Computer Aided Engineering Design
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Lecture - 1

Hello. I am Anupam Saxena, an associate professor in mechanical engineering, at IIT Kanpur. Welcome to the NTPEL course on computer aided engineering design. This is the first in the series of forty or so lectures. Here through very simple examples, I will emphasize how the technology has affected the world around us and specially a common man's life. I will also try to underscore the importance of the interrelation between technology and computer aided engineering design or cad in short.

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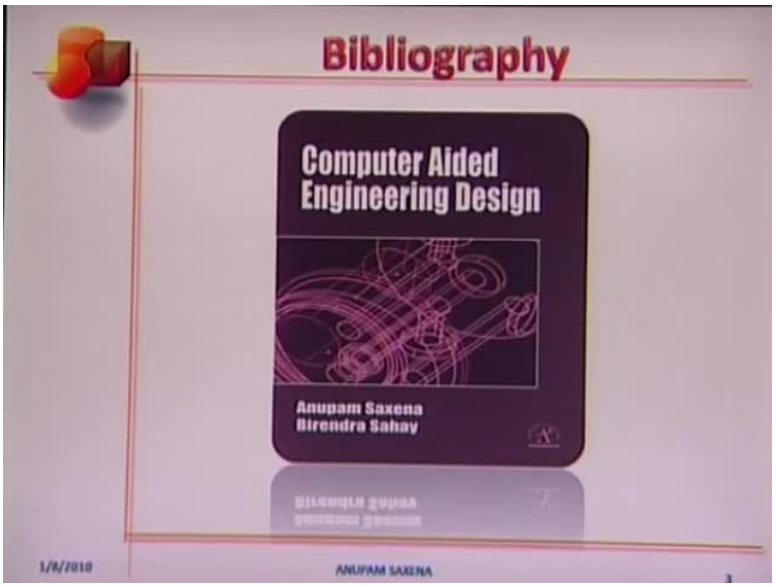

I have used a lot of sources, both books and internet to prepare the lectures. Many of these appear in the bibliography of the book, that I co authored with a senior colleague of mine professor Birendra Sahay. These are the other three main sources I have used mastering cad cam by Ibrahim Zeid, E-notes by C K Shene and the book on computational geometry for design and manufacture by Faux and Pratt.

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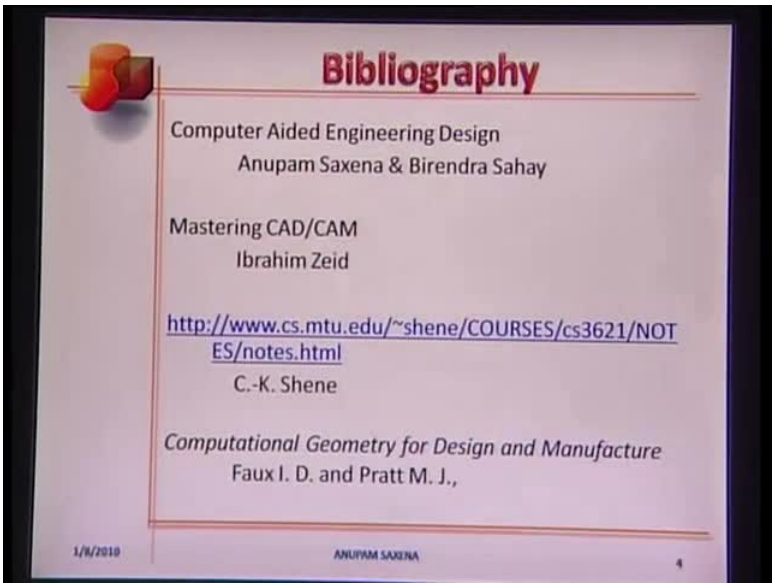

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I have also used Google to borrow various illustrations I will be using throughout with the course. Google uses different icons each day, this Google icon by the way is taken on the day of Sir Isaac Newton's birth, fourth of January.

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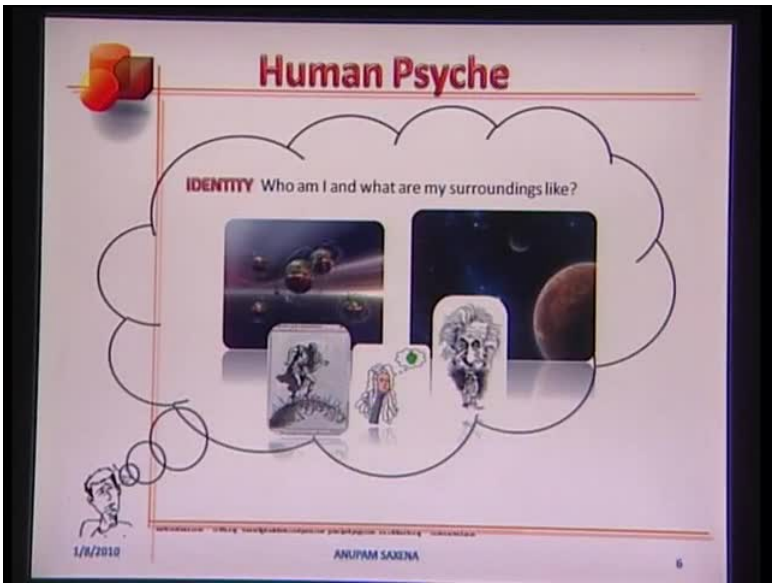

We start the lecture by attempting to understand the human psyche. Of course, we are not going to be discussing sigmund fraud and his theories in general human psychology. But we are trying to find how human's thoughts have shaped the technology from cart feet to an aircraft, from a pestle motor to a mixi grinder, from homing pigeons to e-mail twittering, from a plough to a tractor.

Believe it or not most of us must have thought about three fundamental questions, sometime or other in our lives. Question one; who am I? Question two; am I safe? And question three; how can I make my life most comfortable? I call them fundamental, because they relate very much to our existence and the quality of life we lead. Let us start with question one on identity, who are we and what are our surroundings and how do we relate to the environment around us.

While who am I is more of a spiritual query, many brilliant minds like Galileo, Newton, Einstein from much before and even now, have engaged themselves and trying to resolve the questions pertinent to the environment we live in. In the micro scale researchers have disaffered the act, the very basic unit of matter. They have gone ahead into knowing the composition of the act namely, the protons, electrons and neutrons. And further the elementary particles that they can be split into, likewise we know now that life is composed of living cells and the cells are made up of different sub cellular components.

In the macro scale we now know that the earth is a sphere and moves around the sun, the celestial bodies' follows the laws of gravitation. Light can be dispersed into seven different colours, it can bend due to gravity, energy can be converted into mass and vice versa and the universe is expanding. Many of these revelations are no older than 500 or so years. It just how inquisitive a human mind is and past concurrent and future technology was is and will be a result of the start.

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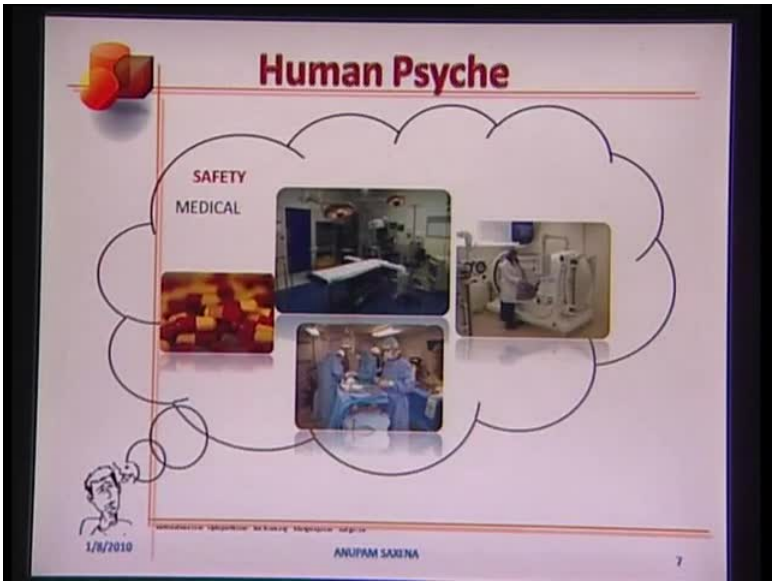

The next question; how safe are we and how can we pro long our lives or may be even define death. Over years human mortality has been observed to natures rack in the form of natural calamities; floods, earthquakes, tsunamis, a variety of epidemics like plague, influenza, small pox and tuberculosis. Humans have always desired to live long, it is painful to lose closed ones.

In recent times a lot of efforts have and are been made to develop a variety of drugs vaccines to ward off different diseases and infections. Healthcare has tremendously benefitted from technology. Cardiac failure, which almost had a 100 percent mortality rate can now be averted and treated, both medically and surgically. Open and bypass heart surgeries have become sophisticated and much easier. Endoscopic surgeries wherever possible have hastened the recovery time. Emitting techniques like MRI, the magnetic resonance imaging and CD scan, the computerized demography have made the diagnosis of complex neurological disorders more focused and efficiently.

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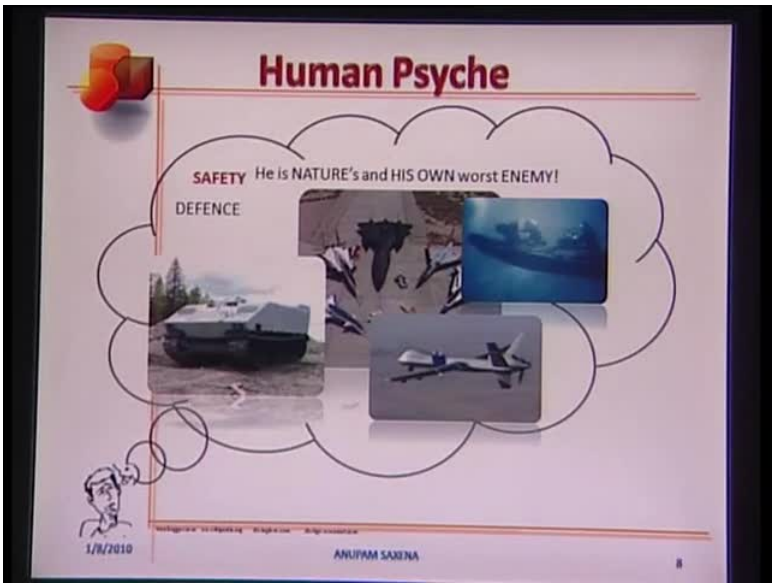

In today's world mankind leads to safe guard against excel. How aranic, more or less all countries have well defined defense programs. They are investing heavily to upgrade and acquired state of the act defense capabilities. Tanks, aircrafts, submarines, traditional war ships and the modern ones having the capability of deploying naval aircrafts. Semi and fully automatic weapon systems, communication global positioning all are the results of sophisticated technology.

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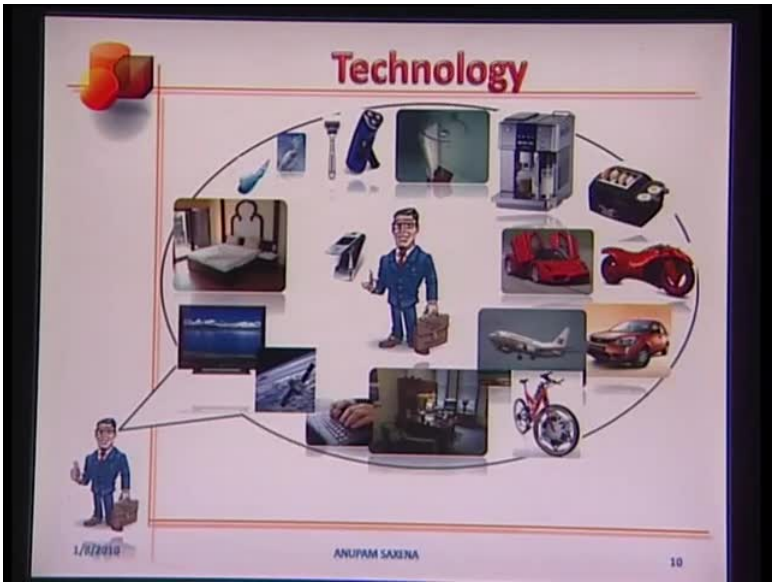

In fact, human life is regarded to be so very precious that even unmanned defense systems unused for developing. The down bomber for instance, it can be remotely maneuvered and does not need active part. Most of us have already witnessed the notion of having robot infantric, in many Hollywood movies like star worse.

Now, for question three; how to make life most comfortable. Let us see how technology influences a difficult work day of our lives from breakfast, bed, bath and beyond. Men and women both form the work force of today's economy. Further they need to work to be productive useful to society and to sustain their family. A person starts the day by brushing teeth; the two illustrations show the manual and automatic options. The manual one provides a nice morning arm exercise, the automatic one is possibly for those who are partly sleepy. Likewise, one has both manual and automatic options for shaving. Next one takes the shower and gets ready for office.

Typically on this time one is on a hurry, as you finds himself a bit short in time. He quickly prepares coffee and breakfast. How wonderful it would be for anyone to drive to the office in a Ferrari, the car or a bike. Most of us show our content with standard family curves, even then numerous of them are equipped with well developed safety features, entertainment options and navigation systems. Or if on a storing he needs a mode of transport that can make him reach his destination within hours, a few within the country, more than that for a destination outside the country. Or if someone is health conscious he chooses to reside near the office and to bike to work.

He reaches his office with his gadgets, briefcase or the office bag, a cell phone and a laptop. Spends more than eight hours of his day at work and comes back a bit tired. He comes back home rests his feet on the table in front and catches up with what is going on in the neighborhood the city, the state and the world. If he has already not done that, in the free time that he gets in his office. He catches on the weather forecast, sitcoms and movies. Thanks to the modern day satellites that make these possible, and then he retires to bed. The punch line technology is homely present in today's world it is everywhere, an ironic observation is that technology is becoming more and more complex and involved in trying to simplify our lives.

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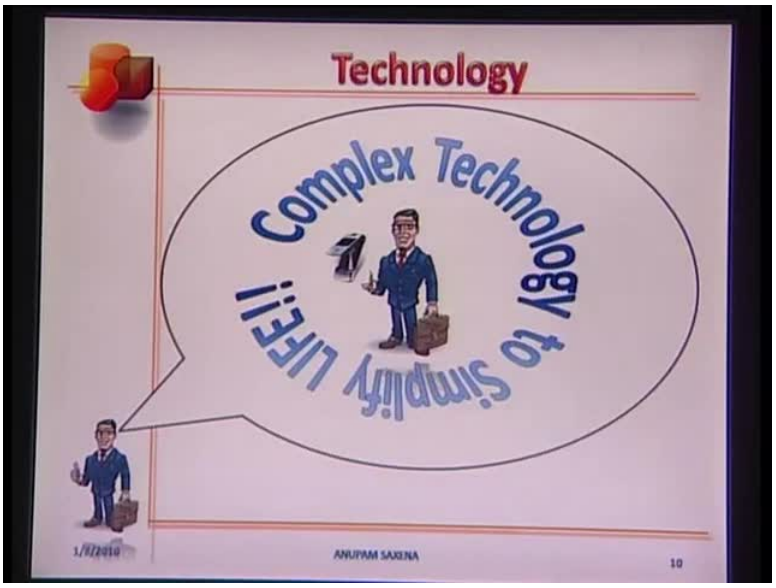

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By the way only a few of the available gadgets have been considered; washing machines, driers, air conditioners, phone handsets, vacuum cleaners, both manual and robotic are a few or many other examples. We shall are see how commonly used equipments can be different in design. Tooth brushes; they come in a variety of shapes, sizes and a varying colours, both manual and automatic options are available in the super markets near you. The shapes and sizes of the bristles and the gap between them vary, the head of a toothbrush can be composed of two or more pieces joined together by a flexible edge. Very similar to the one in the shampoo bottle, this allows the brush head to change its

shape for better access. Even tongue cleaners are now available on the other side of the bristles.

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Next shaving razors; again from the twist razors to an automatic one or many alternatives are commonly available. They come with multiple blades to give a smooth finish. In both modern and automatic ones, the shaving edge is hunched to the shank to allow the blades to align freely with the curvature of the cheek.

Shower heads; many options are available in the hardware stores, depending on how much time one likes to spend in the shower. Options ranging from conventional single head to multiple heads or even wall embedded multiple stream sources can be shown. The shower head on the right for example, has multiple options including one that provides a nice hot water massage. Coffee maker, toasters and juicers; they come with different geometries depending on the quantity of coffee to be brewed variety for example; regular, decaffeinated, espresso, cappuccino. How many beagles of bread slices have to be toasted at a given time.

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Motor bikes, pick one and go for a joy ride or use it as a regular transport. Cars, again buy a one that you and your family needs most. Choose from cool designer bicycles or if you are a bit shot with a gigantic bank balance. You can go to work by your own private jet with a lavishing interior or your own chopper.

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Who would not like to work in a custom designed in man. Laptops or personal computers, one can choose from many options available in a market. So, is the case with the cell phones, in fact they are so many that this picture describes the options best. Again who would not want a custom designed home to come to have a little coffee, chat with the better half, listen to the music of the choice, watch a movie on the television set you have chosen, dine and then go to bed, do not get sleep yet or do not get any ideas. Rather save them for the next lecture where we will try to design something

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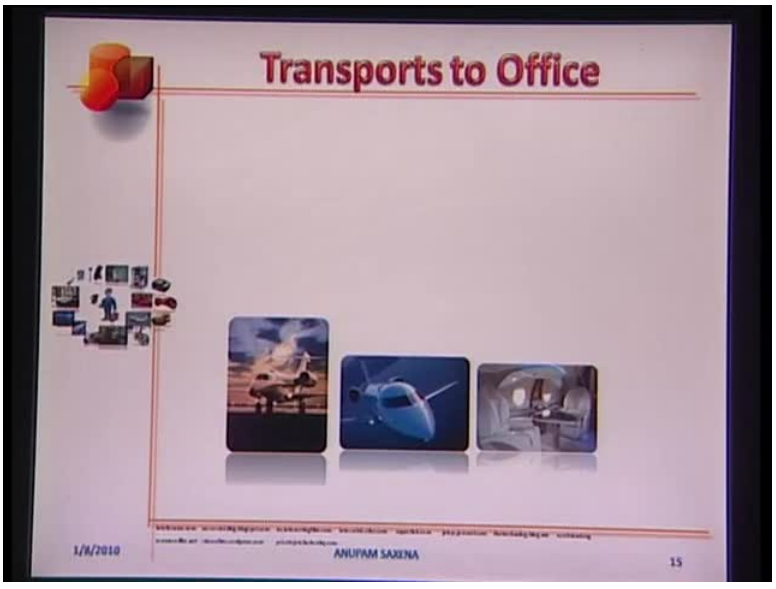

Let us consolidate on what we have covered in the previous slides first technology and productive design appears to be synonymous, they are very strongly co related. Technology cannot progress unless new designs are thought of.

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Then about choices; choices are good, a person can choose a product depending on what he needs, here need is a key word. One can choose depending on what he can afford, afford is the second keyword. Functionality is the third keyword, depends on both the need and affordability form. The fourth keyword is the final design of the product, which depends on its functionality. Accordingly a range of products are available so that the consumer makes the best possible choice for himself.

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Functionality and need are related, however there can be minor differences, for example; a cell phone, one can have a wish list of numerous features. However, the associated cost will be very high and the instrument will be affordable only to a selective. Even though the need or desire has no bounds, it is the affordability that acts as a check to the final list of functions or the functionality of the product. We have briefly review the term design as a concept. We are yet to dive into design procedure, but that is for late. For now let us discuss how complex and intricate different designs can be.

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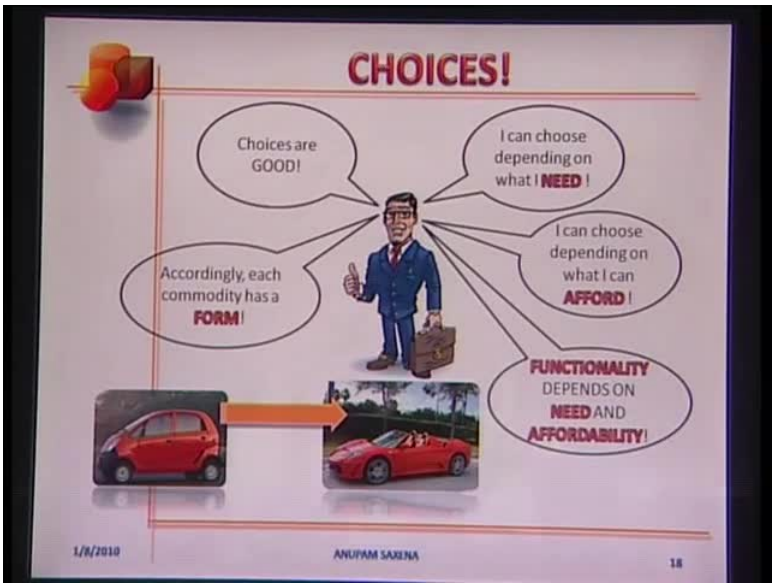

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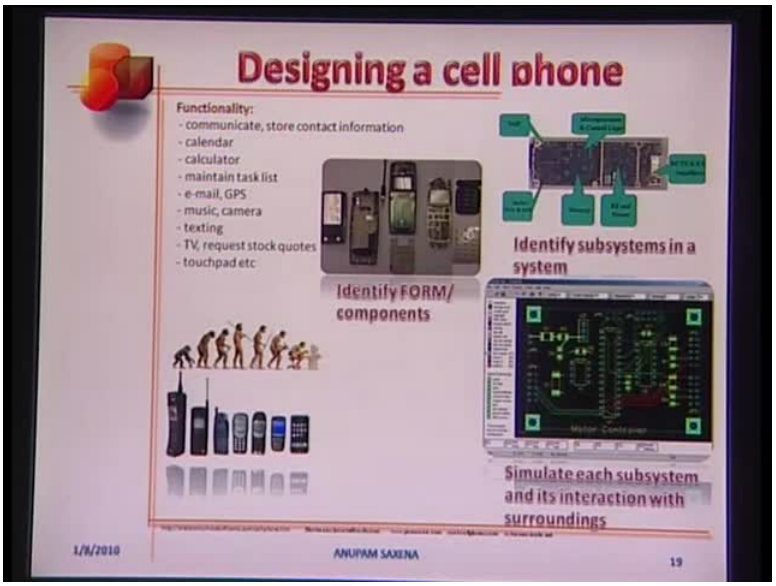

Let us consider the cell phone example again. Besides being a means of communication the one is mobile for which it was originally designed. The cell phones today can store contact information, maintain a task list, have features of a calendar, calculator, an alarm and navigation tool via a GPS, the global positioning system. You can have options of playing radio, listening to stored songs or as a camera. You can have a touched screen can be used for texting, e-mailing or for requesting stock quotes. You can even know the weather forecast watch news or your favorite sitcoms, as this list grew over time the cell

phones evolved. The basic cell phone design will have a display, a battery, an antenna, a keypad and more importantly a PCB circuit which, by itself quiet infrigate.

The circuit has a DSP, a micro processor and control logic memory, audio and video modules and many other features that an electrical engineer would know better. Each feature by itself is quiet complex; it cannot be designed and tested manually. Further different features can interact with each other, getting the circuit on paper and verifying each possibility by fabricating the respective pro type will be too time consuming. Alternatively, stimulating the circuit on a computer is significantly simpler and efficient, as it cuts down all the manufacturing accusations. In other words the design is mostly finalized in the stimulation stage itself and then is given a grow for mass production. An airplane is an engineering marvel for the previous century.

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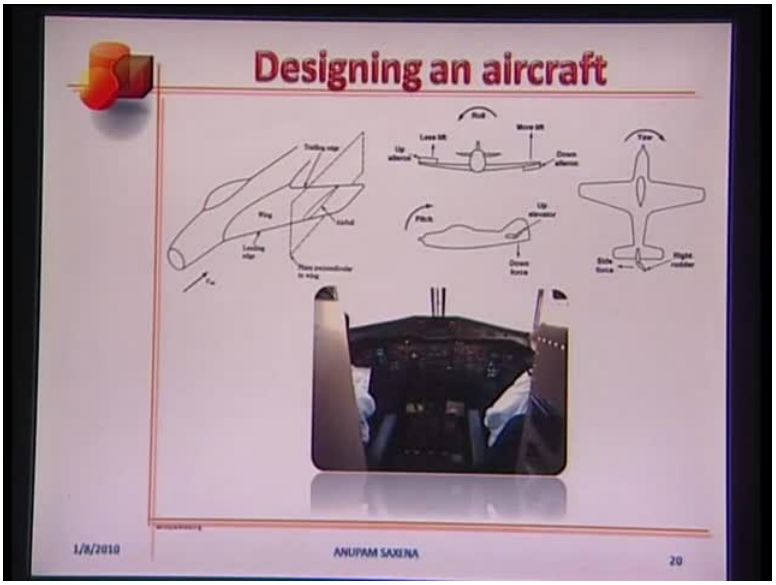

The basic illustrations show different parts of an aircraft; the wings, the engine nozzles, which are not shown in the figure, but which are below the wings. The fuselage, the air fall which is a cross section profile of the wing when different cutting planes are used. The ailerons are moved up and down for the plane to roll. The elevator is spread up and down for the plane to pitch up and down. Radar is used for the yolk motion. While we can understand the basics what is more important is to realize, how complex this engineering system is.

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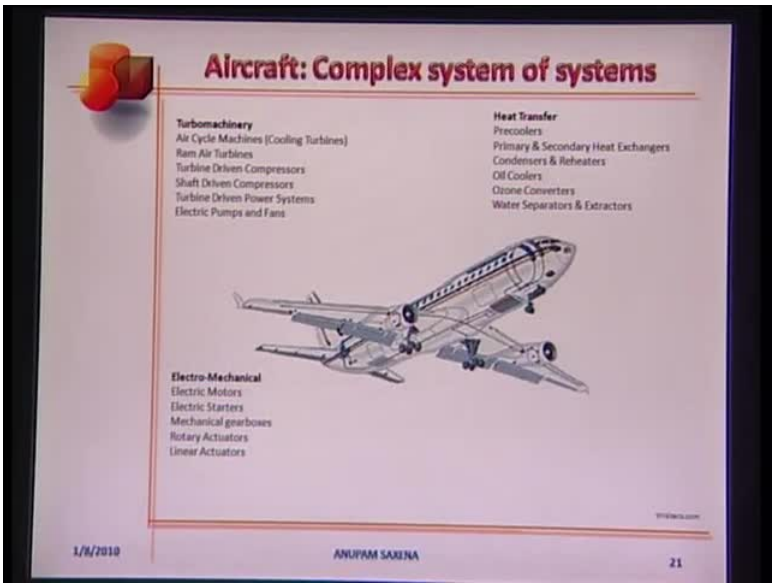

Take a look at the corpict which has mostly all controls enough to need not one, but two pilots to fly the plane. And then there is auto pilot, an automated system that assumes all flight controls is necessary. An aircraft can be regarded as a system of assistance. While each system has specific functionality, the functions of systems can be associated with another. When this association is tight, when A-one system fails the entire design fails, a human body is a perfect example here.

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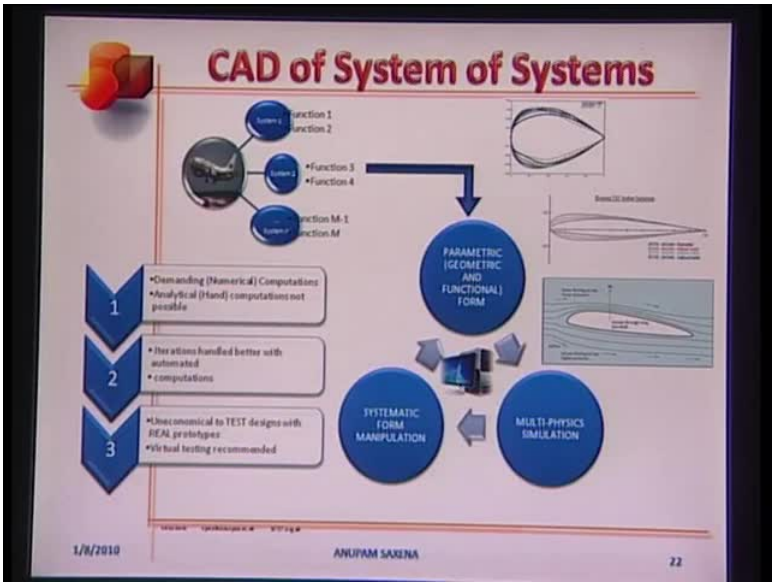

The design metrics or specifications of airplane like systems are so strict that not any, but immure optimal design is always preferred. By no means complex designs as demanded by today's world can be realized on paper, this is where computers step in. In a system of system design different systems can be identified and so can the functions be. For example; individual systems can be, say system one with functions one and two system two with functions three and four. And so on any system design can be performed as follows; first a geometric form is given to this system and the design is model parametrically. By parametric is meant that the parameters of the system can be changed without altering its fundamental form.

For example; a block has three sides and the length of each can be regarded as a parameter value. The values can be changed as desire without changing the basic shape. The parameters can be seen as the design variable, a given design that is a form with a given set of design variable can be analyzed and its performance can be evaluated. A platform suitable, the parameter values may be appropriately altered to obtain a better design. In other words, the design procedure is alternative nature. Most stimulations are computationally intensive and perform numerically. As a very simple example, consider an airplane design, we know that the shape of the airplane plays a vital role in generating enough force for the aircraft to take off and balance its weight when it flight.

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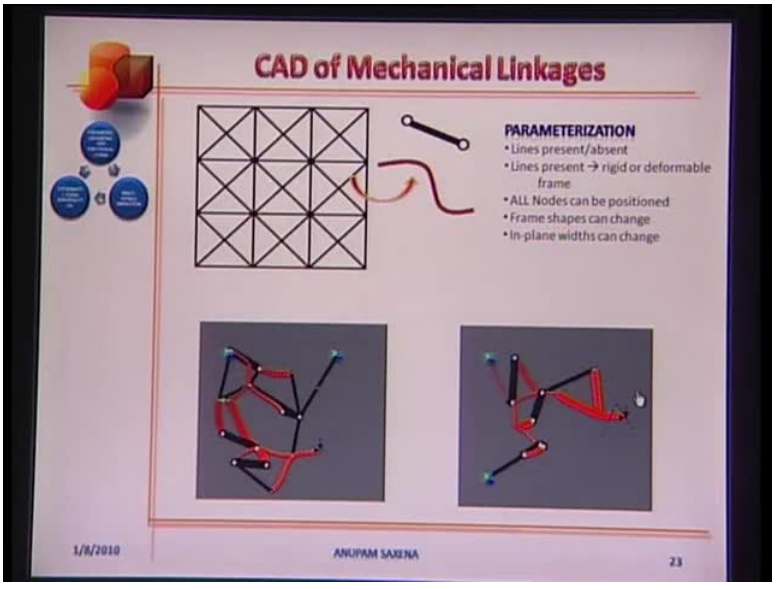

The contour shape is parameterized by means of a set of control points. Computational tool dynamics or CFT is performed to analyze the four pattern around it, the data is used to estimate the left say. The positions of the control points are appropriately updated to improve the length as a result, better airfoil shapes can be obtained. This illustration shows the airfoil contours are different cross sections of the wing of the moving seven thirty seven. In summary, computations involve design mostly demanding and of numerical as supposed to analytical nature, iterations are handled better if alternated through a computer. It is very uneconomical to pro type a design each time it is conceived. Instead virtual testing through modeling and analysis is recommended.

Let me collaborate this iterative design procedure through an example; shown are the two rectangular design regions in the lower part of the slide. Black triangles represent its nodes, green arrows represent the activation forces. In the left figure if you pull a point with the left, we require that the red node traverses I inverse tick path, For the right figure if you push a point to the right, we need the red node to traverse backward. Both of these are challenging path generation tasks, because of the kings corner points present both the parts.

We are looking for appropriate linkage designs within both these rectangular regions. We do not know a priory how the link it is to be look like. So, we lay down the basic rules, we let both rigid and deformable members to be present in the linkage, we allow both fixed and hinged connections. The path lengths are large so we allow the members to undergo large definition, that is we perform large displacement finite element analysis. The problem therefore, is to obtain an optimal linkage topology or connectivity.

First we parameterize the design through a network of lines. Each line can be present in or absent from the layout. To present the line can either have the characteristic of a rigid member shown in black or a curved deformable member shown in red. Further nodes that is all the intersection points between the lines can be repositioned. The shape and width in this of a deformable member can change. Let us find out how the mechanism for the design of the left looks. Once again the black members are rigid members and the red members are deformable members, hinges are shown by the white circles.

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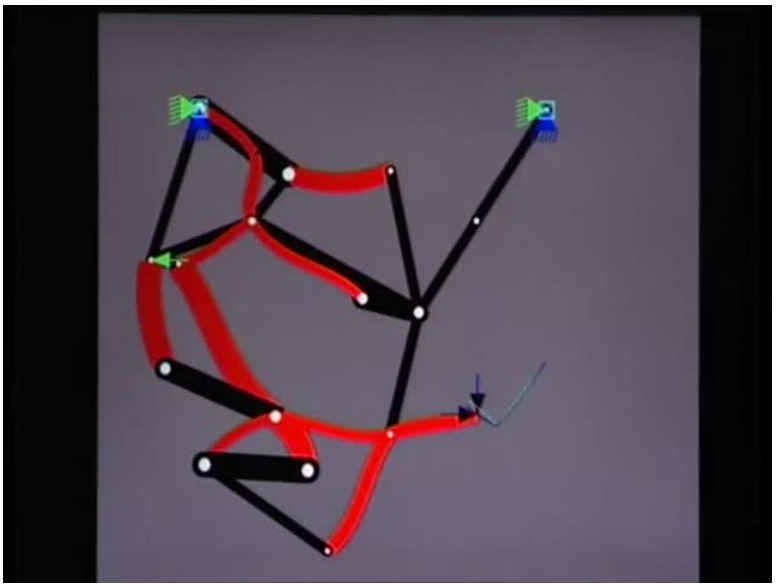

Now, how the linkage for the other design looks, look at the way the cantilevers get deformed. Both these linkages do pretty well in tracing the specified paths, inversed path and the hath path, at least in stimulation or in soft form. Both design are non drivier, it would have been very difficult for one to design such linkages through a paper pen approach. One must note for that the form design is fully automatic, the obtained linkages are fabricated only once. And let us now see how the prototypes perform.

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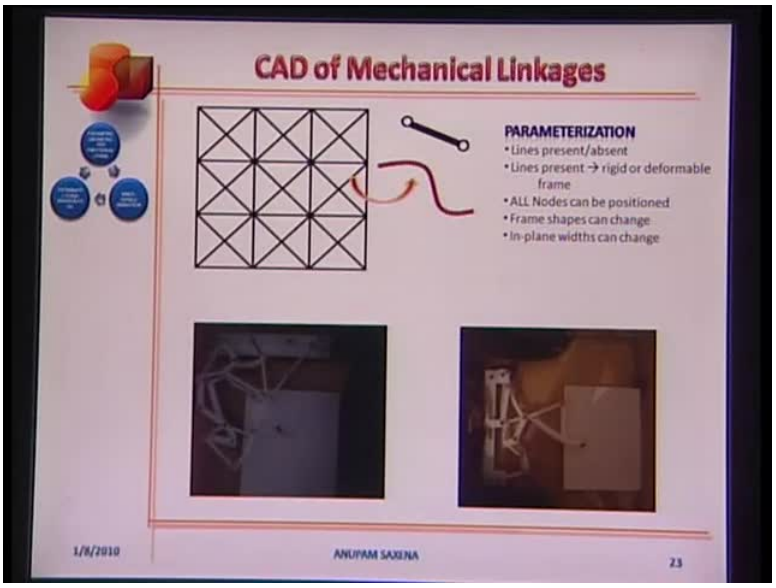

The magnified version of the corresponding prototype could clearly see how a cling created. One should realize here that these prototypes are exact replicas of the stimulated design. Notice how these mechanical linkages and henge falling linkages get logged to produce this skim here. The two examples here show the just of how computer aided design works.

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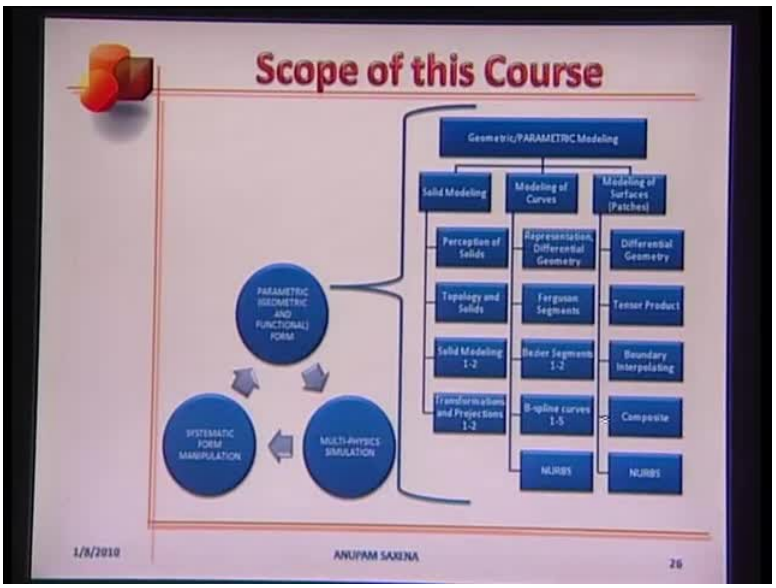

Scope of this course, there are numerous dedicated courses on analysis of different systems in the curriculum of varied disciplines mentioned here and many more. There is

a course in structural analysis, computational fluidic dynamics, electro thermo mechanical analysis, PCB analysis, molecular dynamics and many more, all these courses are numerical implementations. We will not cover them as a part of this course. Instead, we will focus on the three aspects of geometric design namely; solid modeling, modeling of curves and surfaces.

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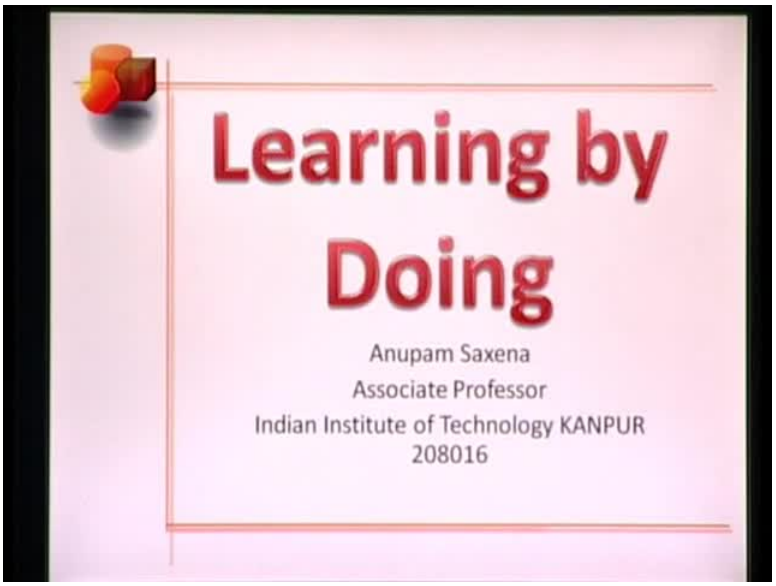

I have always emphasized on this phrase learning by doing. I have encouraged students who have taken this course with me before, on computer aided engineering design to dirty their hands. Because like many others I also believe that unless one dirties his or her hands she does not learn or he does not learn much. Following this slide will be a sequence of movies that I will be describing to you or showing to you on projects that students in different batches have undertaken. We have fabricated virtually whatever they had wanted and we had fun in the process. The first movie mailbot, this is a robot developed by a group of students, who deliver mail or other (( )) from one office to the other. It is essentially a line following robot. Well the robot takes a look to turn now, before turning drops the delivery comes back.

To learn CAD one has to understand design and the best way to understand design is to fabricate stuffs, try different things. Learn with the philosophy as to what does not work and what does eventually. Little magnified view showing different components of this robot motors, batteries, processors. This is another one developed by a single student,

entirely on junk to collect junk or to dispose junk off. Everything you see in this robot except for the motors, is trash is not that interesting, looks like this robot is going to give competition to big companies. Of course, you can use this robot repeatedly. The third project mechanical bendix drive. It is an interface between ignition and the engine in many automobiles. Whenever, you start the ignition in a car or a bus let us say, the engine does not start of immediately. It needs a better help and that is what is provided by the bendix drive, let us see how this is the mechanical version.

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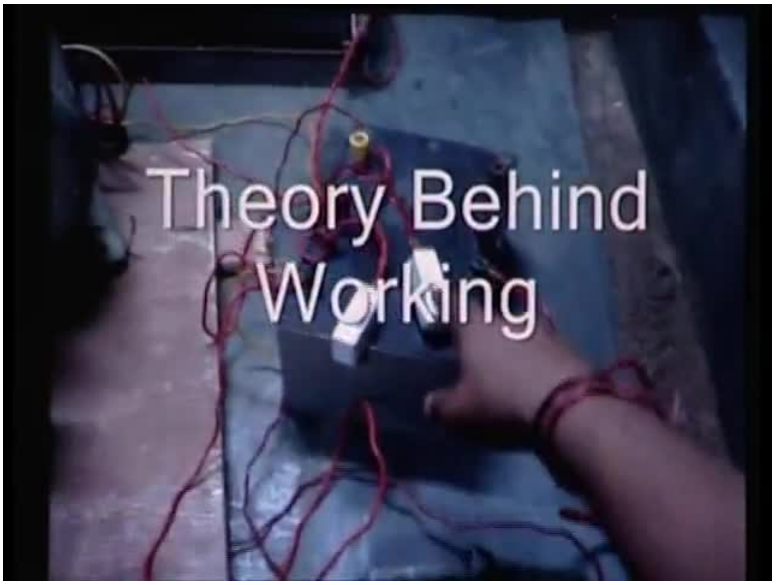

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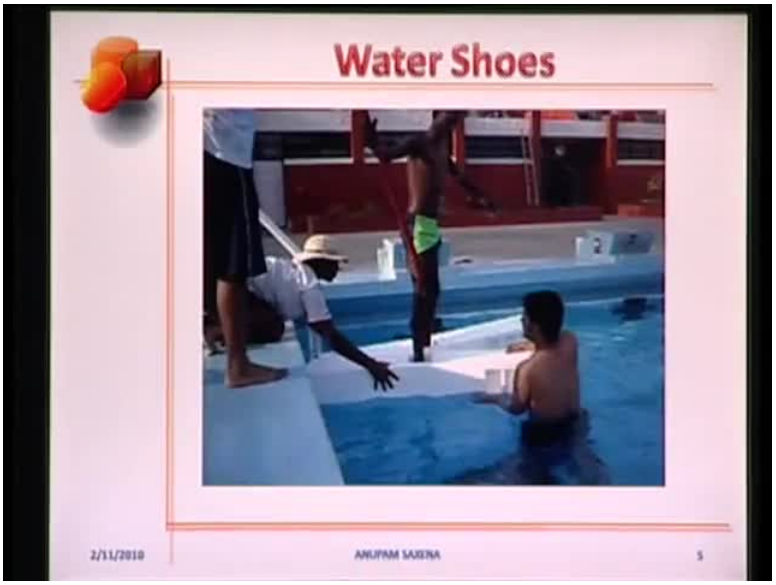

So, the basic philosophy is this, upon ignition the mechanical motor is going to be helping the engine out, before it is on its own. In other words before combustion gets automated in an I C engine. That is the helper motor, this is the I C engine. The helper motor is going to be providing enough sparks to the I C engine to aid in combustion, and then the helper motor is going to cease the function. Look at the mechanism closely; while the helper motor starts the engine after a while the shaft in the held motor gets stationary, while the gear on it keeps moving idle.

Somebody in my course got very excited who wanted to design shoes to walk on water. Let us see if he got successful. Looks like he is in a faxed to walk on water getting better, a group of two designed a wonder clock, for them it is not only noting time, but watching time is also fun. They do not want to take their eyes off the clock, if it strikes a full arm. Some electronics, some mechanical engineering, a group of (( )) gears and the front portion of the clock, wait for the clock to strike eight. I do not in my class emphasize these projects to be named. These products can be very well established in the market. It is just for the students to open them up, dirty their hands, see what is inside and if possible try something new with the existing product. Isn't this beautiful?

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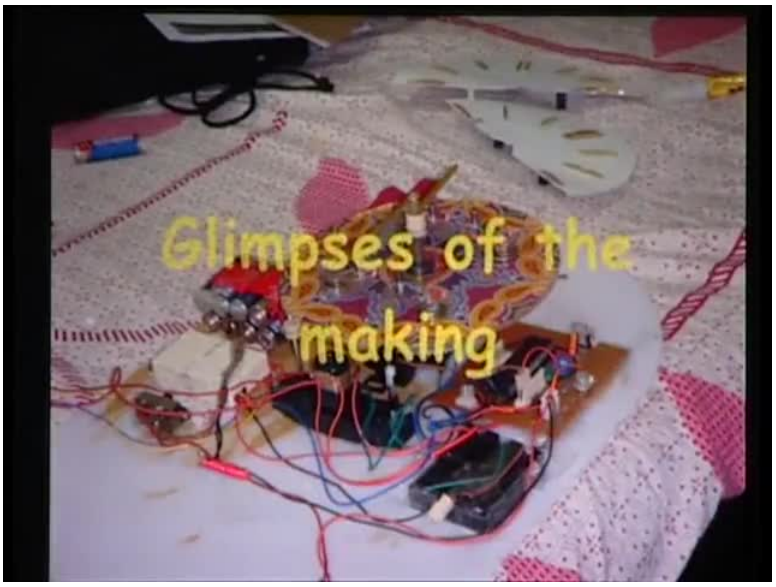

These two guys wanted to come to lecture theatre and attend classes in style. They know it was summer and they worked on this project, crazy and a lot of fun. They designed a hovercraft and they got so excited that they forgot to add a steering to it. People around these two also had a lot of fun. They used a heavy duty motor, a couple of hair dryers

amongst other things, the text would do the explanation. Then I tell you I as an instructor immensely enjoyed this project among others as well their family. They wanted to have an onboard battery, but just to demonstrate they have a long wire.

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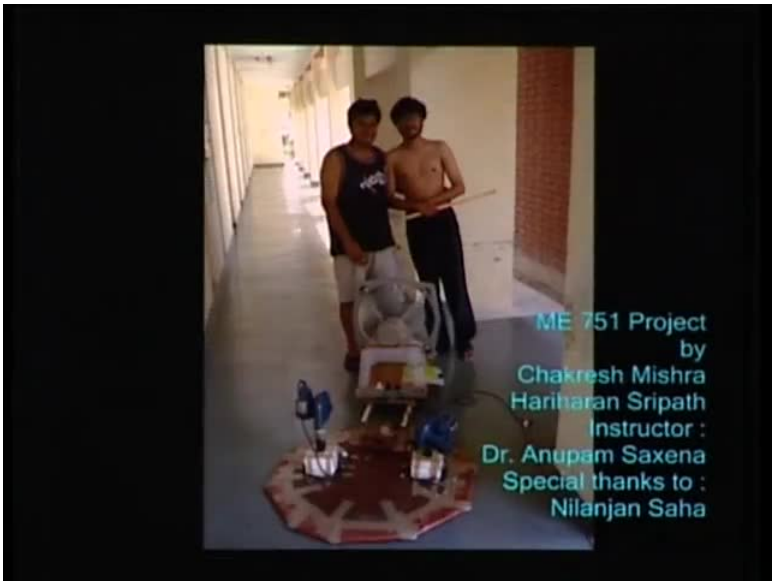

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Let us see who gets the first ride, seems to be working in the corridor at least. But the person maneuvering the hovercraft has to use his hands for steering. This is one of the craft we have here, were they successfully, I would say successfully demonstrated the

first working model of this hovercraft. Too bad they could not come to the lecture in style I am sure they will sometime.

Next one a group of three developed a Sherlock surveillance robot. What you see are used from three different cameras, interestingly a cell phone is being used here, to provide information to a remote system. You will notice that the three movies are not temporarily coordinated so there would be a bit of drag in the three views. Sherlock surveillance, this group of three seems to like Sherlock Holmes for a bit using water as a driving propellant to send a vessel to space. This group of students believes in a clean green environment, they got to allow exercise down the process. Is he pumping in air or playing guitar, some balancing skills. When would the countdown begin, looks like they are just about ready, failed after this one.

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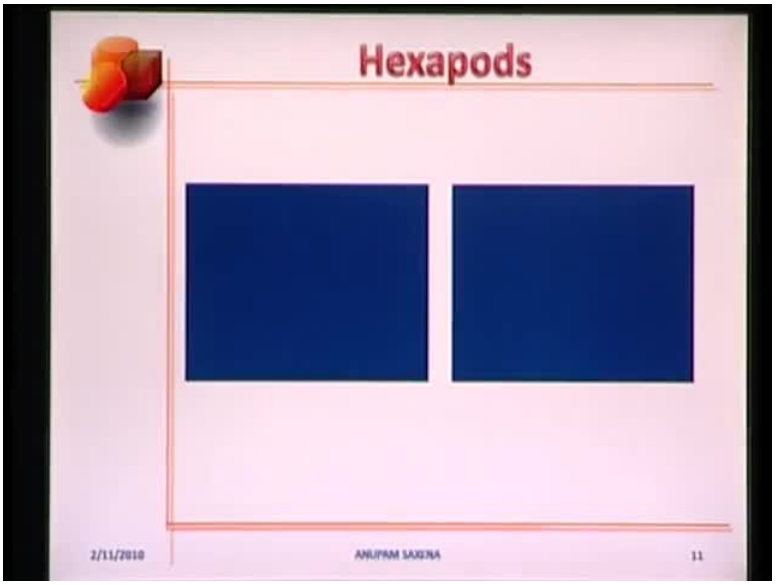

Two hexapods very simple robots, but I am sure students learn something from it. They seem to have used much of gears motors batteries, process of assembly. Looks like the hexapods are warming up, just about rate race now, moving backwards, and then slowing down. The second model, if I remember correctly there was a race arranged between these two models. Who won is not important students learn quiet a lot of things. This hexabot can turn.

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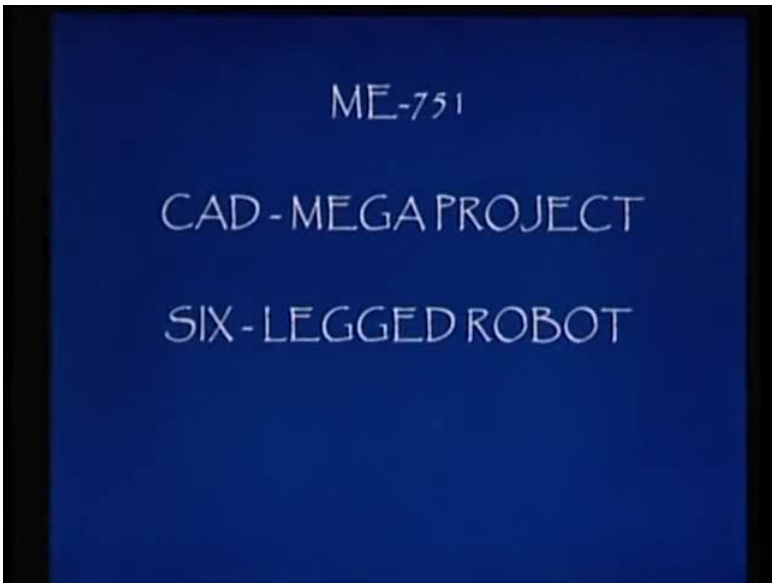

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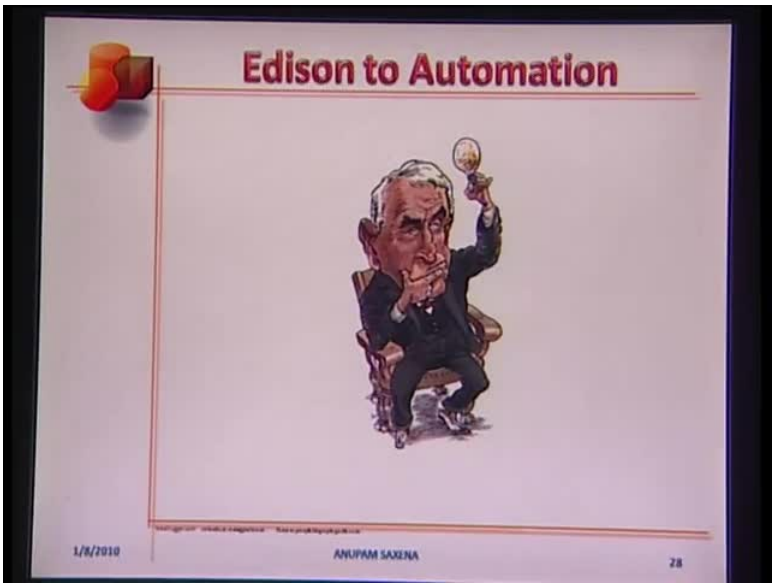

To conclude this lecture, it took a lot of time for Thomas Edison to design an incandescent bulb and figure how it works. In his own words, he did not fail about 4,999 odd times. Rather he knew how the bulb is not work in those many different ways. If only he had used CAD things would have been a lot easier for him.