Space Flight Mechanics
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Lecture No. # 01

Introduction to Space Flight Mechanics

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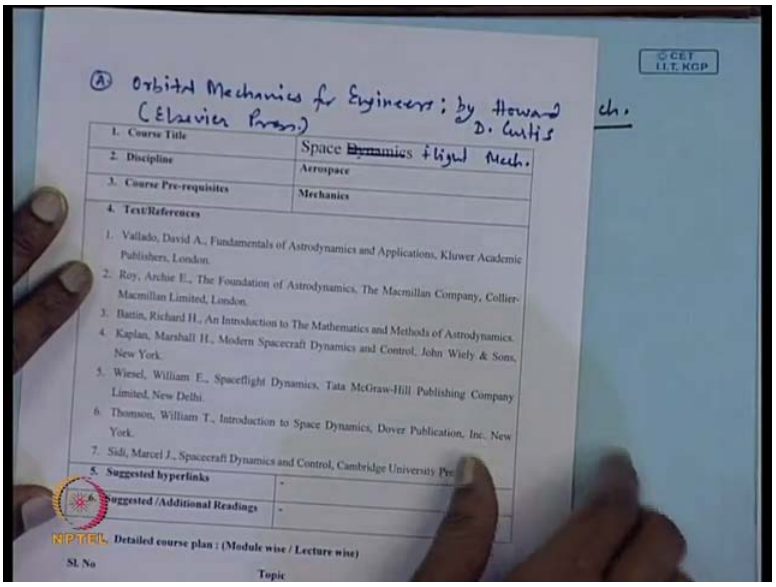

Welcome to the course on space flight mechanics. So, in this very first lecture we will get acquainted with the; what the space flight mechanics is all about. So, we start with the requirements for this course. So, to understand this course we need to know about the basic calculus and mechanics. And the books for this course so, the recent book which has been published on this orbital mechanics for engineers by Howard D Curtis. So, this is from Elsevier Press, rest other books are also available so for those books are of very high quality, but the book which has been published recently this are orbital mechanics for engineers, this is specially it contains a lot of info (( )) solved problems.

So, you can get benefited by using this then, we have some (( )) books on space flight mechanics those are by Vallado. So, this book is on the fundamentals of Astrodynamics and applications. So, this is the book, the first book which is perhaps not visible on the screen. The fundamentals of Astrodynamics and applications and this is by the from the Khiwer publication, Khiwer academic publishers from London. The second book then

we can; so, this we can take as a text book and rest others, you can use as the reference book.

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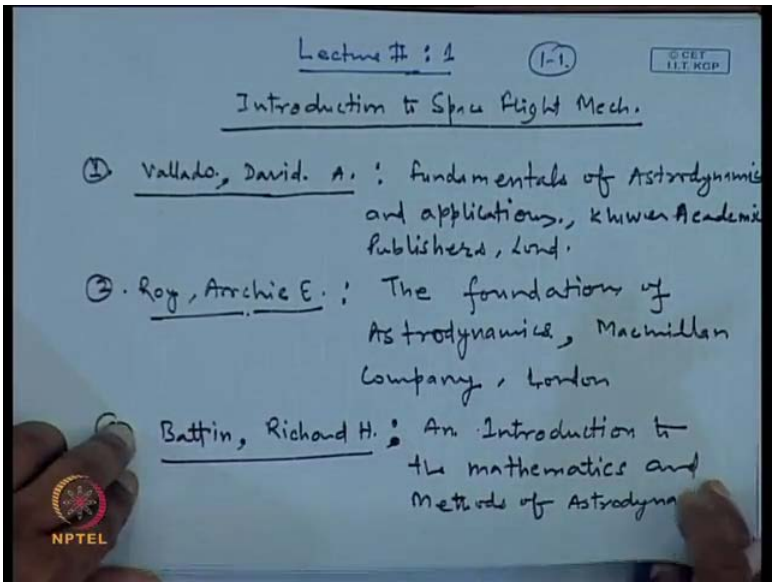

So, this is Arrchie, Roy and this is on the foundations of the Astrodynamics and this is from Macmillan company.

Then are very good books in fact I will say this is the Bible for Astrodynamics or the space dynamics mathematics this is by Richard H, Battin. And this comprehensively describes the mathematics for other Astrodynamics. And introduction to the mathematics and.

So, all these books they are basically concerned with the celestial mechanics or a; what I am going to explain, after writing the names of all this books. So, basically if you are dealing with the celestial bodies so, this Arrchie, Roy this is the book which comprehensively discuss about the reference frame and the motion of the celestial bodies. And obviously this we have written here, this describe the complete mathematics. Here, it takes into account the satellites and also the reference frame are in comprehensively described.

While in our; the space flight mechanics, we also deal with the satellites attitude dynamics means of we are the satellite we can consider as a rigid body or a flexible body. And then ponds it is a moving in the space so, we want to change the orientation of

the space craft then, how to do it? We have to apply the controls and other things. So, we will look into the attitude dynamic and controls so for those issues we have very good books available. So, this is the forth one this Kaplan, Marshall H this is modern space craft dynamics and control. So, this is Marshall H, Kaplan.

Modern space craft.

This is easy to read book, but there are many other books on the space craft a attitude dynamics, which is specialize in attitude dynamics. But those becomes little more lengthy and then it will be difficult to read also, but this one is very simple to read and understand, you can start with this book on the attitude dynamics on the satellites. So, this is published by John Widely and sons is from New York. Another book on the space dynamics is by Marshall J, sidi the space craft dynamics and control. This is from the Cambridge University press (( )) U K.

Then on another book which concisely describes about the space flight mechanics this is William Wiesel space flight space flight dynamics. And this is published by Tata Mc Graw Hill publication.

New Delhi, one very good book, which covers the space flight mechanics and also lot of attitude dynamics and it is a considered to be a classical book, this is by (( )) William T, Thomas. But this book is difficult to read for the first time reader definitely.

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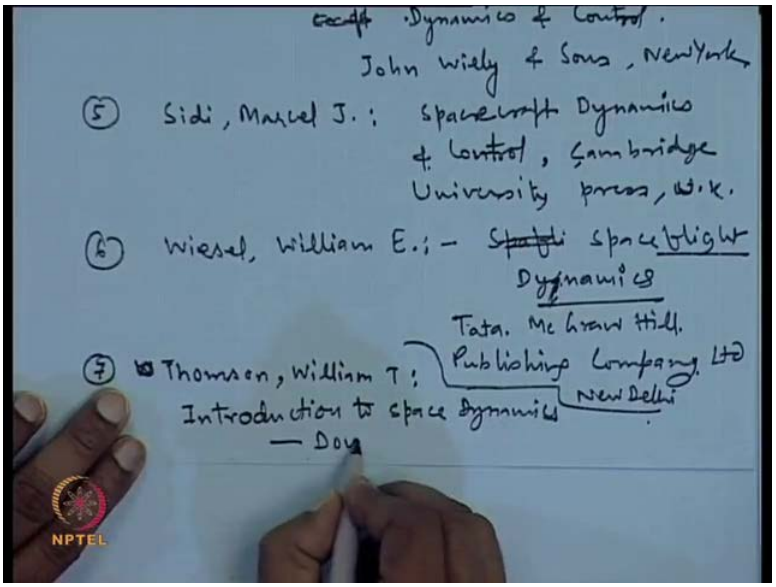

It is difficult to fallow, because this book has in sort it has a written the passages of by skipping a number of steps the final answers are written in many cases. So, it makes it very difficult for the beginners. The book name is introduction to space dynamics and this is from Dover Publication New York. So, these are the books that we are going to fallow then, we have the number of lectures that I plan to give, we will on the introduction to a space flight mechanics. This is the very first lecture then on the particle dynamics, basically particle dynamic will consist of particle kinematics here and rest of the part I will cover in the central course motion.

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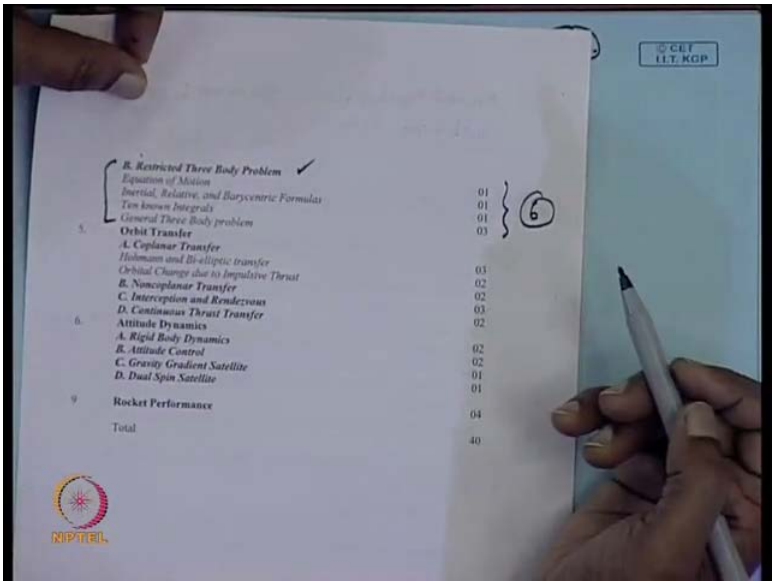

So, two lectures are struggle for the particle dynamics are say, if the particle kinematics then the conic section mathematics of the conic section one lecture is schedule. And then, we go into the central force motion in which we will have the two body problem and restricted three body problems. And here, we have total number of two body problem eight lectures and for restricted three body problem we have three three six lectures, but I hope that I will have to give more lectures than that. Then, we go into the orbit transfers one of the orbit transfer as you will know or you might be aware of that once. The satellite is launched of it is orbit is lower means in which ever orbit you want to put the satellite it is not exactly in the same orbit.

But, it safe the initial attitude may be lower so, inclination may be different so, you need to change the orbit of the satellite. So, the way we carry out the analysis for changing the

orbits so, it falls into the orbit transfer domain and here we have the plan number of lectures are total 12. So, again it may exceed this number of 12 number of lectures, there after we go into the attitude dynamics. So, this is all about the changing the orientation of the satellite. So here, we plan to give around this is 6 lectures. And finally, on the rockets so, here we will be discussing about the rocket dynamics and we do not go into the details of the propulsion wing, what are the chemical being used and other things, we will not discuss about that just about the few elementary ideas about the rocket dynamics Ss, it is a basic propulsion.

So, and this constituents four number of lectures so, total 40 number of lectures are schedule, but definitely it is going to exceed that. And more over in this course, it won not be possible to give solve a number of problems during the lecture. So, for this three we have the wave lecture that we will uploading on the internet. So, in that wave lecture we will solving number of problems and that will help you in this course. So, I will try to give a minimum whenever I feel that it is necessary to give some examples, so at that time I will give some examples, during the lectures.

So, we are start with the basic definition. (( )) Now, let us take the definition of this space is taken the; if the altitude exceeds more than 100 Kilometer. So, the objects at that height will be considered to be in the space or say that the beyond the altitude of 100 Kilometers, we considered this as the space. Now, so for the space we define this as the vacuum outside the earth is atmosphere or say the near vacuum outside the earth is atmosphere. The; another definition you can write for this, this is the volume in which all the celestial bodies so, this constitutes our the definition of this space. Now, you can see that the density of the atmosphere it dies out very fast, if you plot it altitude on the x axis and row or the density on the vertical x.

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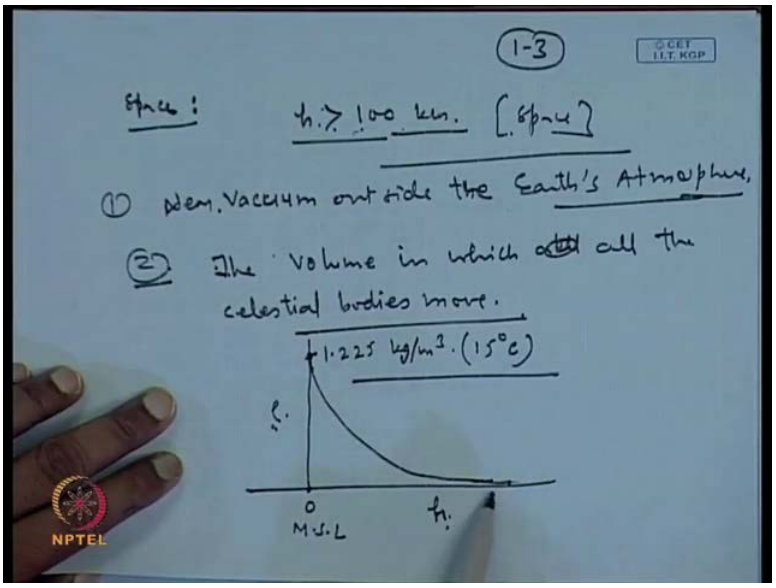

So, here you will say on the mean scale level, if we write this as the altitude zero here, which is the mean scale level. So, in the standard atmosphere we take it at as 1.225 k g per meter cubic and this is at 15 degree centigrade at this temperature this is taken here. And there after the density, it goes down very fast and it becomes graphite at very high altitude. So, at high altitude even though it becomes graphite, but still it molecules of the gases there present and they produce resistance to the motion of the satellite. And they damp out the motion of the satellite and it changes the altitude of the satellite over a period of time.

So, energy of the satellite it is a well defined equations are there which will take later on, but we avoid the equations at this stage. So, you will see that later on that as the say I measure at which is a parameter of the orbit here you can consider that if this is the earth and around this if this is the satellite moving in a orbit. So, the distance from the center of the earth to the satellite, this distance will be termed as the radius of the satellite and if this orbit is non circular, sorry if this orbit is elliptical means it is not circular then, if the same thing you call as the semi major axis.

So, we will see that as the semi major axis decreases as the semi major axis will increase the energy of the satellite will increase, as the semi major axis decreases energy of the satellite will decrease. So, over a period of time what happens that satellite is interacting with the atmosphere and this atmosphere it is a registry force it tries to take away the

energy of the satellite and therefore, the semi major axis the satellite it continuously goes down. So, if your satellite is here and the atmospheric drag is large so, you will see that over a period of time it will start dirking from it is orbit and slowly slowly it will start coming into the inner of that atmosphere. And as it comes in the dens earth atmosphere then, because of the friction with the atmosphere a lot of pit is generated and this gets burnt out.

And that the reason that the satellites are put at high altitude so that it remains there for a longer time. So, even at 300 Kilometer altitude the atmospheric drag is significant for the motion of the satellite to change it is orbit over a long period of time. So, to contract the effect of this atmospheric drag so, the satellite is busted from time to time and is to orbit is raised; means the satellite will be losing it is altitude it will be moving towards the center of the earth over a period of time. So, the rocket will be fired and the altitude will be raised again the satellite will be pushed back into the original orbit so, this is called that orbit raising. So, there are many exercises that once we go through the; this course so, will understand all this details.

So, equations we had at this stage, but it is a very clear so, maybe we can write the equations here. Let us say this is e is equal to minus mu by 2 a, this is the equation for the energy per unit mass, where A is the semi major axis and mu again is a gravitational parameter for the; if it is earth this is written as the universal gravitational constant times the mass of the earth. So, this will be difficult to understand that is why I want to avoid this. So, here you will see that if A is very large, A becomes less negative means and if A is small so, this becomes more negative E becomes more negative means it has lesser energy and if A is very large or say it becomes infinite then, A becomes equal to 0. Means the total energy of the satellite becomes zero, this is the kinetic energy plus potential energy.

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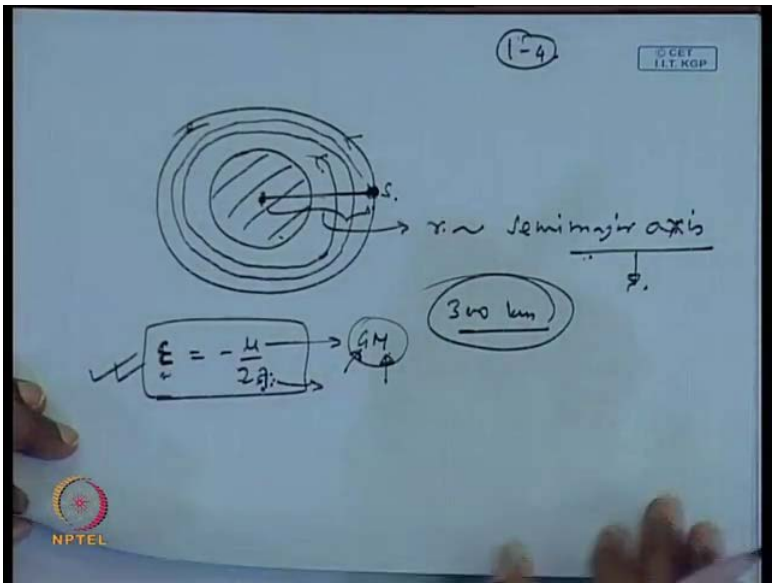

And that is considered to be so, the at a infinite distance from the center of the earth, the satellite will have zero energy. And that is you will see that object on the surface on earth is having an negative energy as compared to a satellite resting at a infinite distance. So, this concept will be clear later on and therefore, I avoid discussing further on this. So, we were working out on the space, what this space is so, after this definition. Now, will have a little bit look on to the; what the kinematics, dynamics and astrodynamics? All these terms are; so, we have the terms like in definition we mention here, kinematics it is a concerned with the geometry of the motion. Geometry of the motion, here mass does not does not appear in the equation on the motion.

So, here the either to the mark or the force the distance will not be done. On the; another hand the kinetics, it purely deals with the motion of a particle so, in this, this is the branch of the dynamics. So, here will be dealing with the forces, but here the static or the stationary a state of an object is excluded from this branch. So, the branch of dynamics which deals with moving body only then, we have the dynamics.

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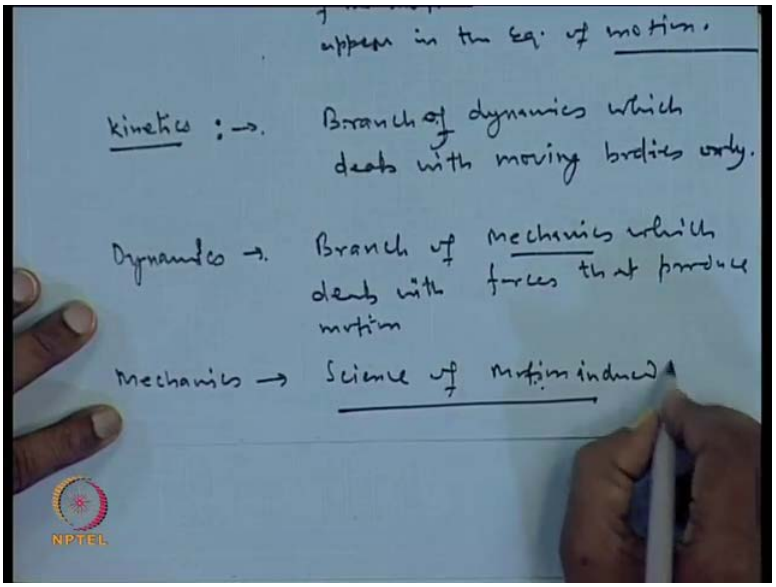

So, this we can define as the branch of mechanics which deals with forces that produce motion. And ultimately the mechanics which we have stated here this can be defined as the sigh of motion, sign of motion induced by forces. Now, our course is on the space flight mechanics, space flights mechanics we can consider even the in this evenly bodies can be included, because we in the space flight mechanics we have studied the motion of the heavenly bodies also, we can divide it into various parts so, I will say the Astrodynamics and the space dynamics, another one purely the celestial mechanics.

So, the celestial mechanics so, we divide our study into three parts, the celestial mechanics, the space dynamics and we will have a Astrodynamics. The celestial may connects it purely deals with the signs of heavenly bodies. So, in the celestial mechanics we discussing only about the motion of the heavenly bodies, while in a space dynamics measure we will be discussing about the manmade objects which are the natural satellites. So, this we divide into two parts the vital mechanics and the attitude dynamics. So, our vital mechanics it deals with the trajectory dynamics of this space craft, while here we deal with the librational motion.

So, this is the attitude dynamics part which deals with the orientation of the satellite. You want to change the orientation of the satellite in a space so, how to do it? The question arises. So, this can be done by applying the top to the satellite then applying this torque naturally then, you need to have either rocket onward. So, fire to rockets to produce the

torque or either you have the reaction will so, various technologies are here, which can be utilized. Even, if you have the magnetic torque on volts that is a current carrying twelve on the satellite so, it can interact if the magnetic field of the satellite and can produce magnetic torque. And therefore, in a it will result in the change in orientation of the satellite over a period of time.

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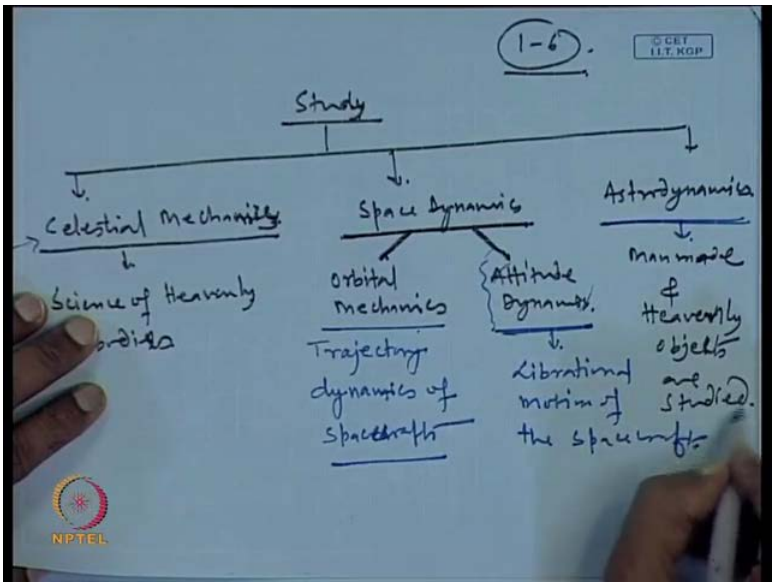

So, various technologies can be used for changing the attitude of the dynamic satellite and the study that we do. So, this study we call as the attitude dynamic and which is followed by the controlling the attitude of the satellite we call this as the attitude dynamic control the overall term logic you used. Here in Astrodynamics it is a broad area and in this both the celestial mechanics and the space dynamics, you can say it is a combined. So, both the manmade and heavenly objects are studied. Next we have many more definitions are there, but only few definitions we will tickle.

Now, we come to a space craft once we have got accounted with the basic of the space. So, space craft as you know it is a satellite or you say a vehicle in a space. So, it is a possible that you; even a brick in the space and that brick is moving around the earth. So, even it is becoming space craft, but it is not useful this is just like any object rather than telling this as the space craft, it want be good rather we say that it is a just like a meter meteoroids so, we have different meteoroids which are floating in the space. So, you will see that in the night, you will see that different meteoroids they are hitting and coming in

the atmosphere of the earth. So, they will pass just over the horizons and you will see a stick of flight going from one place to another place.

And often you call this as the breaking of the starts, but actually this are the heavenly objects and once they enter into the here they get heated and burn and produce light. So, if you are putting a brick in the space so, I will not say that this is a space craft rather it is in a object and it is a object in the space so for a space craft are those objects which are made by the human. And we would utilize for certain useful purpose for imaging the earth surface or from scientific purpose or rather thing. And giving even putting a brick there or a stone in the space and calling it as space craft, it is not correct so, we want the that kind of terms. So for the space craft now, we can go into the little bit history of this the first space craft.

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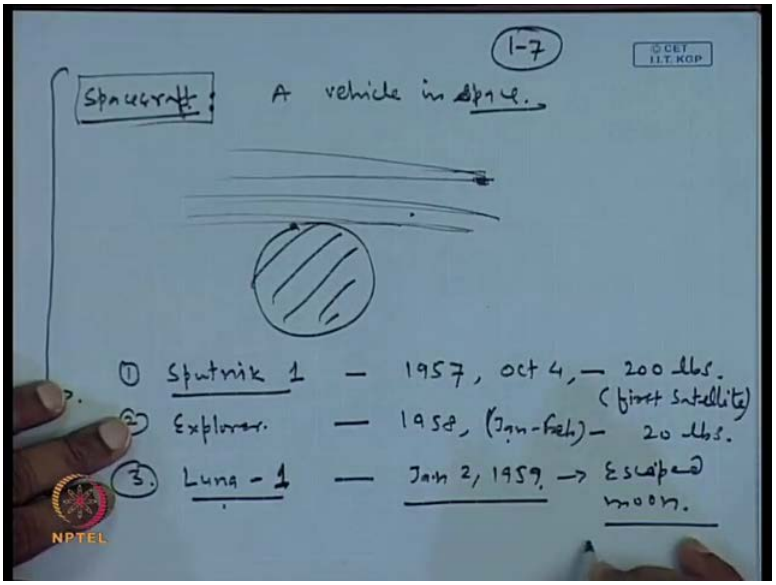

Which was launched in the space it was sputnik Sputnik 1 and it was launched in 1957 on October 4th and weighted 200 ponds, this was a Russian satellite, this is the first satellite. Explorer which is a American satellite, it was launched in 1958 somewhere in January February and weighted 20 ponds. Luna 1 this is a Russian satellite and it was launched on January 2, 1959. So, it was a satellite to orbit the moon, but it did not orbit the moon escaped, it is kept moon so, missed something by 5000 Kilometers the surface of the moon. So, next again the Russian satellite Luna was sent and this impacted so, this was on September 12, 1959. It launched and this was the first to impact the moon.

So, we can see that, how the satellite launched it has started. So, before that we have a long industry of satellite launched, the people had been trying to make rocket, the putting before that the balloons were made which we are sent into the higher altitude. So, the continual effort which we have done, there after only such events could take place. So, after the launch of the first satellite the Sputnik 1, there as a allows in other satellite Luna 1 to than Luna 2. And Luna 2, it impacted with a to impact the surfaces of the moon, so first impact the surface of the moon.

And then, during this (( )) then virtually a race between the U S and this started and they tried to excel each other in the space technology. So, we had the polo 11, you know the polo 11 the as to not polo 11 it first landed on a moon, but before that the number of machines of our polo took place. So, a polo 8 it was first to leave the earth is atmosphere with astronauts. So, astronauts where on broad on polo 8 and this was the first which left the earth is atmosphere. So, this is the history this gets back to before 1969 once the; a polo 11 was announced so of in the polo 11 so, lunched was on July16, 1969 and this is green which mean time. And this landed it is a command module, it is a various model lunar model and the command model was there in the polo.

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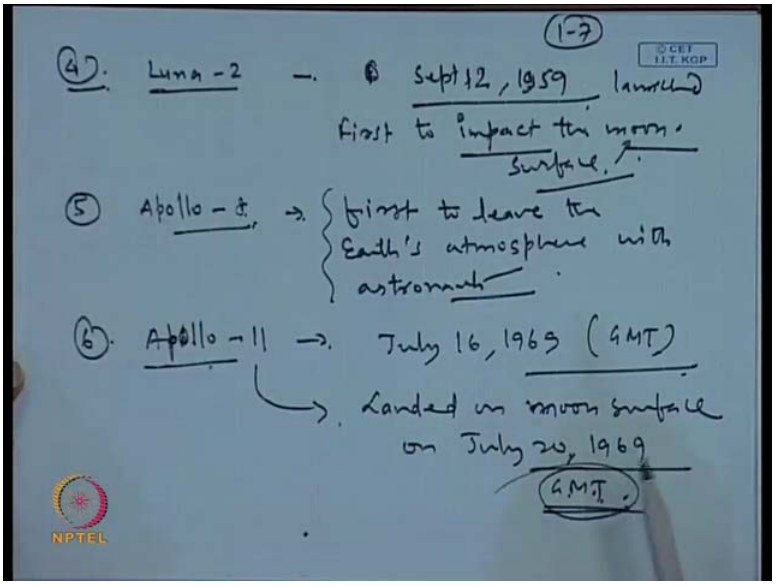

So, the lunar model it went to the moon and it landed on the moon is surface on July 20, 1969 this is g m t, this is green which mean time. This time is very important what the time is in India it is not the same time in the U S A. Therefore, this is being referred to

the g m t time. So, lately India also started in this field and it launched it is first satellite Arryabbat in 1975 from Russian Phisoderm, April 19th and this was the first Indian satellite. There after India has gone a long way in becoming in independent in the field of that is the fabrication of satellites.

So, still putting very big satellites, we require very power full rockets and those rockets which are the g l s v geostationary satellite launch vehicle and whose the upper stage is cryogenic state means, the liquid hydrogen is used here. So, drag technology is still been developed this is not been mastered, but in the as for as the solid rocket motors and liquid at operate motors are concerned so those are already mastered and India whose the p s l v, which is the say work of our Indian space research organization. So, it is working very well and it is a very consolidated technology.

Now, after the launch of the Arryabbat, the next in this series was the Bhaskar this was launched on June 7th, 1979 and this was again launched from Russia. So, we see that satellite launch it has gone along way now, for the satellite launching we need rockets so, till now our own rocket were not developed. Then, the efforts we are made to develop our own rocket so in this series the satellite launch vehicle s l v 3 this is called the satellite launch vehicle. We had before this a so, a s l v this is called augmented satellite launch vehicle.

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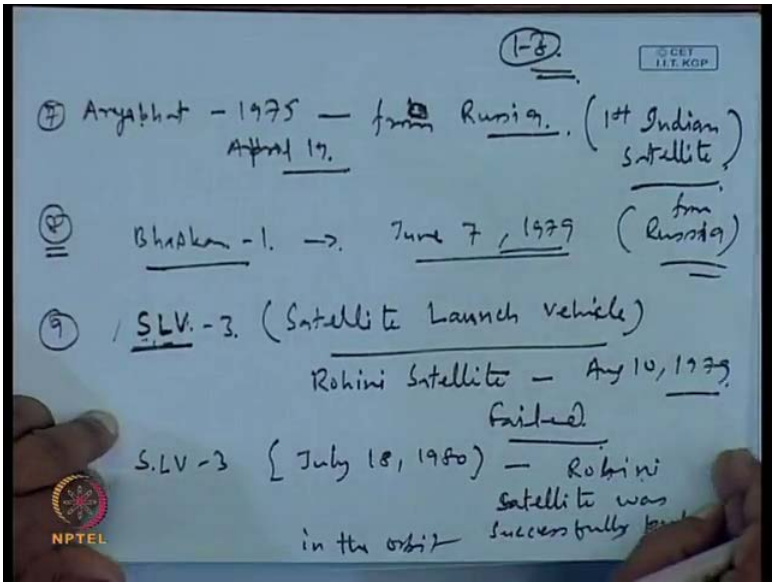

If we add here p this is called the polar satellite launch vehicle if we put before this the g this is called as geostationary satellite launch vehicle. So, this is s l v tried to launch the Rohini satellite in the orbit in august 10th, 1979, but this failed. Then another version of the s l v 3 on July18th, 1980 another satellite named Rohini was successfully launched, it was successfully put in the orbit. So, you already know this p l s v and g s l v can often it keeps coming in the news. Now, the space vehicle they have various categories now, space vehicles you can say our space craft for scientific purpose.

The space craft for doing some Catto, producing some Catto graphic map or remote sensing, military purpose. Military purpose means say doing the spying and then, you have the space station available which are you wants launch it and keep it in the space. And satellite can go from this place to space and it can adapt to those space station where already some scientists may be working. So, the scientists from the earth, we can go and join there and the scientists we are working we are already they can come back. So, it is a permanent station type there so, those are called the space station. There after we have the reusable launch vehicles. So, reusable launch vehicle as you know that reusable implies that you can use it again and again.

So, once the satellite is being launched so, it is a being launched using the rockets. So, rockets launch the satellite and whole the structure is later on destroyed. So, in the reusable vehicle, there will be one main rocket, which will take it to certain altitude and there after the reusable launch vehicle it can it will have it is own propulsion system. So, it will launch the reusable launch vehicle, the rocket the launch the reusable vehicle into the orbit. And it will orbit in this space it can change it is trajectory also, because it has it is own propulsion system and there after once the machine is over so, it can come like come down it can land like an aircraft and again it can be used.

So, here the landing facility is here. So, if the landing facility is not there then, what you need to do? So, you need to have some parachute and ultimately you make the satellite launch in the ocean that was; what was the procedure carried out earlier for the very early man machines. But the; with the use of this reusable launch vehicle so, those situations we are now added. So, here the space vehicle categories, we can put like Colombia Challenger. So, this were our reusable launch vehicle of reusable vehicle as you said, this is reusable vehicles not launch vehicles, because these are boarded on the heavy rockets, power full rockets and the loans.

Than we have the category of man satellites so, these are man revisable launch vehicle are man. And man satellites category we will have for military purpose for communication purpose, so for communication purpose, he now that the geostationary satellite are use. So, in this geostationary satellite, you have the earth here it is a around a radius we can write 6400 Kilometers, it is less than that the mean reduce, but let us write a 6400 Kilometers. And at an distance of from the central of are 42000 Kilometers, you have the geostationary satellites. So, on the geostationary satellites the transponder are there. The rate of; the angular rate geostationary satellites are seen as a angular rate of earth. And therefore, if a; your sitting here or if you have something to watch at this much of distance, you will see always over head this satellites.

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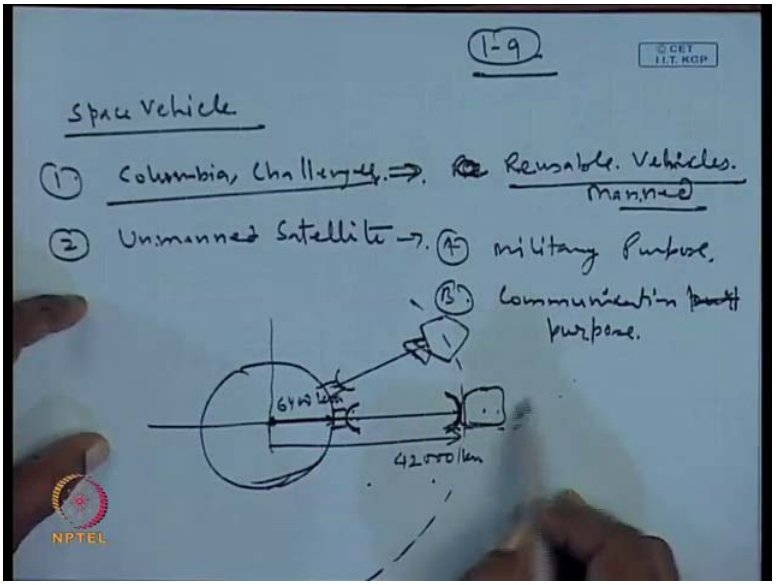

Because as he rotates from here to here, you also rotate from this place to place so, always it will be visible over head. So, this called geostationary satellites and this happens, because seen the reduce of 42000 Kilometer, at which it is a angular rate it same as a angular rate of the earth. So, this used for communication purpose your t v, so and other telephones see all these are based on this long distance telephonic. So, in this series you have the all the insat satellites the Indian national satellite. Than, we can see, you can trust it as remote sensing satellites so, in this series we of the I r s, Indian remote sensing satellite.

In other one, the third one we can raise as space stations and this serve as port in space, just like on the airport aircraft can halt. So, this space craft can go on halt on get on drop them self this to this space stations. And if it is having a; if your insat inside the satellite if it say astronauts there as; those are astronauts they can come out and go in to the space station and if there already laboratory is there on wards.

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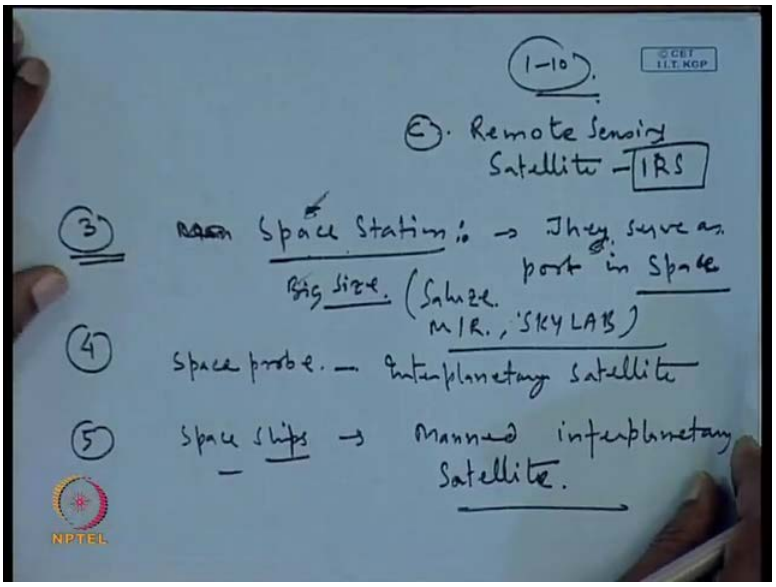

So for they can do some experiments here so, there are very big in size we have Sallusemeer skylark under this category. Then, we have a space Sporps this are inter planetary satellites, that is going from one planet to another planet. And the space ships and still it is a futuristic which will take man from one planet to other planet, man interplanetary. So, man has gone to the Nervering heavenly body which is the moon, but not to the; is still the mars is the way any other planet, moving to any other planet. It is a definitely going to get take a lot of time and you need all the preparation for that the risking the like a breathing all the things are involved in it.

So, if as a child ever if you have gone over the roof and you might have seen sometimes in the; during the dark night. The satellites may appear to move and they move very fast and the it is a; because of the solar panels are there and those solar panels once the sun light beams it. So, they become visible even during; so, it will they become visible this satellite becomes visible even if they are at so much of distance 300 Kilometers satellites. So, obviously here the satellites at 42000 Kilometers you cannot see, but the

lower altitude satellites sometimes we are visible in the sky. And obviously they move very with; very fast speed, the speed is around 7.5 Kilometers per second or more than that computed.

So, say around 8 Kilometer per second and this is very high speed. So, aircraft is speed is quite low, you know the aircraft speed, it can be up to the 700 Kilometers, 800 Kilometers like the going aircraft per hour. And you if you convert say 900 Kilometer so, we can convert it multiplying by pi by 18 so, 250 meter per second, it is a very small as compared to this 8 Kilometers per second. So, this satellite sometimes you can see it with your naked eyes. So, in this satellites, it is a very peculiar that we will have the satellites say this is the equator of the earth so, in this equatorial plane the geostationary satellites are placed.

Say I take a larger distance so, from here to here at the 42000 Kilometers I put a satellite here in this place. So, this is my satellite now, if this satellite is exactly in the equatorial plane of the earth, say this is the equatorial plane then it will you can and also the satellite is moving in a orbit of 42000 Kilometer and this is circular, this is nearly 42000 Kilometer, this is the circular orbit then, this satellite will always appear over head. And therefore, it can be used for communication, you may be on the equator here in this place another person may be on the equator here in this place, but directly you cannot communicate from here to here. But using this satellite by sending the signals from the; you can send the signal from this place to the satellite so, transponders are there. So, transponder will magnify the signal and sent it back to the earth.

So, this signal will be a available to you, somewhere your t v show is been transmitted from this place and your watching it over here in this place. So, therefore, the t v show which are been broadcasted from; telecasted from say India so, it can be observed worldwide. So, if you have multiple satellites, if directly say after some angle it want to be visible once, because this line is from here to here so, as it becomes tangent to the earth beyond that range you cannot go so, in this range you cannot go. So, either you can have another station which will receive this signal broadcast, telecast again or broadcast it to the another geostationary satellite. And from there again it can be received in the here in this place or either from this plates is itself, if it is receive to another satellite from there it can be sent to the surface of the earth.

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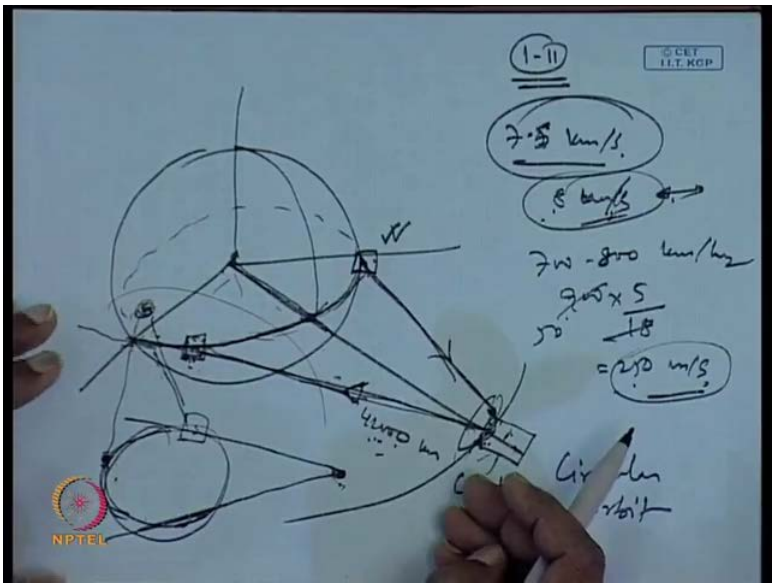

So, technology is then accordingly they will differ they these are all communication technology they come into the play. But before that our; the space engineers role it lies in the designing the space craft, those who are dealing with the electronic part. So, looking into the it is a dynamic of the aircraft so, again the attitude dynamics and study these things all these things in detail. So, you need to know the dynamics of this space craft very well, some body may come work in the area of the control, but without knowing the dynamics it will not be of any help. So, attitude dynamics it becomes an integral part of that. Therefore, we see that the technology it becomes complicated as we go for more and more applications.

So, we have the geostationary satellite and then we have the geosynchronous satellite, geosynchronous satellite are not exactly in the circular orbit, it is an elliptical orbit. So, if it is in a elliptical orbit it will sometimes appear if you are here in this place so, it will sometimes appear front of you sometimes it will appear back of you. So, it will be oscillating over your head and this happens, because this in a elliptical orbit and also there is a left north drift if this is not exactly in the equatorial plane if it is off the equatorial plane if it is making certain angle. The orbit of the satellite is making certain angle with orbit this equatorial plane then, the north south drift is also same. So, we stop at this place and we all this details will learn in the lectures later on so, thank you very much next time we will start with the particle kinematics and then we will progress learning into the space flight mechanics. Thank you very much.