In today’s lecture we will look at the development of aircraft engines using the piston cylinder concept of IC engines using various considerations of thermodynamics and various other mechanical engineering issues that needed to be all put together to make aircraft power plants. First we will deal with various issues that deal with are related to basic IC engines starting with thermodynamics that we did in the last class and we shall see how all these fundamental science is and certain amount of mechanical engineering is put together in making of engine that finally go on to fly the aircraft. The various thermodynamic issues that need to be considered much of it has been dealt with in the earlier lectures. The cycle considerations that need to be looked into and as we have discussed all engines and the engines that we are talking about are the heat engine need to be based on thermodynamic cycles and we will look at some of these thermodynamic cycle issues once again and then we will look into the various mechanical engineering issues that needs to be put together along with thermodynamic issues to create aircraft engines. The IC engines or the piston engines are more popularly called, are quite often the main source of power plant in aircraft for little thousands of aircraft over the last 100 years and even today little hundreds or thousands of aircrafts are still flying around with engines or aircraft power plant based on piston engines. These are the small aircraft which make , which are flown by small engines and we shall have a look at some of these engines today and how these engines are created and put together to fly the aircraft. We started with talking about cycles. Now we look at the cycles all over again. To see and that is where we start again from to build up our engines. Now we have a look at the concept of cycle both in P-V diagram as well as in T-S diagram and let us have a quick look at all over again. We have seen that if you have let us say two different cycles, ideal cycle and this moment let us consider simple ideal cycles. If u have two different cycles given by let us say 1234 and 12341 and then the other one which is 17891. If the two cycles are doing same amount of work from both cycle considerations we can write down that the work done by both of them may be same. But the work input in case of one cycle is more than that of other and the work output also is also different from the two cycles. The result is that the cycle 1234 actually has more work heat input and more heat output. However when you consider the efficiency, the efficiency of the cycle 12341 is actually is less than the efficiency of 17891. Now this comes from the efficiency definition that we have done in last class. If you look at the P-V diagram again, we look at the W done. Now we had seen that two legs of the cycle where the work is done. One is cause the work what we call the power stroke where work is extracted from the engine and the other is a compression stroke in which where the work is put inside of the engine and in this we can see here that the work has been put in and work has been taken out from both the cycles. In terms of the basic considerations that we had seen that the two cycles supposed to do same work. So for both the cases Q1- Q2 is actually equal to W1- W2 so that the net work done is equal to the net heat that is gone into the system and that is same for both the cycles. However as we had just seen that the efficiency of the one of the cycles that is 17891, is actually more than the efficiency of the cycle 12341. Now this brings us to the point that if we have two cycles with same work output but the efficiency of one could be better than the other one. That means the efficiency translated to fuel efficiency. It would mean that the one cycle actually consume less fuel than the other one doing same amount of work. That is obviously a very attractive thing for any engine maker. Now if we look at schematic of the piston that we have here and we have discussed this in the last class. Let us look at this again quickly. We have this piston stroke and during which you would need to perform the work. So when the piston is moving in, it is actually doing the compression work and when it is forced out, that is the power stroke. Now what happens is if you have to do more work out of this piston, you would need to change the volume of this and we will come to the actual formulae in few minutes. The point is that if you have to create more efficiency of one cycle, you would need to create more compression ratio as we have seen in last lecture. The thermal efficiency is directly depend on compression ratio and which means that one of them has a higher pressure ratio than other, which means the process ‘17’ actually executing a higher compression ratio than the process ‘12’ and that is the source of the higher efficiency. Now to create higher compression ratio this piston has to move more, that means the length of the stroke would have to be more. And this would require the piston to be of large size. So if you want more compression ratio, more efficiency which translates to more fuel efficiency and fuel conservation, you would need to probably have a piston which has a longer stroke length. Now this is something which comes out of the basic consideration of thermodynamics as seen from simple ideal cycle analysis. Now this means that you would require a piston which is of larger size or longer in length to obtain higher efficiency. Now this is a bit of a problem in aircraft that if you are looking at anything that has to go on a flying aircraft, the size and weight are restrained and they are premium, because anything you carry in aircraft would have to be compensated by creating more thrust. So large size and higher weight are something that has severely restricted whenever an engine has been considered for aircraft. This is one of the reasons why for example, aircraft do not use diesel engine which as you know are higher in weight because of the fact that they operate under higher compression ratio. And those compression ratios do give the diesel engine the higher efficiency. So conclusion from the earlier slide that you can go for higher compression ratio if we move towards diesel engine, it could become unacceptable to aircraft designers because the diesel engines are typically heavier and would not be carried in an aircraft in efficient manner taken the aircraft as a whole. So even the engine is more efficient the aircraft as a whole would become an inefficient device. So that is one of the considerations. The other is of course the size limitation. If you have larger piston sizes, the size of the whole engine would tend to go up as we have seen before and we shall see again today. The total size of whole the cylinders put together make up the whole engine which means that there is a restriction on the total number of cylinder that you can put, total sizes of the cylinder that can go on an aircraft. Finally whatever goes on an aircraft has to meet on the aircraft shape. The shape of the aircraft is important to make air worthy. And as result of which there is a restriction in the size of the piston length and the cylinder volume that can go on an aircraft. Such limitation normally not there land based vehicles. So land based vehicles quite often can go on for higher efficiency using a heavier or larger engines. So as a result of these restrictions the work done per cylinder in a piston engine that goes on an aircraft tends to get limited. And this limitation is what aircraft engine designers have to live with. Now as a result of the fact that to make an aircraft fly you need certain aggregate amount of power and to use this aggregate amount of power you need to then put together a number of cylinders. So the aggregate amount of power is quite sufficient to meet the requirements of aircraft thrust. So the power of reciprocating engine as we know is proportional to the volume of the combined pistons and quite often many of the IC engines or piston engines you may have heard often is you know referred to or cited as so much of volume and that is because of the volume does represent the work as it is of the particular engine. The other thing that required in an aircraft is a light weight. Anything that goes on an aircraft has to be as light as possible. As a result of which many of the piston engines very quickly started getting made of aluminium alloys which were developed specifically for aircraft grade. So the aircraft grade aluminium alloys were developed of which the aircraft engines were made which are quite often not used in the land based vehicles. So both in terms of the way the engines are designed and created and then way they are made needed to be developed differently for aircraft engines. This is something which happened probably more than forty or fifty or sixty years back. And as a result of which most of aircraft engines today much lighter and much smaller than corresponding engines that used in land based vehicles. Let us take a quick look at some of arrangements that are quite often done in various kinds of aircraft engines which often tend to be multi cylinder engines. And as we seen multi cylinder is often arrived as by putting together total amount of work that is necessary to drive the propeller which of course creates the thrust that flies the aircraft. Now as we have seen the number cylinder arrangements, let us quickly look at this again. You can have cylinder lined up one after another what is known as inline version one after another. The other version is you can put two cylinders in V formation and then you can have a V in line. So you can have two by two cylinders lined up or you could have X type where four cylinders are around one central crank shaft. Then you can have four in line which means you can have multiples of four or eight, just like you have multiples of two, four, six, eight etc. However there are options where you can have four cylinders in this fashion which is often referred to as H type so as four cylinders are arranged in oppose fashion and not in X type. Ok. And the other possibilities, if you have odd number of cylinders depending on as I mentioned earlier the aggregate amount of power that is required finally to drive the propeller, if you land up with a number that is five, or for example seven, or nine and if the aircraft shape accommodates it quite often one of the arrangements, is referred to as radial arrangement where you have five or seven or even up to nine cylinders arranged radially around the central crank shaft. So all these pistons supply power to central crank shaft. Except now in this case as you can see now here you would need large diameter to accommodate all these engine. Ok. So the point here is that each of these as you can see have different kind of final shape. This would have one kind of shape. This would need another kind of shape. This has a different kind of shape. And this of course has a different kind of shape, the outer shape. I am now talking about right now outer shape, within which all these cylinders are arranged. Because this outer shape has to conform to aircraft body inside which this engine is going to be housed. So the final arrangement is quite often decided by 2 considerations. One is aggregate amount of power that is required to drive the propeller which finally flies the aircraft. The other consideration is the shape of the aircraft in which this arrangement is going to go inside, whether it can accommodate this arrangement, is the other consideration. So these two put together finally create the aircraft engine which goes inside the aircraft.

As we have seen in the earlier one, each of these pistons actually operates under particular thermodynamic cycle. Thermodynamic cycle is the basis of each of these pistons actually working. However what happens is that, since they are all supplying power to the same central crank shaft, it becomes necessary to supply power to the crank shaft almost on a continuous basis and to do that the mechanical engineering requires that the power supplies stroke or what we call the power stroke needs to be time standard. So each of these cylinders are now operating in such a manner that the power stroke of those cylinders do not occur simultaneously. They are time standard. Let us quickly go back to the earlier one. If u can see here, for example this diagram the cylinders as you can see here are at different positions. Ok. And you know, these two are more or less at same position and these two are more or less at same position. So the power stroke of these two are probably timed together where as the power stroke of these two cylinders are probably timed together. So where as in X type you can see each of them has a different stroking arrangement. So the stokes are essentially staggered inclined so that the supply to the central crank shaft occurs in a timed staggered manner, so that almost at every split second there is a power stroke being supplied to the main crank shaft. Now this is a mechanical arrangement which needs to be created. Even if you have a multi cylinder arrangement, especially most of the aircraft engines do have multi cylinder arrangement, even though each and every of these cylinders actually operating under same thermodynamic cycle. Let us take a look at now how the piston engines actually create power in terms of actual operation. We have seen how they can be put together in terms of thermodynamic considerations. Now we can look at from pure mechanical considerations. The power created or power stroke is directly proportional to the average pressure that is applied on this piston by the length of the piston stoke. Ok. And the area. Ok. And that into n by 2, n is of course the rpm and n by two is the power supplied per minute. So these parameters put together LP × A is that of course the volume through which the piston is displaces. So that is the displacement volume of the piston. As I mentioned earlier it is often referred to as one of the specifications of every engine. And that multiplied by the pressure so that of course gives you the force and that into the rotation gives you the power per unit time. Now this of course tells you that if you have a longer piston stroke, you get more power, if you have bigger area of the piston, you get more power. If you have a higher mean effective pressure, you can get more power, or if you can afford to or if you are in a position to run the engine at higher rpm you can get more power. Now let us you look at these parameters quickly again. We have just seen that in an aircraft engine, there are size restrictions, there are weight restrictions. So you cannot have a large piston stroke, you cannot have a large piston. You cannot have a large piston area because of size restrictions. So those two get automatically restricted by their requirement of aircraft, they have to be restricted. The pressure gets a little restricted because of the fact that if you have a very high pressure, this piston would have to be built with very heavy material. That what is normally done, for example in a diesel engine which is made for very thick material to withstand the very high pressure normally created in a diesel engine. So the pressure has some restriction. Otherwise the whole piston cylinder would have to build like a pressure vessel. So all these restrictions put together the aircraft engine need to be created or designed. The fourth possibility we have here is the rpm. So most of the aircraft engines do operate at some high rpm so that the power created is of reasonable amount and sufficient to drive the propeller that crates the thrust. As a result the power stroke that is created would have to be very fast. So this is the aircraft engine requirement that you cannot have high length of the piston stroke, you cannot have large area, those are restricted. You cannot have very high pressure because of the limitation on the weight. But you can go for a somewhat higher rpm and as a result most of aircraft engine do operate at somewhat higher rpm than many of the land based engines. And hence we can say the ideal work that is done by an engine and this IHP is something which can also configure from PV diagram or which is often sometime referred in many books as integrated diagram which comes from thermodynamic cycle diagram or pressure volume diagram. You can get the amount of work from that diagram and that would have to be equal to the work done as we have written above and this is now expressed in terms of the volume and this is the volume of the cylinder and as I mentioned quite often cylinder volume is mentioned in the specification of the engine as a indicator of its work done and NC is the number of cylinders. That tells you what is the total amount of work that would be required to be done for the whole aircraft. Not by one cylinder, but for the whole aircraft. So when you put whole of together you will get the total work requirement for the whole aircraft to drive let us say propeller. Now the question here is, let us go back to the pressure which I have written here as mean effective pressure or MEP. Now this mean effective pressure is quite often you know, is the average pressure which is operative on this piston during piston stroke and as a result of which we have what is called and the pressure is actually changing from TDC to BDC as the piston is moving. So the mean effective pressure is defined, it is not one single pressure, it is the mean effective pressure between this point and this point during the traverse of the piston and this is often defined as mean effective pressure or MEP. To facilitate certain amount of computation of power, the prediction of power that can be made from various prior calculations. Now we shall define mean effective pressure later on in next lecture in various ways which can be connected to the IHP or what we call BHP and as a result we could have two mean effective pressures, indicated mean effective pressure or break mean effective pressure. So they are two slight different variants of mean effective pressure and we shall define them appropriately in next class. So for a piston engine the increase in mass flow then either you have more no of cylinder or you have higher rpm so that mass flow per unit time is very fast so the cylinder is filled up and exhausted in very quick succession. As a result of which you get more power. Or you do both. That means you have higher rpm and then you have higher size, now size is restricted. So some of these things would have to be optimised for every engine that you need to configure. Now suppose you have an increase rpm to crate large mass per unit time. This will mean that the piston will be moving up and down the length of the cylinder more frequently and as a result of which it will actually encounter more of sliding friction, as a result of which there will be frictional losses which we shall be talking about a little. And as a result of which there will be a loss of efficiency. That is a mechanical loss. Not thermodynamic item really. But all that has to be considered once you consider how the aircraft engine works. So there are thermodynamic issues, there are mechanical engineering issues. And all of them put together make for an aircraft engine and we shall look into them one by one as we go along. Let us quickly look at some of the thermodynamic issues all over again. We have the real cycle which we had look in the last class and we see here that the actual work involves the number of things we have the heat input here and then the work output here. Now what happens during the heat input is, it is entirely possible that the process of combustion as we are looking at is not complete combustion. And a result of which during the process, you know 3 to 4 the combustion of fuel is actually incomplete. And as a result of which it does not reach at the top value. This is what we are seeing in a real cycle. Apart from the incomplete combustion, the combustion within the piston engine. If you have a look at the volume that is created here at the end of TDC, this is the volume in which the combustion is to be performed, combustion is to be done. It is entirely possible that when the combustion is initiated, it is not uniform along this volume, it is not uniform around the cross section of the piston head. So this non uniformity also again leads to certain amount of work done which is less than the ideal amount of work considered. Then we look at the fact that the piston is moving. The movement of the piston of course entails as I said. The mechanical friction loss between piston and cylinder body and as a result of which it happens twice. Once during the power stroke and once during the compression stroke. So the friction losses would have to be brought into reckoning while considering the real efficiency of engine. Then larger the engine size, that is length and diameter, more is the surface of the friction loss. And as a result, higher are the losses. Larger the cylinder size more are the heat losses through cylinder surfaces. So those are the other losses coming into the picture now. Now the cycle efficiency as we have seen is directly influenced by compression ratio, the pressure ratio and the temperature ratio. Now more the compression ratio, or pressure ratio, we have seen the cylinder would need to be built of heavier material. These things as I have mentioned are prohibited. So if you want to overcome some of the incomplete combustion by building heavier engine, you really can’t do that. Because aircraft requirements put some prohibitions on such increases. Now the other issue that often occurs in aircraft is that quite often an aircraft as you know, it has to fly which means that it has to take off, it has to climb, it goes through cruise operation and it has to come back and land. So during the entire process of operations the engine has to continuously operate at various operating condition. And as a result of which it has to create more power or less power during all these operations. Now as a result of that the power input to the propeller from the main shaft is finally the consideration and that is referred to as the brake horse power. That power finally supplied to the propeller. Now this work done and heat transaction of the engine has to be controlled and it has to be changed with the operation of the aircraft and it can be changed with fuel flow into the cylinder. Now that is the primary control of the engine. The fuel flow and the fuel control provide the engine control primararly. Now what we can see from here from the thermodynamic cycle diagram, version of the real cycle that we have seen before in the P-V diagram, that if you have the fuel supply that is reduced, the work done will be reduced. So that reduced work done and quite often aircraft could do with the reduced power, especially when it is cruising. On the other hand you may need to have more power when the aircraft is climbing. So it has to climb from low altitude to high altitude and you would have to pump more fuel into the cylinder and you would need to get more power. So as a result of which the piston has to operate differential or different kinds of fuel flow. Now the fuel flow that is considered depending on the property of fuel, most correct is often referred to as a stoichiometric ratio and that is the most correct fuel air ratio that needs to be supplied to the engine. It depends on the fuel and every fuel depending on the chemical composition as identifies stoichiometric fuel air ratio. Quite often around this ratio there is a safe fuel air ratio zone that can be identified and the aircraft has to operate within this fuel air ratio zone. That is the reduction or increase of fuel air ratio has to stay within this safe zone, so that the engine continues to operate. If you go outside the zone, the engine could actually get blown out that means the compression process would get blown off and engine would get stop operating. Hence it is necessary that you stay within this fuel air ratio all the time during the entire operation. So now when we talk about entire operation which is said that the entire operation means it has to aid the aircraft to fly, it has to take off, it has to cruise, it has to climb and during the world war 1 and 2 many of the aircrafts are actually have been used for military purposes which mean they have to do all manoeuvre and during the entire all this manoeuvre and finally landing of course the engine has be supplied the fuel in a controlled manner within the stoichiometric ratio defined by the chemical property of the fuel. If you can do that then the engine is in a position to continuously supply power to the aircraft during the entire flight spectrum. Now to do that it is necessary that you supply power within the stoichiometric ratio, which means the engine would be operating under the lean air fuel ratio or rich fuel air ratio. If it is too lean, it would have a lean blow out, if it too rich it would have a rich blow out. So that is the danger which we are talking about and you will have no work done out of this cycle. Now quite often the way the engine is designed and put on an aircraft during its entire cruise operates at lean air fuel ratio. During which as you can see the fuel consumption would be less which is good that the amount of fuel carried in an aircraft would carried further. So the engine is to be designed such that during the cruise it would always operate under lean fuel air ratio. Now this means that the actual working cycle changes with fuel air ratio. Each fuel air ratio then actually produces one real cycle. And as a result of which one can say that every engine during its entire fight spectrum is operating essentially in a variable cycle manner. That means the cycle of the engine is actually changing depending on the fuel air ratio and the work done capability. And hence it is effectively becomes variable cycle engine. Effectively all engine that are operating on an aircraft and goes through the entire spectrum of flight operates on essentially variable cycle mode. Of course there are terms like variable engine cycle engines which have now many people are trying to develop that means something quite different from what we are talking about. What we are talking about is a normal engine put on an aircraft and during its entire process of flying actually undergoes variable cycle operations. So this is what we mean at this moment that every engine operates on variable engine mode. Let us look at the efficiency that we have talked about, the finally engine has to fly the aircraft and it has to actually power a propeller. The power developed supplied to the propeller creates the propeller the thrust power. This thrust power is actually required by the aircraft what the engine supplies is the engine shaft brake horse power. This is referred to as BHP. And this is available at the end of the shaft. Quite often the shaft operates through a gear box. So there is a certain amount of loss of power in the gear box, and what is supplied to the propeller is BHP. What is created by the engine is IHP. So the ratio of those two is essentially referred to as the mechanical efficiency of the engine which is as you have seen is different from earlier considered, the thermal efficiency of the engine, which is born out of thermodynamic considerations. This is the mechanical efficiency of the engine. But BHP is what the propeller gets. And then propeller creates thrust. So that thrust if you consider into thrust power the ratio of the two actually gives the propeller efficiency. So we have three efficiencies now. One we have referred to as thermodynamic thermal efficiency. Now there is a mechanical efficiency of transmission of power from the engine to the propeller and finally the propeller efficiency by which the propeller creates thrust. So at the end of whole thrust creation it has to negotiate through three different efficiencies and it is necessary for the aircraft power plant designers to keep in mind that all the three efficiencies need to be as high as possible to get maximum utilisation of power that is create by the engine. Now if you look at, let us say all over again, the typical piston cylinder arrangement. As we have seen here quickly, the cylinder, you know, this is the volume of the cylinder which we are talking about and the cylinder is often typified or specified by the volume. And let us say that we have, let us say 6 different equal volumes of the cylinder. You could have cylinders made of any of these number of volumes put together. So more the volume, more is the work capacity of the cylinder as we have seen before. This is what the initial engine mechanical designers will have to decide what should be the volume of cylinder which creates work. And as a result of which within which the movement of the piston will have to be restricted. So the movement of the piston is restricted within this and the volume of the cylinder or more specifically the volume of the displacement of the piston is what is to be considered in creating the engine. So one could have the volume that is most appropriate or most optimised for a particular kind of aircraft on which those cylinders would have to be arranged and put together to create an aggregate amount of power. Now let us look at an arrangement of cylinders. Let us take four cylinders, the kind of thermodynamic arrangement we have, we have 4 stroke engine. So let us say that we have 4 cylinders. And let us look at 4 strokes that it has to undergo. Now it is entirely possible that if you have 4 cylinder arrangement, each of these cylinders could be operating in a time standard manner that I mentioned earlier. Let us say the first cylinder could be undergoing an air intake stroke. The second cylinder at the same instant could be undergoing compression stroke. The third cylinder could be undergoing power stroke. And the fourth cylinder could be undergoing exhaust stroke. So the time stagger that I was talking about is shown here in this diagram that if you have a cylinder arrangement in line or oppose to or X type, whatever you could have them staggered in a manner in such a way that 4 stroke that the engines typically undergo can be operated simultaneously through these four cylinders and each of them supplying power to central crank shaft. This is the kind of radial engine that often powers the small aircraft. Now this is the kind of shape that typically a radial engine would have to be housed inside. You would have circular front body of the aircraft within which the radial engine would be housed inside and it would of course drive the propeller. So the shape of the aircraft then comes into the picture and we need to know what would be the shape of the front part of the aircraft within which the engine would go. And the other consideration that we have mentioned is the aggregate power that is required by the aircraft for flying its passenger or whatever other material that we wants to fly. So the shape of the front body of the aircraft is what accommodates this radial kind of engine. This is an engine which is nowadays being considered all over again. I mentioned earlier that this engine was completely ruled out for aircraft usages. However very recently some people have started looking at the diesel engine, simply because of the thermodynamic consideration that we are talking about that diesel engine has more efficiency, thermal efficiency and that is something which has triggered recent research in which people have tried to design diesel engine that is light, made of light alloys and uses normal aircraft variety of gasoline and it can be used to power the propeller. This is the kind of engine that people are now trying to develop to make use of fundamental thermodynamic consideration that diesel engine are more efficient because of high compression ratio. This is a design of 4 cylinder opposed IC engine which shows the internal parts of the 4 cylinder IC engine and it powers one single crank shaft and powers the propellers. So this shows all the details of, cut out of typical 4 cylinder opposed IC engine. This is a 4 bladed propeller you can see here that the shape of the aircraft again has detected the kind of engine it should use. One can make a guess that the engine used here is the opposed type multi cylinder oppose type, probably 3 into 3. That is 6 cylinders in oppose formation housed inside this fore body of the aircraft powering four bladed propeller. This is a very famous splitfire military aircraft used during the second world war and it is a four bladed propeller. It has an engine here, which is a big engine probably 8 or 12 cylinders and this particular splitfire military aircraft use the piston probe .and as I mentioned, military aircraft need to have all kinds of manoeuvring capabilities and as a result of which many of these configured to have very good combination of aircraft and engine to aid the aircraft manoeuvre. Some of these need to be considered during the choice of the engine or design of the engine itself so that they provide the continuous power during various manoeuvres’ of aircraft. This is very important for aircraft operations.

Once the amount of engine power required goes up, we have seen that we could have 6 cylinders, you could have 8 cylinders, you could have 10 cylinders and you could have 12 cylinders and you could have 9 cylinders and you have 9 into 2, 18 cylinders. So there are engines, piston probe engine where up to 18 cylinders have been put together to power an aircraft. However if the aggregate power becomes more, it becomes more and more difficult to put together more of these cylinders in which case one has to look for the some other solution which is not probably piston based. You need more power you need to have engine that supplies the power. An aircraft engine may not be the piston engine, may not be the best aircraft engine in such circumstances. These are the situations in which you then start looking for other alternative, and that is where the jet engine came in. After the second world war the requirement of power for the aircraft to fly faster, for the aircraft to fly higher and the aircraft to become bigger to carry more passengers or more material or more cargo required more power. And the bigger engines had not to be in the form of piston engines, they had to be in the form of gas turbine engines. And these gas turbine based engines are what finally created today what we called turboprobs. That means the propeller remain the thrust making devise. But the engine that finally came to here not the propeller not the piston engines, but the gas turbine engines. So the amount of aggregate power that an aircraft needs decides to what extend or what level that you can arrange the piston engines and how many cylinders you can put together. And the at the end of the day if the amount of aggregate power required is more, then you have to go outside the piston engine requirement, and if you look for other kind. So what is shown here is turboprob engine where supplier is a gas turbine engine. But the thrust still the propeller. However we will continue to look at various kinds of piston engines and performances of piston engine in the next class and we shall see how the piston engine performances can be estimated and we shall see the various kinds of ways by which the aircraft engineers have devised methods by which the piston based engines continue to give good efficiency and good power supply during its flight. Much of the flight often happens at high altitude and we shall see how aircraft engines are configured to create power at high altitude where the air is thin, the density of the air is thin, but the piston engine continues to give good efficiency and good power supply. And we shall look into some of these aspects of engine design in the next class in which we shall consider the performance of piston engines as used in aircrafts.