Jet and Rocket Propulsion
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Lecture – 1

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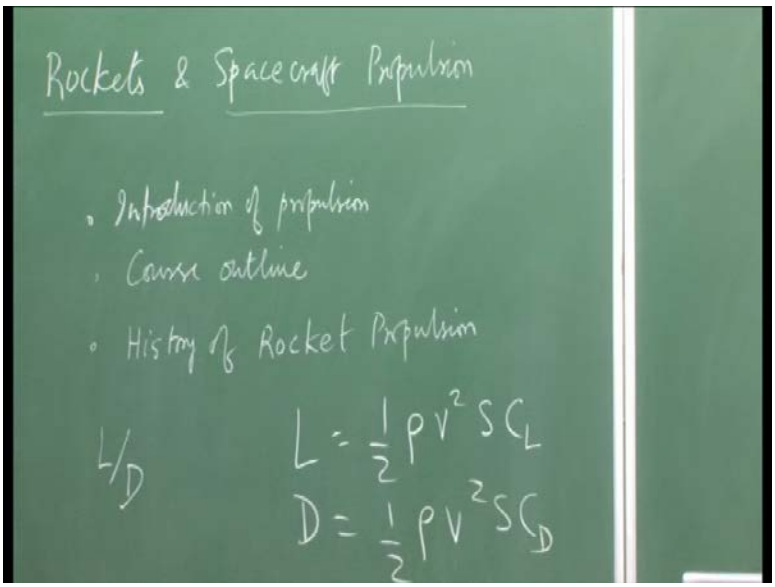

Welcome to this video course on rocket and space craft propulsion. Now, in this course rockets and spacecraft propulsion... So, as you can see from the name we are going to talk about two types of propulsions; first is a rocket propulsion and then spacecraft propulsion, which also include rocket propulsion, but something additional like electric propulsion systems. Although I think the electric propulsion systems can also be considered as rocket in the broader definition of rocket propulsion. But since those are for very specific ((Refer Time: 01:08)) space applications. Therefore we can club them as a separate group as spacecraft propulsion.

So, in this course we are going to talk about various aspects of propulsion involving extreme speeds and very large distances; that is where rocket and spacecraft propulsion are used. So, before we progress first let us talk about what are we going to discuss today? First let us just talk about the basics of propulsion; what is propulsion? After that I will give the detail outline of this course content; what are we going to talk about in this course? And then after that we are going to talk about the history of rocket propulsion. So, the first topic is essentially little introduction of propulsion essentially I am going to

talk about what propulsion means? Then the course outline; this will also include the textbooks that we are going to follow in this course and then little history of rocket propulsion. So, in today's lecture we are going to cover this 3.

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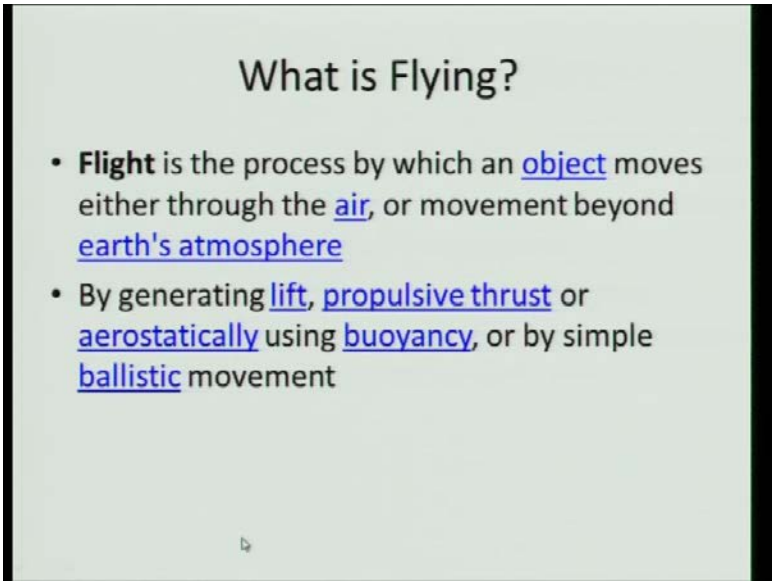

Now, first let us see what is propulsion? Before we talk about propulsion let us first talk about what is flight? Flight is the process by which an object moves either through air and using the atmosphere or if an beyond earth's atmosphere; essentially where here not on the ground; and we are moving that is what flight is. Now, in order to do that you have to generate some lift so that it can be lifted away from the ground. So, the flight involves generation of lift; and then if we are moving particularly through atmosphere there will be frictional forces which will try to slow you down.

Now, in order to compensate for this slowing down you need to have some propulsive device; which will provide the propulsive force or forward force which will allow you to keep upload. Therefore, the propulsive thrust is essentially a very important part of flying. Now, this propulsive thrust can be generated aerostatically like in balloons using buoyancy or by simple ballistic movement or by powered flight; the power power generation. So, first once we talk about what is flying?

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Next, let us look at that various types flight that are possible; first is buoyant flight where typically we use lighter than air concept. So that because of the buoyancy forces the vehicle goes upward and then the wind will just blow it in the direction it is going. Second is gliding which also does not require any power; essentially it is just aero dynamics and the wind motion that propels the vehicle. So, beyond this now when we come to the other type of flights they are essentially powered flight. So, powered flight is the third category; particularly in this context I am talking about powered fights as vehicular flight like aircraft or helicopter flying with an engine that is what a powered flight is. Another category is ballistic flight; where you provide a very high initial velocity to a vehicle or an object. And because of its inherent inertia or moment it just propels through the atmosphere. So, that is ballistic flight.

And, then another category is space flight where typically we do not have atmosphere. So, in that case if the initial velocity is high in the absence of atmosphere may not have much of drug, drag. Therefore, we do not need much of propulsive force; only thing is that light small amount of propulsive force is required to compensate for gravitational pulls etcetera or for some ((Refer Time: 5:50)). But essentially it is primarily divide in a ballistic mode when there were put in the orbit or in the outer space; if they are delivered with a very high velocity the velocity can some remain constant because the retardation is less. So, in this course we are going to talk about this powered flight and space flight primarily as well as ballistic.

Because ballistic is very important as when we talk about space flight. Because many times we do not need to have continuous power provided to the vehicle; we can provide initial power richer velocity and then cut it off. And the because the ballistic itself it will move typically like missiles. If you are talking about ballistic missiles they are not powered all through their flight envelop only for a portion of flight envelop whereas the cruise missiles which are typically powered all through the flight envelop. So, depending on the machine environment whether you can operate in a ballistic mode or in cruise mode.

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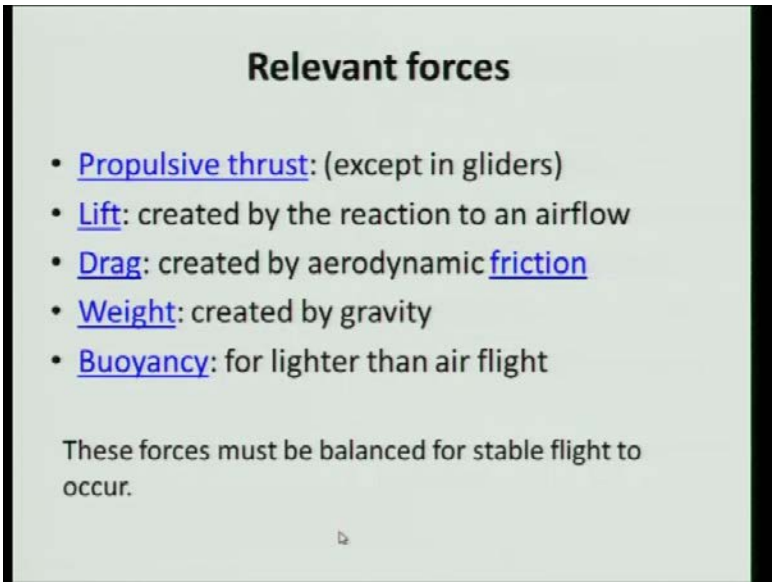

So, when we talk about the flight what are the relevant forces we are looking at; first and foremost is the propulsive thrust. I have put it at the top because that is the focus of this

course; propulsive thrust is essentially except gliders or balloons we are going to have we are going to need propulsive thrust to generate enough velocity so that we can fly. Now, propulsive thrusts are another important aspect also that is the generation of lift. Lift is primarily generated by the flow of air over the wing or the body. But in order to produce that force, lifting force you need to move their at a very high relatively high speed.

Now, if we have to start from 0 in order to move the air you cannot move the air. So, what you do is you move the vehicle. Now, in order to move the vehicle at relatively high speed; you need to have propulsive thrust. So, that it can move the vehicle propellant in the forward direction. Therefore the lift is also somewhat generated by the propulsive thrust that we are producing or providing to the vehicle. Drag on the other hand is something that is trying retard it. Now, drag is like the lift; lift as you are already aerospace engineers you know that the lift is proportional to velocity square; typically lift is given by half rho V square S C L plus rho is the density, V is the velocity of the vehicle, S is the plain form area and C L is the lift coefficient.

So, as we can see the lift is proportional to velocity square. Similarly, the drag is given by half rho V square S C D. So, everything remains same because half rho V square is the dynamic head or dynamic pressure area and C D is the drag coefficient. So, in both of them what we see is lift is proportional to velocity square, drag is proportional to velocity square. Now, for applications that we are we talk about in aerospace engineering lift is something that is good we want to produce lift; whereas drag is something that is bad we want to reduce drag because it is can retire your vehicle.

But both them are dependent on V square. So, if we increase the speed lift increases but drag will also increase. So, there is a ((Refer Time: 09:13)) to situation what we want to optimize. So, typically for the vehicle designers we want to optimize the L by D ratio lift to drag ratio we want to optimize. But that is beside the part that is not part of this course; let us come back to this course. So, here primarily what we are generating high velocity and that is done by using the propulsive thrust. So, propulsive thrust is a force that is created; that will propel the vehicle at a high speed. Now, in order to… So therefore, the other forces... Now, let us look at the other forces that are acting on the vehicle as I said is the lift, then drag, then the weight of the vehicle which acts downward.

And, for lighter than flights the buoyancy which also acts upward. So, these forces must be balanced in order to get a stable flight. So, as we are discussing there are typically the forces acting on the vehicle are the lift forces and drag forces; which are aerodynamic forces depends on the vehicle design and the speed; the weight due to gravity acting down word and the propulsive thrust which essentially is produced by the engine. So, in order for the for a stable flight in order to have a stable flight all these forces must be balanced.

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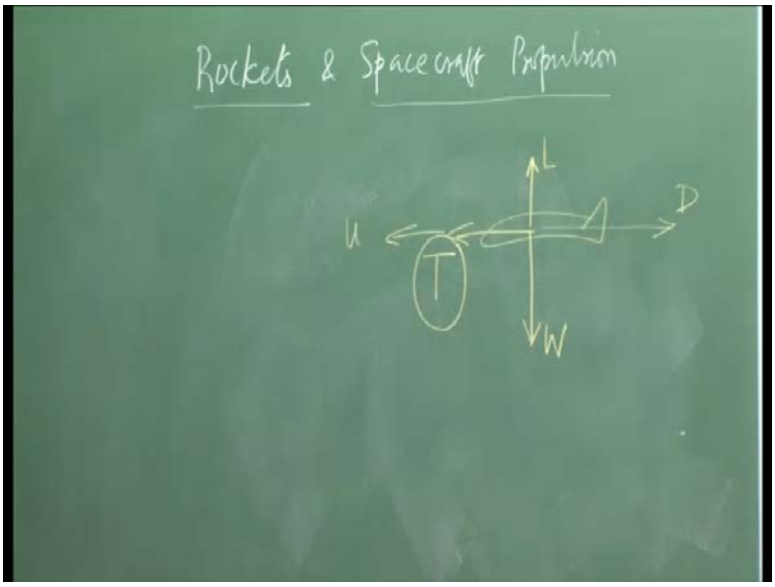

So, if we draw a diagram of free body diagram of a vehicle; we will have lift acting upward generated by the aero dynamics; the weight acting downward. If the flight

direction is this the drag will be acting in this direction try to slow it down. And the propulsive thrust let us say T is acting in this direction. So, now all this forces must be balanced for a stable flight ok. So, out of this 3 as I have said that lift and drag are dependent on aerodynamics, weight is dependent on the weight of the vehicle is essentially the total mass and size etcetera; thrust is something that is produced by the engine.

So, this is something that is essentially what is in your control we put it this way; for the vehicle designer or the engine manufactures control. So, therefore this is something that is manipulated to ((Refer Time: 11:45)) the vehicle particularly in the forward direction. So, this is where the propulsion comes in.

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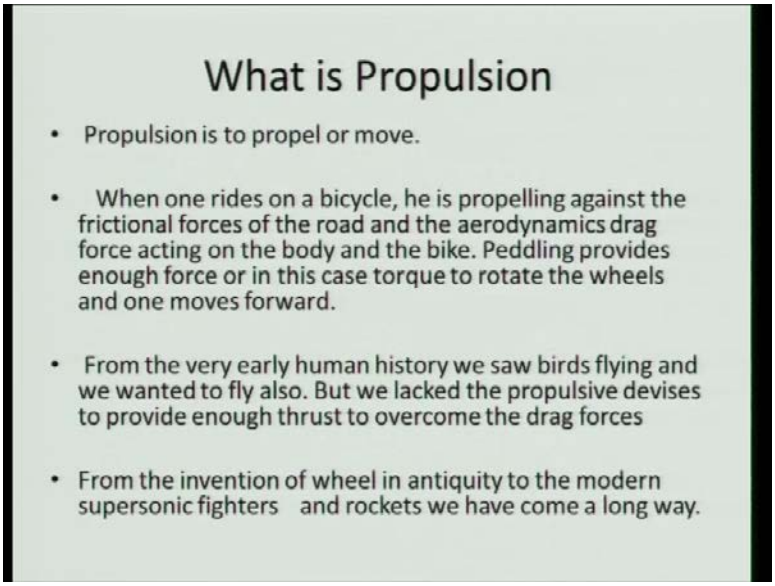

So, now let us see what is propulsion? So, propulsion is originates from a Greek word called propel; which essentially means to move a propel is the word which essentially means to move and pro is forward. So, essentially propulsion means forward movement or forward push. So, propulsion is something that gives the forward push. So, the classic example let us look at a bicycle. If you are riding a bicycle the rider essentially propels himself or herself against the frictional forces that try to slow down; that is aerodynamic drag that is try to slow down. And this drag acts on the body of the cyclist as well as on the bike. Now, when the bike has its paddling; the paddling provides enough force or in

this case the torque to rotate the wheels; so that one can move forward. So, here the propulsive force is coming from the biker himself or herself.

So, but what the action is essentially is propulsion; from the very early human history we have seen birds flying and we thought that we should also be able to fly. So, there have been numerous attempt in flying using different devices; if go to mythology there are even mythology the concept of flight is present. But the problem was again coming back to this diagram; the thrust that will allow us to generate enough velocity. So, that we can produce the lift; the we lacked the propulsive devices to provide enough thrust to overcome the drag forces. So, that we can not only move forward, but also can lift.

So, that was the missing piece; otherwise we are looking at the birds we kind of figured out that we need a wing to fly etcetera but we did not have the force, the propulsive force. So, if you look at the first invention of human beings essentially there are 2 inventions which differentiated human beings from animals; one was fire otherwise other was wheel ok.

And, the combination of this 2 is propulsion. If you look at the invention of wheel in the antiquity till the modern supersonic fighters and rockets we have come a long way. And essentially the development of human beings are because of this 2 inventions. So, that we can move faster without expanding lot of energy. So, this is the crux of human development. Therefore propulsion essentially takes inspiration from the basic need of human development.

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So, before we progress further; let us look at the mythology where propulsion comes into picture. Every mythology talks of flying; if you look at the antic mythology every mythology talks of flight in some way or other. If I look at Indian mythology let us say this is the corner picture here this is ((Refer Time: 15:18)) Indian mythology in Ramayana you have heard of pushpak vimana; this is vimanas were conceptualized long time back vehicle to fly. In Egyptian mythology we have this one is Egyptian picture; where we can see a wheel, horse and sun; sun represents the fire. So, combination of wheel and fire is something that allows you to move faster that is there in the Egyptian mythology. Chinese mythology flying dragons are very frequently depicted in Chinese mythology; where again these are fire breathing with wings, dragons are fire breathing animals with wings. So, once again now we see wings and fire coming in. Then if we look at Greek mythology the Pegasus that is the flying horse is a wing horse. So, again wing comes in repeatedly.

So, what we see that similarly in Jewish mythology typically various types of flying devices like flying chariots and flying thrones etcetera have been depicted. If I look at the communality between this all the concepts; what we see is wing, fire, wheel these are the 3 things that keep on coming again and again. So, therefore essentially flight is dependent on this 3. In fact, without wheel it is very difficult have flight particularly atmospheric flight because otherwise it has to be like a sledge. So, wheel provides you the initial platform to start moving at the high speed; and then wing and fire will provide

the final propulsive forces. So, therefore the combination of this 3 essentially constitutes propulsion. So, now the next thing what I am going to talk about is the history of aviation. But before that as I have said at the beginning; let us talk about what we are going cover in this course?

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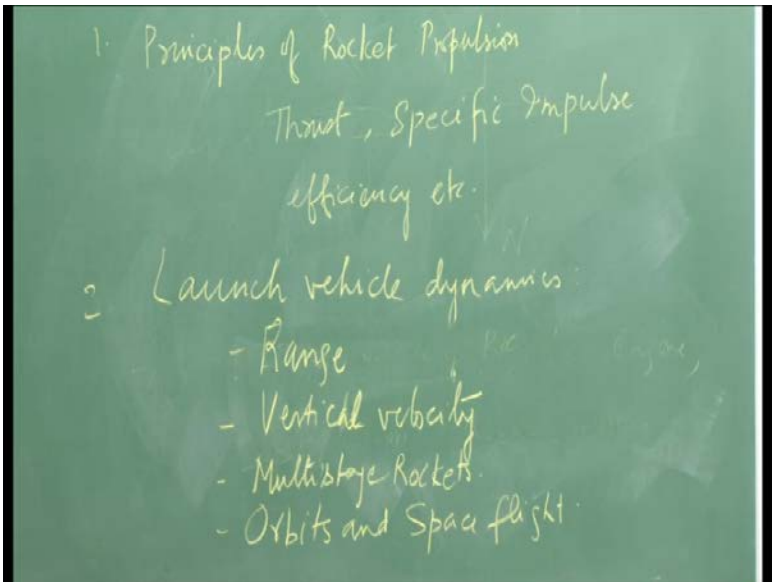

So, first we will talk about principles of rocket propulsion. Here, we will in the previous discussion; we discuss that one of the most important component of flight is thrust. So, in this topic we are going to talk about how thrust is created? And we will get the thrust equation. So we will define thrust and see how it is created? And we will define other parameters which are used in rocket propulsion like specific impulse then efficiencies etcetera. So, we will define various parameters, performance indices that are used in rocket propulsion. After this next we will talk about launch vehicle dynamics. So, in the first topic we talk about thrust specific impulse etcetera; we see how thrust is generated. Next thing what we talk about let us say we have generated some thrust; in material how we have generated? We have generated some we have a vehicle which produces some lift, some drag etcetera.

Now, in the under the action of this thrust how the vehicle is ((Refer Time: 19:10)). So, essentially for a given machine requirement I reveal the thrust we are providing is it sufficient to successfully complete the mission; that is going to be the focus of this. So, yeah launch vehicle dynamics first will be range, then vertical velocity, then multi

staging or multi stage rockets; then we are going to talk about orbits and space flight. So, these are the topics that we will be covering in the launch vehicle dynamics; we talk about the range of the vehicle. Then how far and how long can it fly; then how do we increase the range or the height by doing multi-staging? What is the optimum configuration for a multi stage rocket and then orbits and space flight this essentially space dynamics. Once we had done with this then next topic will be how do we produce this thrust? In the second topic we are not saying how the thrust is produced; in the first topic we are saying the thrust is produced by some means but this is essentially a reaction to particular action. So, the third we will talk is essentially focus on chemical rockets and we will see how thrust is produced in chemical rockets?

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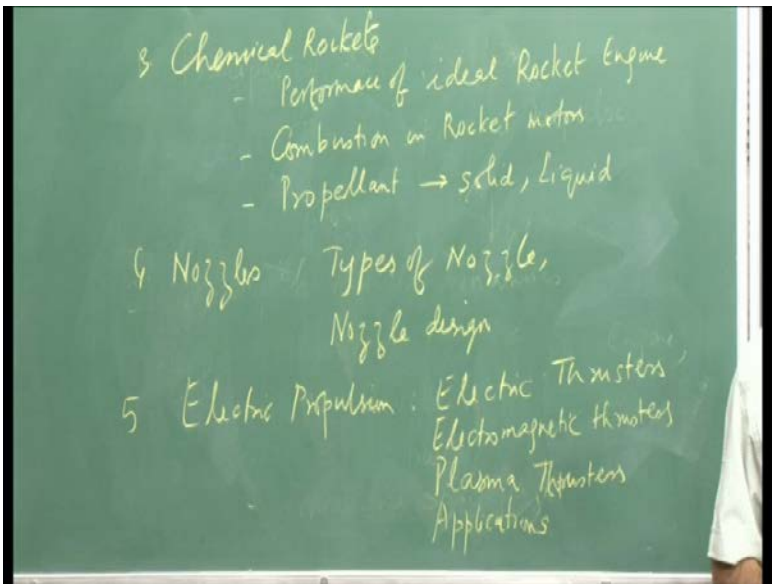

So, the third is chemical rockets. So, in this first we will talk about performance of ideal rocket engine; then we will talk about combustion in rocket motors. Then we will discuss little bit about different type of propellants that are used; that is solid propellant and liquid propellant. Now, one of the subclass of liquid propellant is cryogenic propellant; which essentially are the propellants which are in the atmospheric standard atmospheric pressure and temperature or in gaseous state. But under very high pressure and low temperature they are in liquid state.

So, these are called cryogenic fuels or cryogenic liquids which we will be discussing as well. Now, the in this topic we essentially talk about production of high pressure and

temperature using some chemical means. But that is not enough the high pressure and temperature gases which are produced in a chemical rocket needs to be expanded through a nozzle; as we go along we will see different components. So, one of the major component of a rocket is a nozzle; the high pressure, high temperature gases needs to be expanded through a nozzle to produce the final thrust. Therefore, we will talk about nozzles as well; which is a very important topic as far as rocket propulsion is concerned. We will talk about the types of nozzles, we will talk about nozzle design?

Because we can have a very good rocket combustor. But if your rocket nozzle is not a good design we will not be able to produce enough thrust if there are lot of losses in the nozzle; we would not be able to produce enough thrust to fly a vehicle; actually what I am going to discuss today in the history we will see that one of the major invention which allowed rocket flight was the nozzle design. So, therefore nozzle is a very important component of rocket propulsion; after this then we go to non chemical rockets or non chemical space vehicles where we talk about electric propulsion.

So, we will dedicate few lectures to electric propulsion systems; we will talk about various type of electric thrusters, we will talk about electromagnetic thrusters, then we will talk about plasma thrusters. And finally we will also talk about applications of electric propulsion; essentially we will discuss some missions which have already taken place involving electric propulsion systems. I like to point out here is that most of the deep space missions involves some kind of electric propulsion system; because they are very very efficient in the deep space. So, this is we are going to talk about in this course. Now, let us next talk about the text books that we are going follow for this course.

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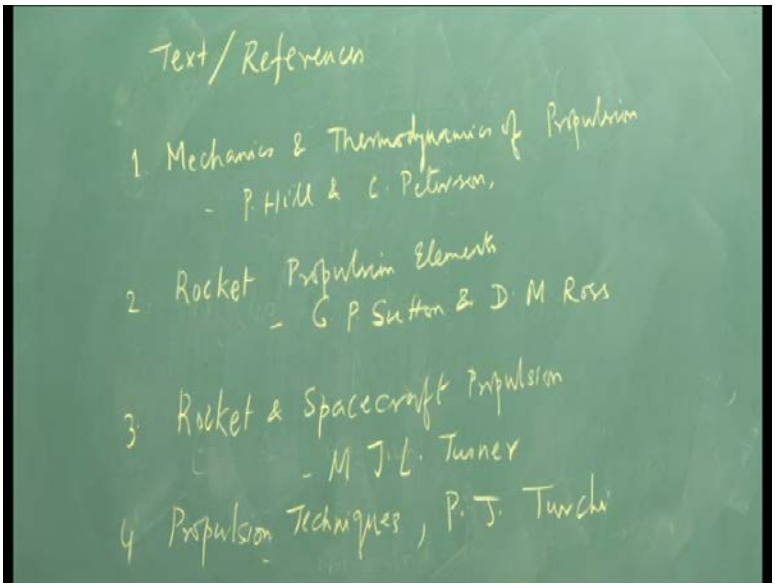

So, the books which can be text as well as references; first and foremost there is a very good book on mechanics and thermodynamics of propulsion by Hill and Peterson. And the second again a classic book rocket propulsion elements by Sutton and Ross. Then rocket and spacecraft propulsion by Turner and propulsion techniques by Turchi; this books primarily talks about electric propulsion systems. These are the 4 books we are going to follow apart from that as we go along we will see that we will require lot of thermodynamics, lot of gas dynamics and little bit of combustion for this course. So, there can be some additional reading on this topics. First of all the most widely used topic in this course will be gas dynamics or compressible flow gas dynamics to be more precise compressible flows.

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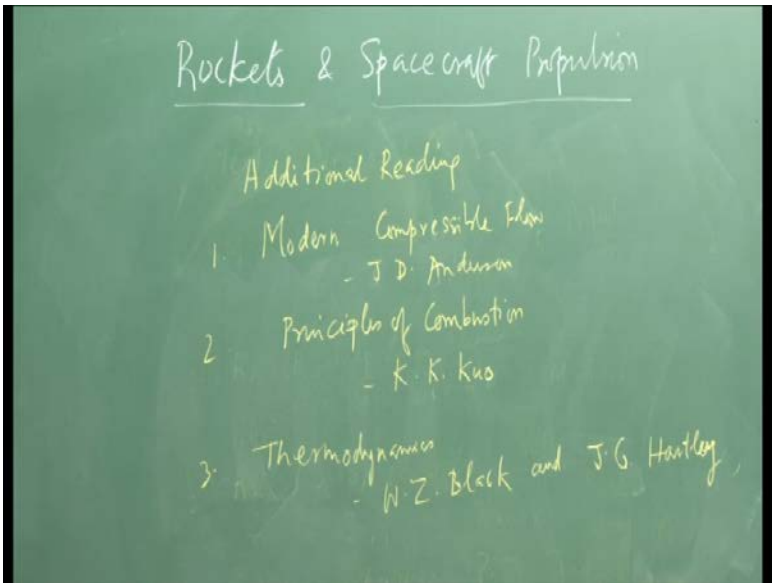

So, the additional reading will be modern compressible flow by John D Anderson; then little bit of combustion. So, principles of combustion by Kenneth Kuo and any thermodynamics book will do advance thermodynamics book. So, I am listing one of the books which is by black and Hartley. So, these are going to be the text books that we will be following in this course. So, far what we have done is we have talked about little bit of mythology, little bit of basics of what is propulsion. And now I have listed the course content for this course.

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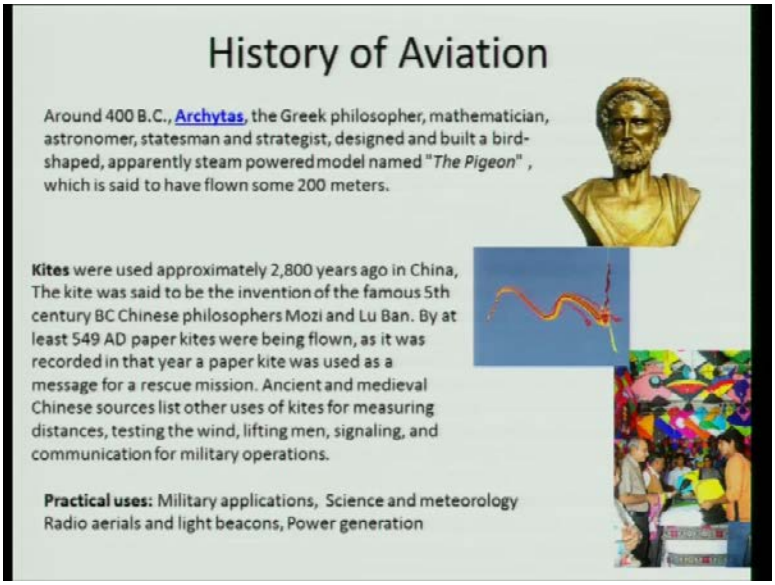

Let us now as promised proceed with the history of propulsion. So, first before we talk about history of propulsion; we need to know history of aviation that is flying. The first man made flying objects were essentially kites which were flown about 400 BC. As we can see here Archytas who was a Greek philosopher and mathematician he designed and built a bird shaped apparently a steam power small model; name the pigeon is set have flown about 200 meters; that was done in 400 BC long time back. Then kites were approximately in two about 2800 years ago kites were invented in China. And it is said that it is it is invented in 5 century BC by Chinese philosophers Mozi and Luban and by 549 AD paper kites were flown all around China and they were used for various applications. In fact, since then there were kite flying competitions as well.

So, first paper kites were used to send messages of our rescue missions. And Chinese have been very enterprising in various use of flying vehicles as you can see later even they invented the first rockets. So, in ancient and medieval Chinese sources they list the use of kites for various applications like measuring distances, testing the wind speed, lifting man in certain cases, providing signals for armies and all and communications for military applications. So, as you can see kites were used for various applications over the years. The practical uses essentially were military applications science and meteorology. Then now presently kites are used as radio antennas or radio aerials; they are used as light beacons and sometimes for power generation as well.

I hope that all of you know the famous story of ((Refer Time: 31:52)) how he invented electricity flying kite right. So, essentially we can see that even electricity was produced by a flying vehicle for the first time. So, the first flying I would say manmade thing was kite.

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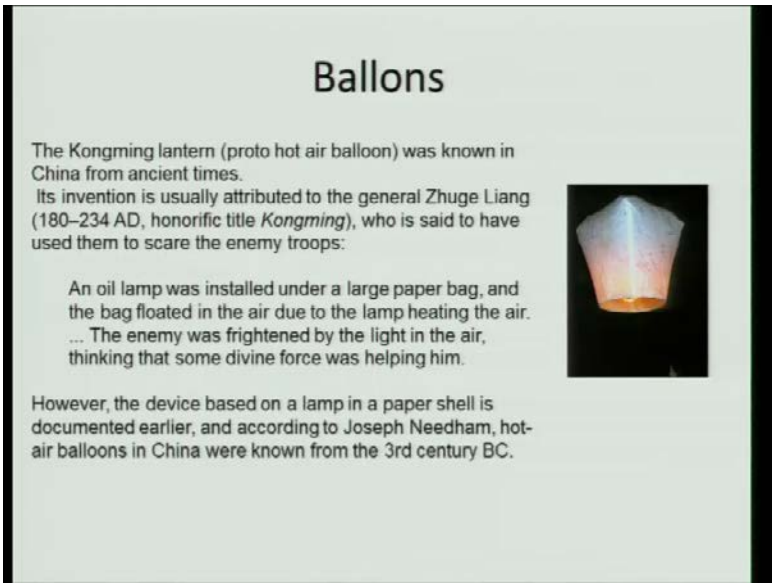

Then, the next thing was balloons; this balloons essentially were first invented as decorative items they were called Kongming lanterns; again they were invented by Chinese. And they were known in China from ancient times; this invention is usually attributed to general Zhuge Liang in about 200 AD. And he said to have use this lanterns at night to scare enemy troops. Because in the darkness of night what he used to do is he used to put small lamps in this balloons; and send them upward. And the enemy soldiers will see that flying lights and they used to get scared.

They thought they were dragons actually; they used to get scared. So, essentially the first use of balloons again were military use to scare the enemy soldiers. And later on initially those balloons were made of paper; later on there have been very massive development in balloon technology as well again balloons are being used now for about 2000 years now; even today balloons are used. And in the first half of 20 th century balloons were actually the mode of trans atlantic transport; big huge balloons were created for flying from going from say Europe to America.

Then, there were heddle bug disaster; after that the balloon flight was stopped saying that these are not very safe. But they have been used still being used for various applications like for advertisement, for recording, for weather measurements, weather predictions etcetera balloons are very much in use till today.

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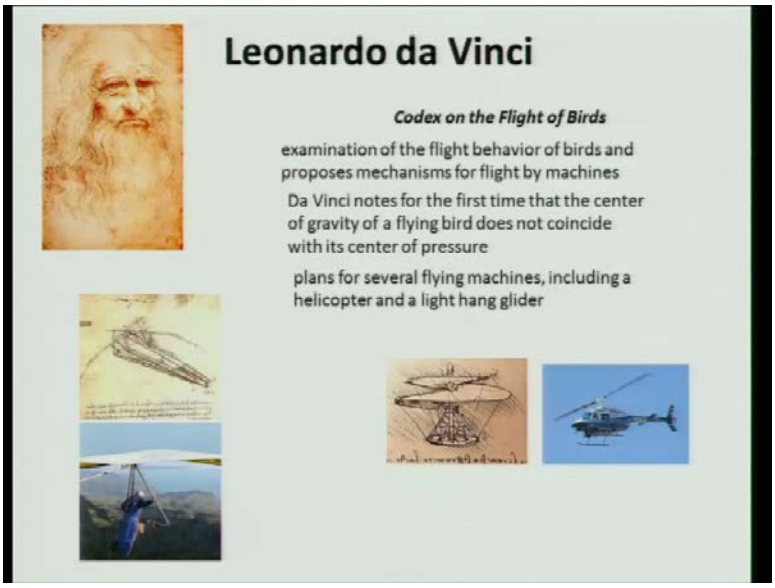

Then, the history of flight is incomplete without talking about this man Leonardo da Vinci. Now, he essentially wrote a men script called codex on the flight of birds. Here, what he did was he examined the flight behaviour of various type of birds. And then proposed mechanisms for flight by using machines; mimicking the birds. So, da Vinci for the first time noted that the centre of gravity of a flying bird does not coincide with the centre of pressure; what does it mean? If your centre of pressure and centre of gravity are not at the same location we will have a moment, right. So, essentially he was the first one to propose that there will be a moment.

Now, if you can design the moment properly you can have a pitch of moment; then you will not go down you have a nose of motion right. So, inherently it will be more stable. So, therefore he was the first one to identify that centre of pressure is the very important location as far as aerodynamics is concerned. Then he sketch plans for several flying machines including an helicopter which is you can see here this is this a helicopter model. And this is the modern helicopter as you can see he has proposed the rotors also and. So, first helicopter was proposed by Leonardo da Vinci in 16 th century. He also proposed a hand glider as you can see here in this figure; figure this is a hand glider. Even the present day hand gliders are not much different from what da Vinci has proposed. So, hand glider and helicopter were proposed by by Leonardo da Vinci.

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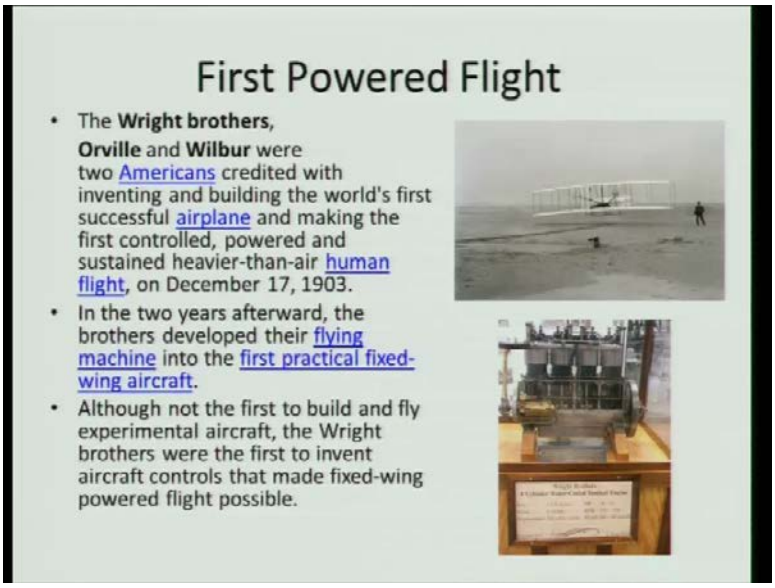

Now, first powered flight. Now, we are talking about just general history of aviation. So, first powered flight as you all know was by Wright brothers Orville and Wilbur Wright and it was in December 1903 in kitty hawk in north Carolina USA. The first heavier than air human flight was successfully achieved in the Wright flyer; the picture of that you can see here. And they used the piston propeller engine, a big piston engine as you can see this is the engine that they used with the big propeller, they used the piston propeller engine to provide the thrust to fly their vehicle. And in the 2 years afterward they developed their flying machine into the first practical fixed-wing aircraft.

So, the first practical aircraft was also developed by Wright brothers. Although there were not the first to build and flight experimental aircraft; that has been happening before that also. But they were the first to invent aircraft control systems and without the control systems this vehicles were not flight worthy; they were not stable. So, people have flown unstable flights were possible even before that. But first stable sustained flight was made possible because of the control system that was developed by Wright brothers. So, therefore we essentially call them the father of flight.

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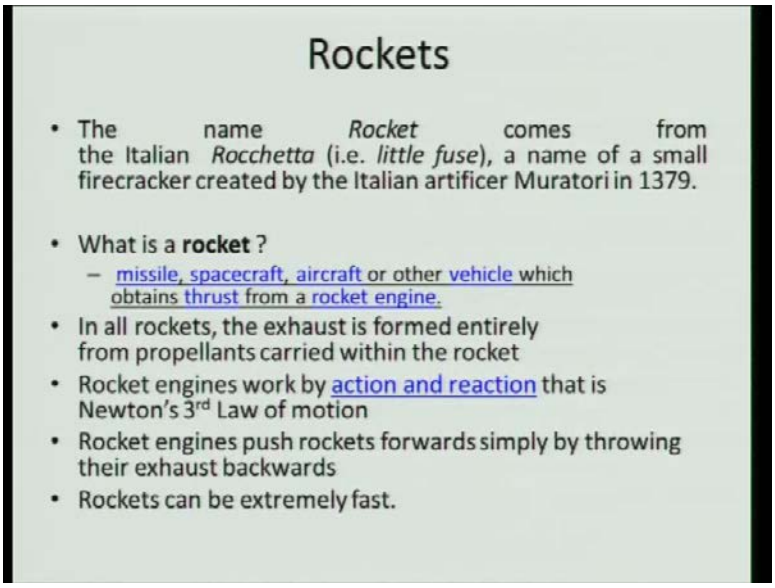

Now, this has been the general discussion on flight. Let us now come to the specific for this course; which is rockets. What is a rocket? The name rocket comes from the Italian word Rocchetta which means little fuse; this is the name of a small fire cracker created by Italian artificer Muratori in 1379. So, essentially it was a fire cracker which is to move. So, that is what rocket is. So, if we look at the definition of rocket; what is a rocket? A missile is a rocket, a space craft, aircraft or other vehicle, which obtains thrust from a rocket engine can be termed as a rocket.

Now, therefore the important word here is the rocket engine; what is the rocket engine? In all rockets the exhaust from the exhaust is formed entirely from the propellant carrying on board this is the difference between a rocket engine and an air breathing engine; in most of the aircraft engines the main propellant is air fix the engine sucks from the atmosphere energy as you read. And then flows out where as in the rockets the propulsion system apart from the back pressure at the exit of the nozzle; this kind of secluded or independent of the flight. Because both the oxidizer as well as the fuel or all the propellants are within the rocket; they do not interact with the atmosphere, they do not take anything from atmosphere and that is what a rocket engine is.

So, again going back to the first line the missile, space craft, aircraft with rockets actually there have been aircraft with rocket our doctor APJ Abdul Kalam started his carrier in DRDO by making rocket powered aircraft; which then because of that

experience he was later taken to DRDO to start the missile program ok. So, there has been rocket powered aircrafts, there has rocket powered in cars. So, essentially where they do not interact with the atmosphere and take they are carry their own propellant is the rocket. So, the rocket engine is essentially work based on Newton's third law of motion; which is action and reaction. Every action has a equal and opposite reaction. So, that is the primary and basic principle of application of a rocket engine.

So, the rocket engine essentially puts pushes push this rockets forward simply by throwing their exhaust backward. And the amount of thrust produced will depend on the amount or the mass flow rate of the exhaust and the velocity. So, essentially the rate of change of momentum of the vehicle is equal to the rate of change of momentum of the exhaust and that produces the thrust. Because of this since it does not have any exposed system we can keep on increasing the velocity as well as mass; of course depending on the availability and can produce very high thrust.

So, therefore this rockets can move extremely fast; it can be 30, 40 mass speed also can achieved by rockets; of course rockets can move up to escape velocity; they can go to a high as high as escape velocity, so that they can go outside the atmosphere. So, they can move extremely fast that is the biggest advantage of rockets; the very high speed that they can attain.

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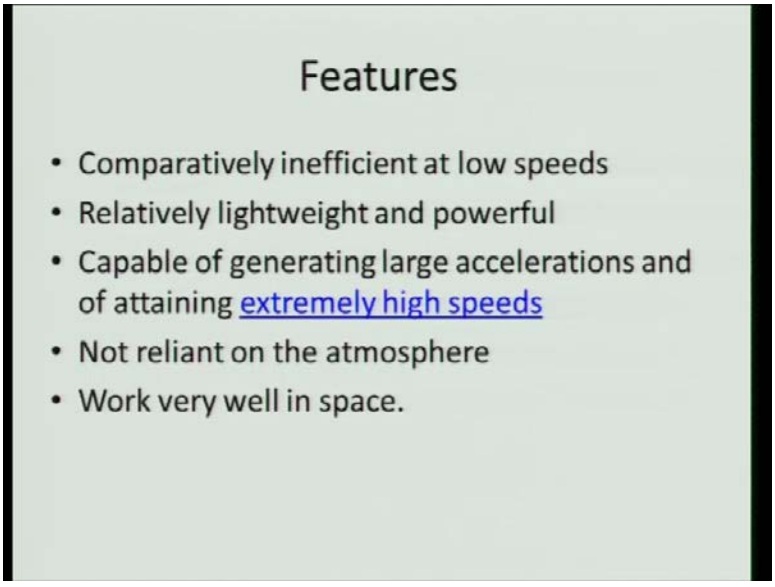

So, the basic features of the rockets then. First of all they are quite inefficient at low speeds; we do not want to use rockets for low speed applications because they are very very inefficient. Only when we go to high speed applications then the rockets are efficient. So, therefore we use rockets primarily for high speed applications; they are relatively light weight but very powerful; they are capable of generating large accelerations and attaining extremely high speeds. These are the basic features of the rockets; they do not depend on the atmosphere, they do not interact with the atmosphere, they do not a take anything from the atmosphere.

So, therefore they can work without the atmosphere as well; that is the very big advantage and that is why they are the only medium useful for space ((Refer Time: 42:03)). And because of this they work very well in space; where the drags are anyway absence there is no drag in space. So, small amount of thrust is good enough to overcome all the slight retardation that we experience. So, if the vehicle is moving at high speed and a small acceleration will just maintain the speed. So, therefore rockets essentially for space application or application in outer space or essentially the only possibility that we do; we do not have anything else to propel as that high speed at that high altitude.

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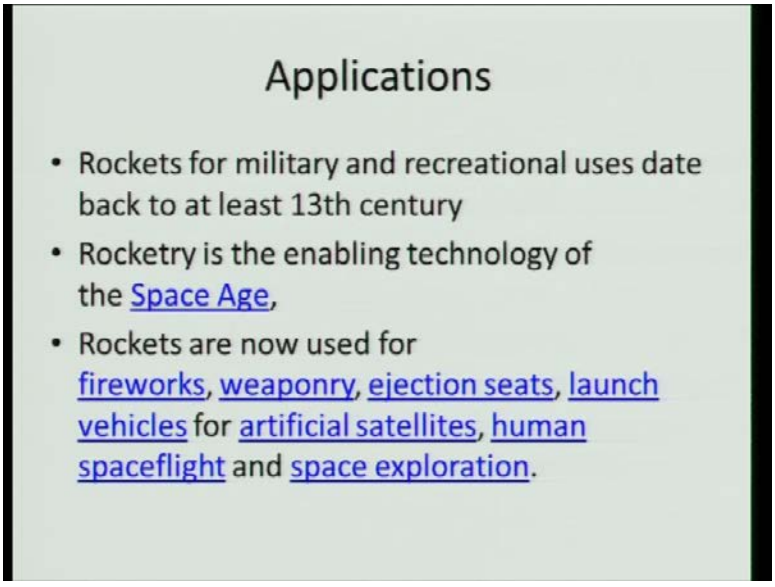

So, if you look at the applications of the rockets. Rockets are used for various military applications like in missiles and all; they are used for recreational purposes which date back to 13 century like fire crackers and all. Rocketry is the enabling technology for

space age; the age that we are here today, the advancement that we are seeing in science and technology essentially the communication revolution that we are seeing today is all possible because of the rockets. The mobile phones that you are using are not of at any use without the satellites; even this course, which is being recorded would not be accessible to others without the satellites. And we cannot put satellites in outer orbit without the rockets. Therefore, without the rockets the advancement in the second part of 20th century and the till now in the 21st century would not have been possible, because they made possible the space communication, satellite communication. So, the whole I T revolution as well as communication revolution can be attributed to the presence of rockets ok.

So, rockets at the present day are used for fireworks, as weapons for ejection seats in aircrafts; particularly military aircrafts in some sometime. Because of some emergency the pilot has to eject that requires a very small response time and has to be run very at a very fast rate. So, rockets are used as for ejections seats and when they pilot is ejecting the vehicle is also moving. So, the pilot has to be taken away from the vehicle at a very short time and that is requires lot of acceleration which only a rocket can provide. So, ejection seats have rockets. Then launch vehicles are of course for all the satellites; then even the satellites themselves have some kind of small robertory devices. Because the life of a satellite is defined as how long they can remain in the specified orbit?

Now, as the satellite keeps on moving in the orbit slowly because of the gravitational pull and because of the small drag that is present; its starts to deviate from the orbit also it may loses attitude. Now, if it beyond the certain point then it is of no use to the user because the signals would not be coming back in a proper place. So, periodically satellite has to be bought back to the orbit and as long as it remains in the orbit it is useful. So, the life of the satellite is as long as it remained in the orbit and in order to do that rockets are used extensively.

So, small thrusts are produced for course correction of satellites. So, therefore even rockets are not only used to put the satellites in orbit but also to maintain satellites during its life. So, that it is useful; because if it goes beyond the particular attitude and goes out of the orbit is of no use. Then human space flight for mission to moon or the space mission the space station. Now, we are talking about mission to mars as well of course rockets are the only thing that can take us there so and space exploration.

Now, Galileo has gone beyond the solar system going in to the deep space; ((Refer Time: 46:15)) telescope is a space telescope which was put by rockets in the space. So, therefore various applications for space exploration were essentially dependent on rockets. So, rockets are something now although they are I would say not that the rocket community rocket science community not very much vocal about their achievements. But if you look at the present day today's life; they have touched almost everybody's life. So, therefore it is a technology which is very, very important. And in this course that is what we are going to talk about.