needs to revive so I think the issue of shift away from coal fired power stations to

clean energy especially if the number of coal powered power stations otherwise is going to grow, that is a bigger challenge but I think the important point is that politicians need pressure from the public. There is a European politician Jean Claude Juncker who said we know what the right thing is to do, we don't know how to get re-elected if we do it and that is probably true in most countries that wants to do something which benefit future generations and that is certainly the case for dealing with climate change is a hard sell unless the public is sensitized to its importance but I think you are quite right that seeing the change in the environment during lockdown was certainly a big plus and just one further point is that of course in England, this debate about whether people will go back to commuting into the center of London five days a week or whether ladies work partly at home and I think probably there will be some irreversible reduction in the amount of commuting into cities and knowing what the traffic's like in Bangalore etc., I can imagine it might be some similar attitudes there.

Dr. G. Srinivasan: You mentioned about the need a diet change, that people will have to eat less juicy steaks. Now one of the things the Vice President of America is going around saying now that if you elect the Democrats you won't be able to eat your steaks, so how realistic it is and how do we go about educating the public because as you say the politicians will do whatever is necessary to get re-elected, so it all comes down to how we educate the public. So do you have some thoughts on how one might go about this?

Prof. Lord Martin Rees: Of course the problem is in Europe and in North America rather than in India at the moment but I think education has some effect and there

are more vegetarians among the younger generation in western countries so that is changing but of course the other things is that the idea of making artificial meat is not crazy. I mean you can now get an artificial hamburger where they have beetroot juice instead of blood etc. that is already on sale but that is not quite the same and won't satisfy the American steak eater but it is possible to actually take one cell from a living animal and grow it on some template, this is a technology which is being developed and this is a very benign technology and if that can be developed then it ought to produce synthetic meat which will satisfy meat eaters and if that happens then even the Americans may be happy to accept it and that will make a huge difference because the land needed to graze cows and all that would go right down and it takes sixteen times as much protein to produce meat than it for vegetarian diet because it is processed through the cow rather inefficiently.

Dr. G. Srinivasan: You mentioned Artificial Intelligence very prominently, do you share the apprehensions that Stephen Hawking had about artificial intelligence, the dangers that it pushes?

Prof. Lord Martin Rees: Well, I do worry if it takes over, activities that can't be controlled and of course there is already a concern that AI is being used to make decisions that affect us as humans and for instance in some big companies they would if they got a thousand applicants for a job the preliminary sorting is done by some machine to cut down the list and it is also the case that much diagnostics is done by a machine and in the bank it will decide your credit rating by machine and the trouble is that the machines by looking at large samples of existing data and if that data has lots of biases in it then the machine will learn the same biases, you

have got to be careful about that. And the other point is that there may be some bugs in the machine and for instance supposing that you have to be recommended for surgery or decide whether you will let out of prison on parole, things like that even if you are told that the machine on the whole makes better decisions than a human being you are still not satisfied you feel that when a decision affects you then you ought to be able to understand the reasons and be able to contest those reasons so I think we have got to fight against the use of AI to make decisions that affect us whether we need surgery, whether we are let out of prison, etc. So I think that is a short term danger.

Dr. G. Srinivasan: There are lots of questions from the viewers, perhaps the most efficient way for me to pose the question is to perhaps paraphrase them and condense them. When we first met almost 50 years ago, the way of life was very different in the world, there was no Internet, there were no smart phones and yet there has been no dramatic revolutionary discoveries in science which has led to this changed life style, it is mainly technology but if we look at when Einstein was born, radio waves have not been detected, x-rays, nobody knew what x-rays or gamma rays are, Wright brothers hadn't flown, so what do you think of the possibilities of as one of the viewers asked the question, a phase transition like behaviour in science, a very dramatic discovery which will lead to completely different types of evolution of technology, do you think that is likely?

Prof. Lord Martin Rees: I think it takes over a decade because going from the first transistor to the smart phone that was 50 years or so and if you think of biology, going from the double helix to what we have now, that is a huge advance, we can

now synthesize the human genome and analyze it using AI etc., so I think biological development is going to raise huge numbers of ethical issues, they will develop fast. Another point I would like to make, most developments they are not growing exponentially like a sigmoid curve, they go up fast and then they level off and you mentioned what our lives were like 50 years ago. We did the big transformation since then which is the Internet, smart phones and all that but the advances which had happened before that time say from 1889 to 1960s, they were far more important, the electricity, the car, the railways, domestic appliances, radio, television, etc., they were far more transformative and far more changed between, say 1890 and 1950 than any changes between 1950 and now. You think of lives of ordinary people, so I think it is a mistake to think that the change has been rapid it has been one very powerful technology based on the silicon chip which has changed but others haven't changed and to give an example, you mentioned flights, it was 50 years between Alcock and Brown's first trans Atlantic flight I think in 1919 and the first flight to the jumbo jet 1969 and in 50 years since then we still have this jumbo jet, there has been no change in civilian flight except it has become rather less pleasant and less comfortable, there had been no advantage. Concorde came and went and so I would make a hazard that the iPhones we use in 20 or 30 years won't be very different from what we have now which has been this surge of development but the iPhone is complicated enough for anyone and then it might level off. So I think we are going to see levelling of some technologies, I think in the biological area we are going to see some resurgence of serious new technologies.

Dr. G. Srinivasan: Towards the end, you mentioned the human being is not ultimate in evolution, it is not the climax of evolution, so here is a question, one of the viewer's wants to know how likely is it that life on Earth will become extinct one of these days.

Prof. Lord Martin Rees: I don't know but the point I want to make is that it is going to be possible to redesign human beings by modifying their genetic code and by the end of the century I think we will know how to do that and we will understand the human genome better and it might even become possible to have a machine which has some sort of human qualities, so post-human evolution could happen. I think it may happen first on Mars where there are no impediments. I would hope that there are constraints which make our Earth a better place to live, less pollution etc., but of course that is still talking on the timescale of centuries, if we think on time scales of billions of years, then we have no idea what will happen at all because once we have technological change then that happens on the time scale of centuries or even less whereas Darwinian changes happen on a time scale of hundreds of thousands or million years so any future changes are going to be far faster than the ones in the past but the amount of time available even longer and of course we don't know what is out there already. We may discover evidence for advanced kinds of intelligence and we may detect them or they may be living conservative lives under some cosmic ocean not communicating with us. We don't know what is out there but it is important that the cosmological time scales last longer than technological time scales so we just can't predict the future but the Earth we know remain habitable for at least a billion years and lets us hope we don't prematurely snuff out the life on it.

Dr. G. Srinivasan: Global warming and climate change have a catastrophic effect on their life.

Prof. Lord Martin Rees: I think it could, I mean if you take the worst case scenario by the end of the century this would push up global temperatures by on an average six degrees centigrade and of course that is just an index for massive change in weather patterns and some parts of the world more than that, so it won't make the world completely uninhabitable and it will make the world much less pleasant if everyone will have to live like it is in parts of the Middle East or the Death Valley in California where the temperature reached 54 degrees recently so it will make the life less comfortable but it won't wipe out life. It will just be a degradation of the life we are used to.

Dr. G. Srinivasan: What are your thoughts on life which is not based on carbon and oxygen, one of the weakest ones?

Prof. Lord Martin Rees: Well of course that is an interesting question because as I said we don't understand the detailed chemistry which led to the first life and the good thing about that is that is now a serious problem, it used to be a problem put into the too difficult box. There is this Urey Miller experiment nearly 60 years ago, people still talk about that, there hadn't been much work done on the subjects but now; there are very serious people, some in Cambridge who are working on this topic. So I think we will have a better idea on how life began and that work should tell us two things, it should tell us first how likely it is, secondly it will tell us is there something very special about DNA and RNA etc., or could you imagine life in other

ways and that affects what we might find in the solar system because if you have seen pictures of Titan which is one of Jupiter's moons, it looks rather nice, there are lakes and rivers but they are lakes and rivers of liquid methane, the temperature is minus 160 degrees so you can't have any water based life but may be methane based life could exist then and we would like to know that and let me mention one other thing, looking for any kind of life elsewhere in our solar system, evidence on Mars, more evidence on Europa or Enceladus, find anything that is crucially important because if we can infer that life emerged twice independently within one solar system and immediately says it can't be rare fluke but it must exist in a billion places in the galaxy, there would be a really transformative discovery and a huge boost to what is already an exciting field of science.

Dr. G. Srinivasan: Going back to Artificial Intelligence, is there a need to regulate it, are there bodies trying to regulate artificial intelligence development?.

Prof. Lord Martin Rees: I think very much so, simply because it is being used in contexts which are an invasion of our privacy - face recognition for instance - and also it is being used in context where its decisions are important to us as humans but they may be unreliable, for instance face recognition it has been shown that the machine can be completely confused if you make just a tiny change in the face. It then just completely classifies it differently and ditto there will be a problem with those self-driving cars, people have shown if you change the wording on some very slightly it completely screws up the system. So I think there are problems with the use of AI systems and also at the geopolitical level we need exactly a regulator because at the moment dominated by these global conglomerates and it is very

hard to tax them adequately and very hard to regulate them adequately at the national level so just as we have the International Atomic Energy Agency, and aviation is monitored internationally we probably need new international bodies in order to not only tax these big companies fairly but also to regulate their use so it doesn't invade our privacy.

Dr. G. Srinivasan: The questions are literally pouring in and we have just a couple of minutes, I should hand over after that, so here are two questions which are unrelated to what you spoke about today. One of the questions is Roger Penrose says that consciousness may not be possible with sheer competition, you need something else. Given that what is your take on artificial self aware intelligence?

Prof. Lord Martin Rees: I am not an expert but I think this is a very very important question, the question of whether intelligence is an emerging property which any sufficiently complex network would have. And I think to have anything that we call human like intelligence it has got to actually be able to interact with the external world by its senses as we have - so it may not happen. I think it is very important because to quote an anecdote, I wrote a newspaper op-ed on this, I talked about post-humans probably being electronic rather than flesh and blood spreading through the universe beyond us and there were two kinds of responses, some people said, “isn't this wonderful, these are more advanced things” whereas others said “may be unconscious and wouldn't it be tragic if there is no conscious entity able to appreciate the wonder and beauty of nature” and I think it is a very very important question, does self-awareness emerge in a complicated machine automatically or is it special to the flesh and blood and sense organs of human

beings so I think it is a very important question and it does affect very much one's reaction to these far future scenarios.

Dr. G. Srinivasan: Lord Rees, you are a Astronomer Royal of England after all so for the last question, let us go away from this and a viewer wants to know do you believe in parallel universe.

Prof. Lord Martin Rees: I think the answer is you don't know and I would say it is a matter of principle it is a mistake to have a very firm dogmatic view on things which are uncertain but what I can say is that there are some theories of the Big Bang which naturally give rise to not just one Big Bang but a whole lot of them, the so-called multiverse idea; this possibility and there are other ideas that there may be separate three dimensional spaces embedded in a fourth dimension. So there are lot of ideas and we don't know which of them is correct so there are some theories where there will be just one universe, there is some where there could be separate ones and then there is a second question, if there were other Big Bangs that gave rise to other expanding cosmoses, would they be governed by the same laws of nature. Would there be atoms existing with the same strength, will the nuclear forces and gravity be the same or not and this is another question. According to some string theories, they would have different low energy physics, different atomic laws etc. and they may be still bald or unsterile because complexity couldn't emerge for instance if you don't have any periodic table you can't have complex chemistry, if gravity is too strong anything big enough to accomplish it is crushed so there are two questions, one is “Is there one Big Bang or many” and second “ If there are many Big Bangs are they all like ours or do some of them have very different physics

governing them so that they evolve very different and in many cases are sterile or stillborn because no complexity can emerge". So I think these are possibilities. I think it is a mistake to have any beliefs but let me just quote an anecdote to finish with, I was asked this question at a conference at Stanford University where Andrei Linde was one of the other speakers and he is a person who has promoted an idea called eternal inflation with many Big Bangs etc. and the Chairman who has Bob Kirschner, you may know Srini, he said how much would you bet on this idea on the level - would you bet your gold fish or your dog or your life and I said I was nearly at the dog level and Andrei Linde said well he spent 25 years developing this idea of eternal inflation so he would bet his life on it and then afterwards Stephen Weinberg, the great theorist was asked what was his fuel, he said he would happily bet Martin's dog and Andrei Linde's life. That is over, would you be open minded on these questions, it is a serious scientific question not just metaphysics but we don't know the answer yet and of course as a final word there may be some important questions which are beyond our capacity to answer because a monkey can't understand quantum theory and there is no particular reason to think that our brains are matched in an unaided form to understanding the most complex and important aspects of reality so we have got to be open minded about that too.

Dr. G. Srinivasan: Thank you very much Martin, I now hand over to Dr. Susheela Venkataraman to formally thank you and close the webinar.

Dr. Susheela Venkataraman: Thank you very much Lord Rees. As you know the audience reaction tells us this has been an absolutely fascinating talk, I have heard that from so many of our viewers today and it is also has been extremely thought

provoking in several ways. Prof. Srinivasan, your conversation has been absolutely wonderful and the way you have been able to pick up very key questions and bring up some very key issues has been wonderful. So thank you both ever so much for being part of today's webinar. We are really honoured to have both of you here. Just a few takeaways that I would like to summarize. Lord Rees started by saying that for the first time in 45 million centuries of life the humans species holds the long term future of the Earth in its hands. There is enough for everyone's needs but not for their greed and then he went on to talk about several aspects of where the big shift is likely to happen, the big impact is likely to happen. The first he talked about is the change in diet and there has been discussion ending up technological solution if you like with artificial meat and so on and the second aspect was around the possibility of migration and war unless the gaps between nations is reduced and there is sufficient redistributions of resources to enable all of us to have a reasonable life. We are facing an ecological shock and we need to understand the interdependency between different species of life and also if we don't take steps very urgently and again Prof. Srinivasan brought this up in terms of what have learned from the lock down and the quick reversal of environmental situations that we have seen during this time. So if you don't understand this interdependence of different species of life, if you don't understand what that is about and take steps very urgently, we may actually trigger a mass extinction of some more species and that would be spelling complete disaster for the planet. Lord Rees then talked about climate change and said that this is for real, it is not an imaginary thing, there is no need for debate about whether the climate may change or not. This century is indeed the last chance that we have to avoid getting to the tipping point that might result in an irreversible destruction of the planet. So again the key message

is it is in our hands to do something about it. Finally he talked about the need for resilient networks because our lives are so intertwined and so dependent on technology now and then he went on to talk about looking at a little bit of crystal gazing if you like into the future the kind of key technologies, a few key technologies for 2050 and beyond, mainly AI, robotics, biotech, space and he talked about the good and the bad and again a few takeaways, technological solutions for short term issues can have long term negative impact unless we design them and implement them in a way that takes care of the long term as well. How can we legislate and manage globally rather than at a national level because what happens in the world of technology today is global, it is no longer restricted to the national boundaries as we know them. We need to be responsible for creating and harnessing technology. He also took us into a little bit of gaze into the future and talked about the possibility of people settling on other planets but that does not mean that we have less of a responsibility for our planet here and now. So just one other aspect of the kind of shifts that are being caused by technology the first is power shifting from governments to technology companies or private hands. The second is about crime, the nature of crime, it is now something that is impinging on our freedom, our privacy as well as our personal security, the redistribution of wealth that is now taking place as technology sucks money into specific areas and in to a few hands. He talked a lot about ethical considerations and especially when it comes to areas like artificial life extension and finally he said the Darwinian evolution which is what we have been known all this while is going to be superseded by technological evolution and that is going to bring a lot of changes into the way we think about and we understand where things are going and the kind of actions that we need to take and then he ended with a perspective of life on Earth and he asked these questions

about will the post human be of the kind of life form that we have known or would it be electronic, either way we must understand that we are only part of an evolution and we have a huge responsibility that we are carrying now. Einstein said that we are but a spec in an unfathomable large universe and today Lord Rees, your talk has explained to us why we should feel humble and why we should understand that we have this huge responsibility to the Earth, to the planet, to ourselves, to the species, and, to the other species that we coexist with and this responsibility is larger than any responsibility that any previous generation has carried with it.

So with this I would like to once again thank our speakers both for having participated in today's webinar and made it so interesting for all of us and so valuable as well as for having been part of releasing the first set of webinars in book form. For our viewers, thank you very much for being part of this for bringing up those questions and participating.

The webinar books we are going to be loading them up on a drive somewhere and we will be sending out the link to all of you.

CREDITS

This Book would not have been possible without the help
of so many friends of IITACB. Thank you all.

FOR DELIVERING / MODERATING THE WEBINARS

PROF. ASHOK MISRA

DR. AJIT SAPRE

PROF. PUSHPAK BHATTACHARYYA

MR. ANOOP KUNCHAKUTTAN

PROF. SUDHIR JAIN

PROF. P. D. JOSE

MR. SUDHIR SETHI

MR. SAUMIL MAJUMDAR

DR. SIDDHARTHA PANDA

DR. SURAJ RENGARAJAN

DR. AJIT RANADE

PROF. SUDARSAN PADMANABHAN

DR. K. RADHAKRISHNAN

DR. KOTA HARINARAYANA

DR. HARISH HANDE

PROF. SOURAV MUKHERJI

MR. ANIRUDDHA BANERJEE

DR. SUBRAT PANDA

PROFESSOR LORD MARTIN REES

DR. GANESAN SRINIVASAN

FOR REVIEWING TRANSCRIPTS

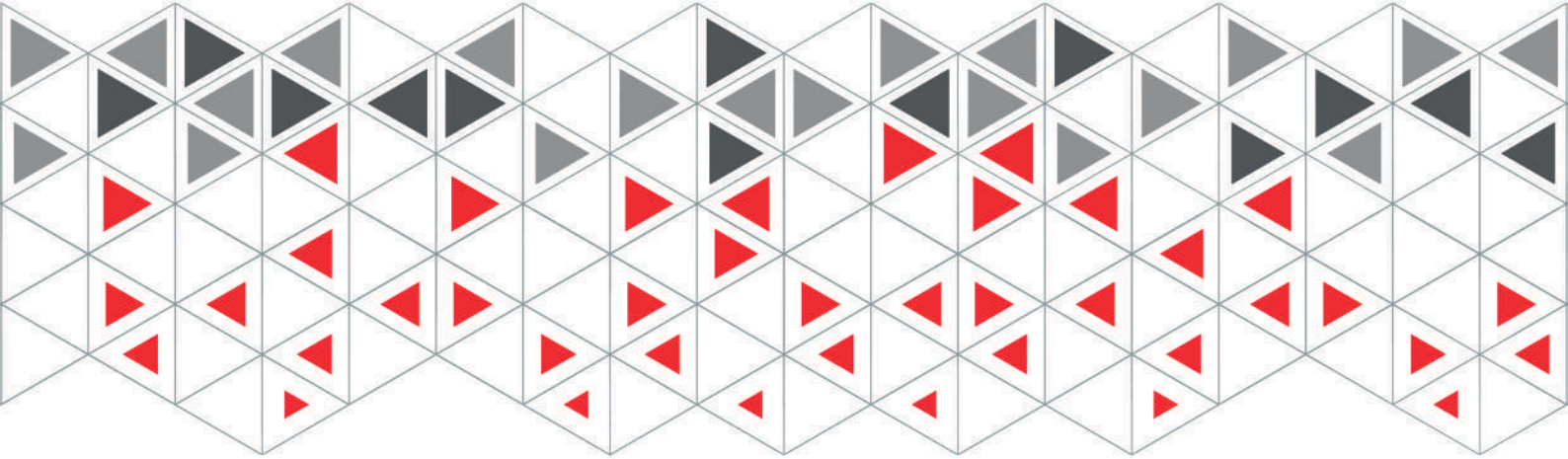
PROF. ABHA MISRA

PROF. RUDRA PRATAP

MR. ANILKUMAR K.S. **FOR TRANSCRIBING**

MS. SUSHMITA ANANTH **FOR LAYOUT AND DESIGN**

DR. SUSHEELA VENKATARAMAN **FOR WEBINAR COORDINATION**



NO.56, 'SAI MARUTHI', 13th CROSS,
MALLESWARAM, BENGALURU 560 003

TELEPHONE: +91.80.23310824;
EMAIL: iitacb2010@gmail.com