Introduction to Flight
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Lecture 09.1
Gliding Flight

So welcome to lecture number 13 which is the first lecture of capsule number 7 after the mid-sem. Today we are looking at three components of a flight; gliding, climbing and ceiling okay, so again this presentation has been prepared by this student called Udit Vohra, we are already familiar with him because if you recall he was the one who made the presentation on the atmosphere also. This is the second presentation that he prepared for me while he was here as an intern during this summer okay.

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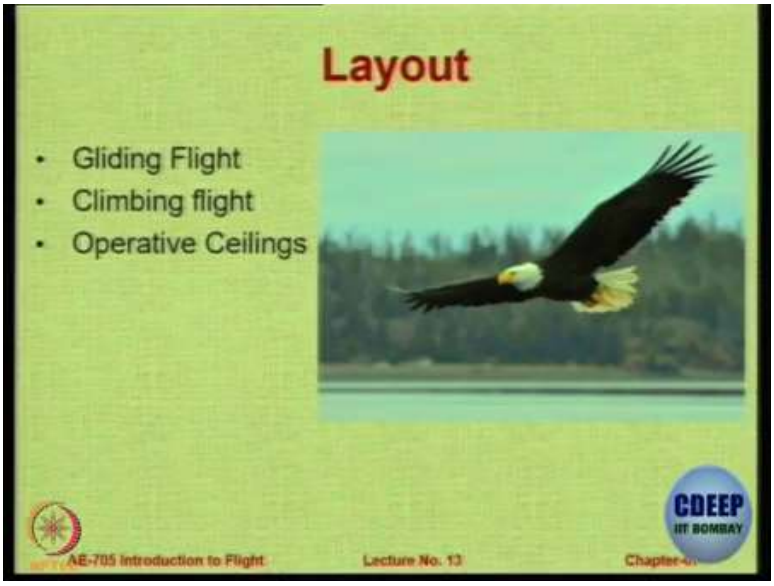

So the layout is very straightforward, we are going to look at some birds. We are going to look at how they glide, then how they climb and what are limits to their altitude of employment or the operative ceilings that is all, the three things today okay.

Let us see the gliding flight, this is how aircraft glide okay, right okay. So what exactly is a gliding flight?

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Not hitting somebody with a thermocol plane, that is not a gliding flight.

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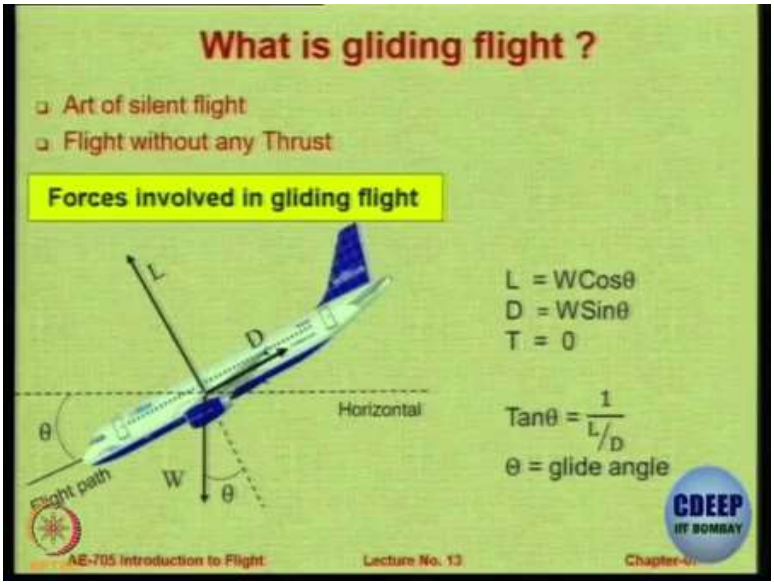

Gliding flight is basically the art of silent flight or flight without any thrust. In the history of aviation I have spoken a lot about Otto Lilienthal and so many other people, they were the ones who perfected the aerodynamics of flight by learning how to glide and it was only later on that sustained flights were possible because of the provision of power plant on the aircraft.

But if you really want to enjoy flight and if you want to test your skill or airmanship as we say then gliding flight is the most challenging and exciting thing okay, so even though glide is a very silent flight still we have forces acting on the aircraft in the glide and this is a dramatical representation, so we do not glide like this okay, this is a very large angle but just to increase the visibility, we have an aircraft which is operating at an angle with the horizontal.

Its mass X downwards towards the center of the earth and from the flight path perpendicular would be the lift force. The drag force would be along the flight path opposing the flight and the angle between the path at which it operates or glides in this case with the horizontal is the flight path angle or in this case the sink angle or the gliding angle θ, not sink angle that is a wrong thing it is gliding angle θ, okay. So if you resolve the forces on an aircraft during glide we can see that there is the lift component will be $W\ cos\theta$ and then drag $W\ sin\theta$ T will be zero.

So straightaway we get $tan\theta = \frac{1}{L/D}$ okay, I have not said D/L because we are interested in L/D as a parameter you could always say Tan theta is equal to D/L where θ is a gliding angle. So

obviously, if you want to have a low $tan\theta$ which means if you want to have a lower glide path angle, you would like to have higher L/D. So L/D is directly controlling the angle during the glide. So hence aircraft with higher L/D will be in general gliding at a lower angle theta compared to aircraft with the lower L/D okay.

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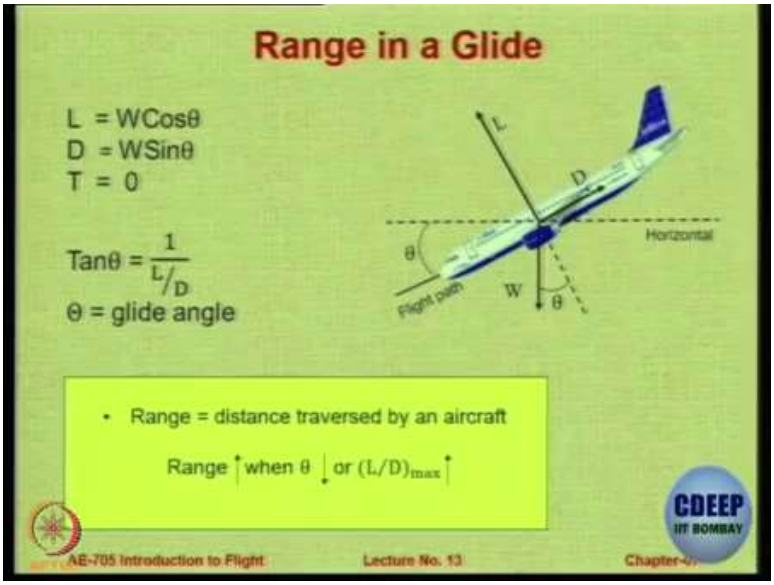

So when you glide, you actually cover some horizontal distance in glide, from the point where you start to the point where you hit the ground the horizontal distance on the ground is called as the range in a glide and the range is going to increase when either the theta reduces or when the L/D max increases. In other words, if you are gliding at conditions such that L/D is $(L/D)_{max}$, you will get the least angle of theta and longest range during glide, okay. So that is now how do you know at what angle I should fly? At what angle of attack I should fly, so that L/D is $(L/D)_{max}$? For a pilot is very difficult to know, so the pilot determines this only by speed and also by flight experience or flying experience.

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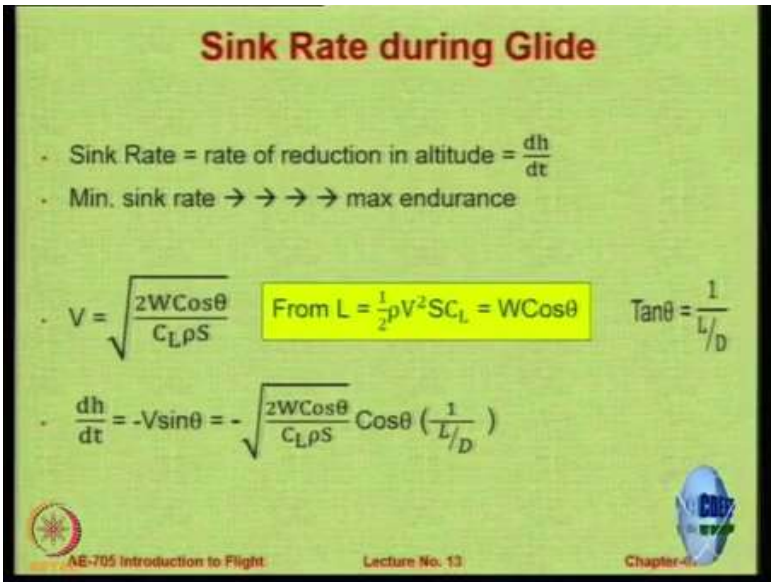

Another important point is after your glide starts, how much time can you stay in the air? That is called as the sink rate or the rate at which you lose the altitude $\frac{dh}{dt}$, sink rate. So it is very obvious that if your sink rate is low you may travel distance less or more we do not care but you will be in the air for maximum time after your glide starts. So it is not necessary that the distance traveled will be the largest when you are operating at the minimum sink rate. The distance travelled is the function of only L/D and the angle and glide angle theta but the sink rate during glide is a function of dh by dt, so we will see, we will derive the expression.

So from the previous figure you know where we had $L = \frac{1}{2}\rho V^2 S C_L$ okay and $W\ cos\theta$ not equal to W but $W\ cos\theta$ it is equal to W when you have θ equal to zero or when you are in level flight and we also know that Tan theta is equal to 1 by L by D, so that means Sin theta upon Cos theta is equal to $\frac{1}{L/D}$ so $cos\theta$ will be you can replace it. Now $\frac{dh}{dt}$ as you can see from the previous figure is actually the sink rate $Vsin\theta$. So I take $sin\theta = cos\theta * \frac{1}{L/D}$ put it inside. Now you can push this $cos\theta$ inside, it will become $cos^3\theta$ and there is L/D, so L contain C_L. You can replace L/D, by C_L by CD, so you will get ${C_L}^3$ also inside.

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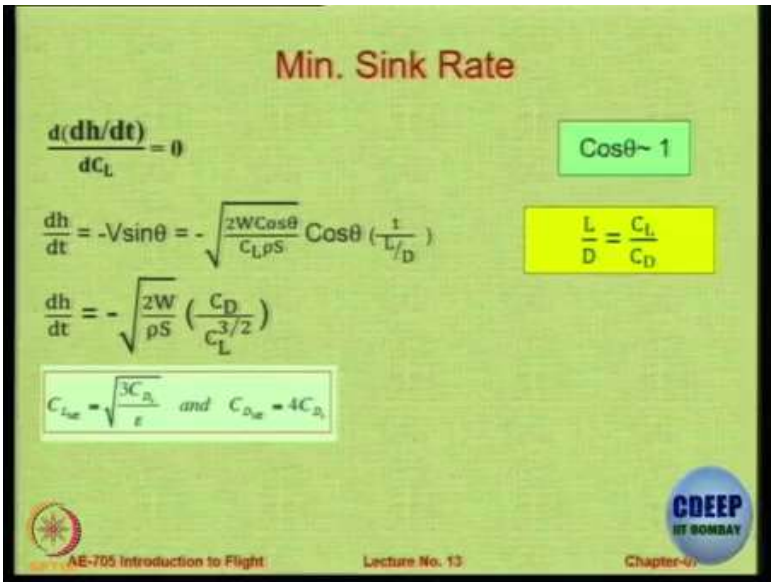

But suppose for example, a situation where theta is very small, which is normally the case in the case of gliding okay, so now we want to find the condition at which what should be the C_L and hence what should be the V? Because the V and C_L are connected to each other, what should be the C_L at which I get the maximum sink rate? And I am assuming that $cos\theta$ is almost equal to 1. So therefore this expression will now become $-\sqrt{\frac{2W}{\rho S}}\left(\frac{C_D}{C_L^{\frac{3}{2}}}\right)$.

So $\frac{dh}{dt} = -\sqrt{\frac{2W}{\rho S}}\left(\frac{C_D}{C_L^{\frac{3}{2}}}\right)$, this is a familiar ratio. We had this ratio also for the minimum power required in flight. So hence it is interesting that you can get the condition at which the sink rate will be minimum, so the range in the glide is maximum when you fly at by $\left({}^{C_L}/_{C_D}\right)_{max}$, the endurance or the sink. Endurance is maximum or the sink rate is minimum when you fly at the condition at which $\left(\frac{C_L^{\frac{3}{2}}}{C_D}\right)$ is maximum because that maximum will give you the lowest $\frac{dh}{dt}$. So the conditions are not the same as I mentioned a few minutes ago okay, and you can derive this expression by going further into it, you can get this expression.

So the ${}^{L}/_{D}$ for maximum endurance will be approximately 0.866 times $\left({}^{L}/_{D}\right)_{max}$ okay, so you do not fly at $\left({}^{L}/_{D}\right)_{max}$ but you fly at around 86 percent of the max of ${}^{L}/_{D}$.

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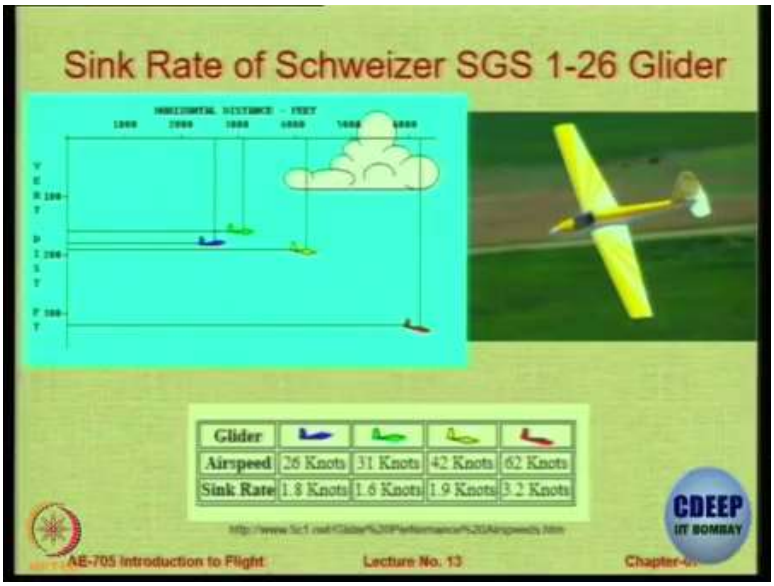

Okay, now just to get some idea about sink rate and how it changes I have taken one of the most successful gliders in the world called it the Schweizer SGS 1-26 it is an old version, there is a new version called as 1-36, this aircraft went out of production many years ago, there is a better version available, but this is one of the world's most famous and popular gliders. Now let us see, how does the sink rate of these gliders change for various conditions? So the same glider I have shown under four conditions or what are these conditions?

Basically these conditions are the speeds at which you fly, remember for the pilot there is nothing like what is $\left({C_L}/{C_D}\right)_{max}$? What is $\left(\frac{C_L^{\frac{3}{2}}}{C_D}\right)$ maximum? These ratios are only for us, those who do analysis or performance calculations or those who design, for the pilot everything is speed. So the pilot relates speed to ${L}/{D}$, so the pilot is told that if you want to glide maximum distance, glide at this particular speed. If you want to be in the air for maximum time, glide at this particular speed then your sink rate will be the minimum.

So you can see the sink rate can be between 1.8 knots to 3.2 knots. Now “knots” is a standard speed unit for aviation. Those of you do not understand knots or do not appreciate knots just multiply it by almost 1.853 or let us say by 2 to get kilometers per hour so we will get an idea ,oh oh sorry! meter per seconds ok so it will give you an idea just multiply by almost 2 to get in meter per second, that is what probably you are more familiar with. So the air speed you can see the four colors shown there also correspond to how much distance is covered in the glide. So when the

aircraft is gliding, it can cover around 6000 feet. All of them began from the same altitude but they hit the ground at different distances depending on the speed at which they are traveling okay, right.

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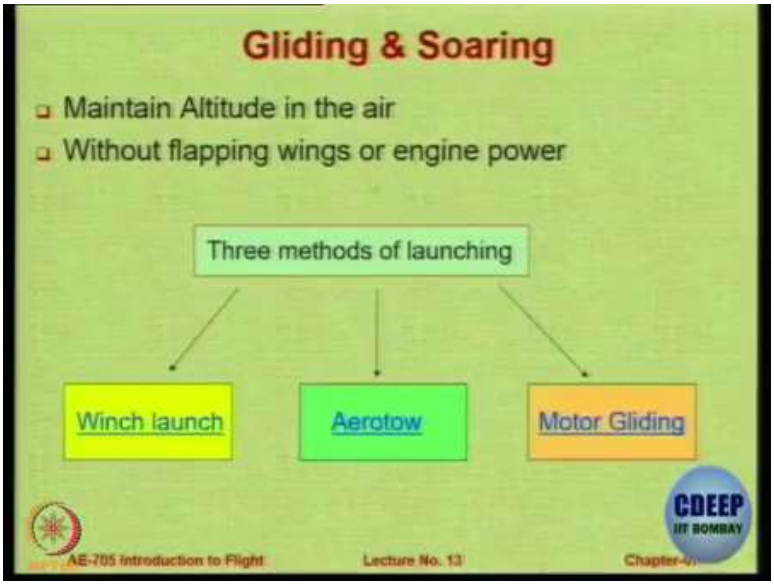

So while we are at this particular point I wanted to just share some excitement with you about gliding and soaring. So can someone tell me the difference between these two terms as far as the aviation is concerned, what is meant by gliding and what is meant by soaring? What do you think? Anyone? The mikes are all around here, so I will give you one example, the birds are soaring and the aircrafts are gliding, in general okay. Aircraft normally do not soar, they only glide but birds are the ones that are champions in soaring. So now do you get? Yes, what is your, What is your view? Yes.

Student: Sir my name is Atharva, I think soaring means using ambient air

Professor: Yeah, okay, that is very much close and is correct actually. Essentially anybody wants to add to this, soaring and gliding? Pretty much, pretty much true what he said but one can elaborate it a little bit more. So in gliding you are only sinking down continuously, you can minimize the sink rate or you can maximize the range, okay but you are always coming down. It is a continuous downward spiral. But soaring is something where you can even go up or you can maintain the altitude for a very long time.

So that you cannot do unless you have a power plant, but power plants cannot be there in gliders. So then we use ambient wind. So if you are able to maintain your altitude in air in a power off

situation for a very long time, mainly using the thermals as you said or upward drafts of air, then you are soaring okay, but you should do this without any power neither flapping of birds when they soar, eagles when they soar they do not flap their wings, they are not using the propulsive power to keep up, they are basically looking at the currents. So sometimes they glide and then they soar and then they glide and then they soar okay.

So we tried to emulate them in the gliders but we also have a category of aircraft called as Sail planes, we have gliders and we have sail planes. So what do you think there is a difference between a glider and a sail plane? What is a glider and what is a sail plane? A sail plane is a very advanced glider, a very efficient glider is called as a sail plane because sail planes are designed essentially for soaring and gliders are designed basically for gliding okay. But each can do the other thing also subject to the flying skills. Now since there is no power plant available or since there is no means of thrust then there are three ways of launching or three ways of operating a glider or a sail plane. The first way is called as Winch launch, this is the most common one and let us have a look at what is meant by winch launch.

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Hey this is Bruno, I am excited to share with you what we have been working on over a last year. We have spent literally hundreds of man and hours refurbishing this all the glider winch and now we are winching out of and if you are from Europe or UK if you are from the US check this out, this is going to blow your mind.

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Some of you who are not very much, you will see very beautiful views here and some people had difficulty, now I can pull up. Do you think the cable is still attached or it is released? Still attached, you cannot see it right now, it is in the nose

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So still attached because the Winch is at the end of the runway. I was not exaggerating when I said I was stinking amazing this is, here the glider is climbing faster than an airliner taking off. We have about 8000 feet of rope on the drum right now we can do as much as 11,000 feet and with that we can get many thousands of feet in the air above the airport with just a single launch. At this point of the launch we are now getting towards the top. So the glider starts to roll forward to get ready to release the road. Now the glider is almost vertical. You can see you can actually hear it. Now we are free so we just quick push the nose down. So that way we can maintain airspeed and I am going to raise the main gear which you can see underneath us, goes right there.

Now we are free to soar with the birds and fly for many hours. We are thousands of feet above the airport with plenty of altitude to go find a thermal and enjoy the day. Hey, thanks for joining us and hope you enjoyed this video.

So now this is a simple question, there is a winch which is pulling the aircraft, when the rope becomes almost vertical, the rope is released and now the glider is free to fly. How much time do you think it can keep flying? There is no power plant, what do you think? So is there a limit to how long can you stay in the air? What is that limit? Come on, you can guess. So let me ask you it in simpler manner, what is required so that you do not come down?

Upper draft of air okay, is there a limit to how much upper draft of air is available in nature? There is no limit, it all depends upon weather conditions, location and where you are. So what do you think is the world record for maximum glide after a launch? How many hours do you think it has been possible for a person to stay in the air after launching? Take a guess. So is it like 2 hours or is it 4 hours, 8 hours? Can you stay for 8 hours? Yes, you can there is no limit.

It could be actually, even 20 hours. It all depends on where you are flying, what is the condition, if you keep getting thermal; you can keep up in the air. So the question for you on Moodle is what is the world record for soaring after a launch? Okay, let us see how many hours people have been able to stay up in the air after a single launch, right? Yeah, winch is not shown, winch is basically a drum winch is a drum on which you wind a rope or a cable and then that at the end of the runway you put that and using an electrical motor you wind it at high speed so it pulls the aircraft as it pulls the aircraft the aircraft gains altitude. So the cable is still connected and then when it reaches some height you release it. There is a hook in the aircraft, the pilot releases it so the rope falls and the aircraft is already up, so it can glide. So the winch is basically the thing that pulls a drum cable mounted on a drum that pulls the aircraft that is a winch and that is put at the end of the runway.

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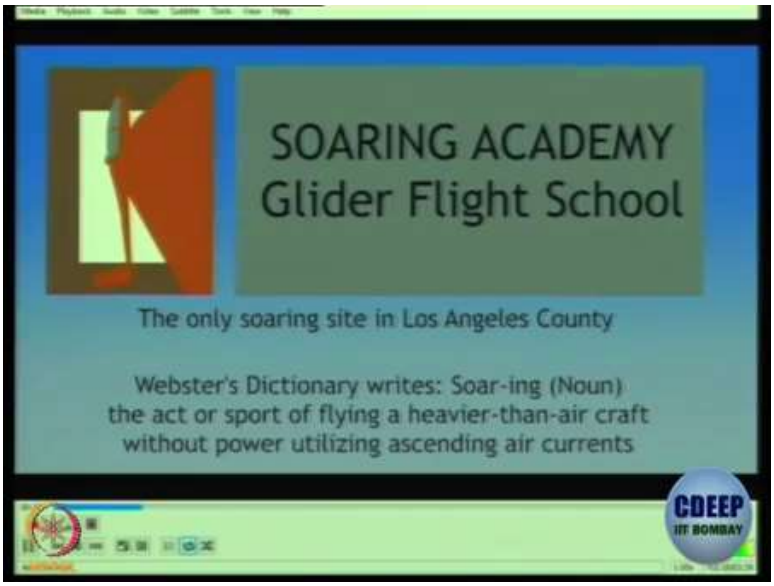

Okay, the other way in which you can launch a glider is called as a Aerotow, this is an expensive way but here is a flying school which tries to sell itself by showing you how you can do,

Video: what is soaring? Webster's dictionary writes soaring the act or sport of flying a heavier than air craft without power, utilizing ascending air currents. Those that choose to experience soaring will provide a more personal definition that expresses freedom and excitement from a truly 3D environment. What will be your definition?

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Watch as we take you on a brief flight showing you what others have done and what you can do.

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The line crew takes the tow rope and connects the glider joining the two aircrafts. This is not a launch, this is just tightening the cable. Once a slack rope is out and when the glider is ready, the gliders wings are leveled. The glider is behind, wings are leveled, with the signal from the glider the tow plane advances to full power, 250 horses pull both aircrafts to flying speed throughout the tow the glider pilots demonstrates their airmanship, staying in formation with the tow plane. The glider pilot pulls the panel mounted release letting go of the ropes, the tow plane job done. It now heads back with the rope, ready for another tow.

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The shots show the grace of long wings in lift, flown by professional pilots after a lengthy briefing.

You can see there are wing tip devices to reduce induce drag and it is a light wing which is bending up because of the load okay so this is called as aero tow, how would you describe soaring to our friends? Schedule your flight and find your definition.

This is expensive but it is very common in areas where there are many winch failures. There are complaints that winches get stuck, so this is also one very common way of doing it. Can you think of a third way. What would be the third manner in which you can provide the force for the glider? Yes.

Professor: Right, so one can use MGH the altitude. Let us say there is a mountain, you go to the top that is what we do in hang gliders. We go to the top of a mountain and then we jump down okay, but we are going to start from the level ground here. So what can you do? Anything else can be done? Yes.

Student: Catapult.

Professor: Catapult launch is also possible but catapult is like a winch only, it is a type of a winch okay, but catapult normally is slightly different because but yes I mean you can use it for launching, but I would call it like a winch type only. Any other way you can think we can do it. So we can do

it by cheating, by putting a small engine on the glider. I am saying that oh this is a very small engine it just provide minimum amount of thrust. When do we need it? Just to take off and whenever there is a problem you put the engine on otherwise engine off and their the aircraft gliding, such a launching is called as a motor gliding or a Motor Glider. It is a small aircraft actually.

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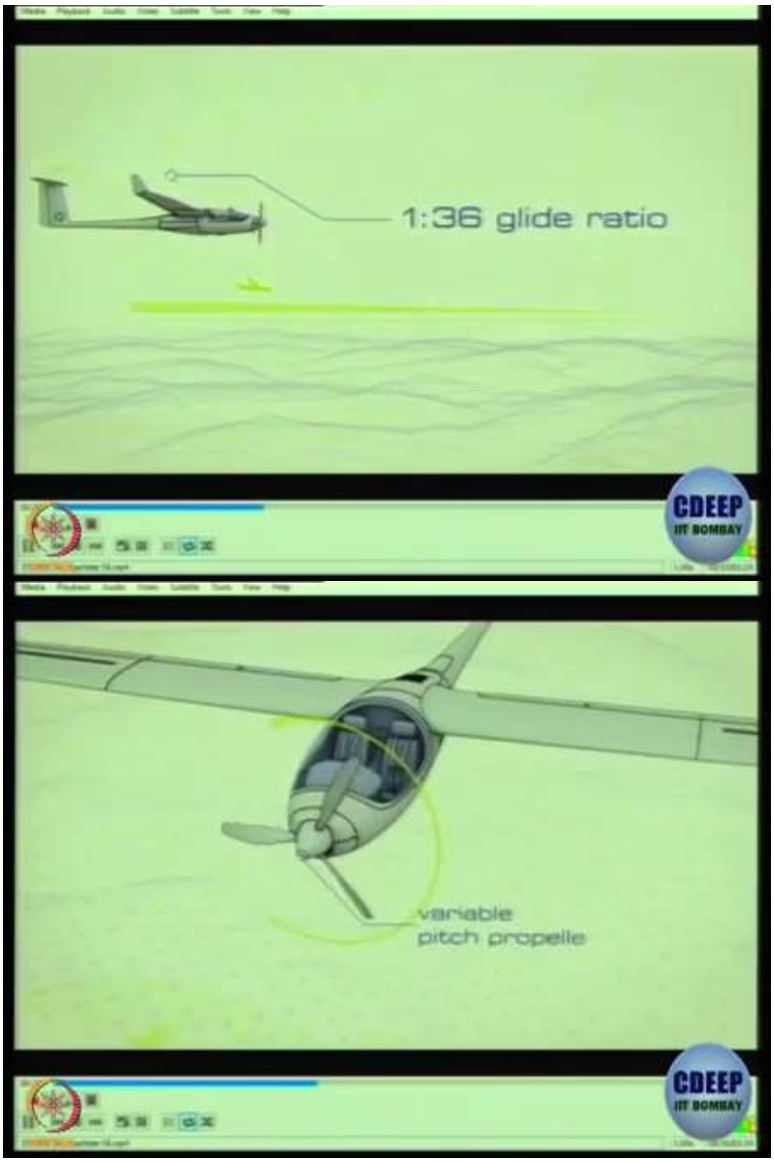

So here is again one of the best motor gliders available today is this one. This is with the engine 1593 kilometers with the engine so glide ratio means L by D, L by D is 36 in glide, this is a sales video which says that you can do so many things, you have so many choices.

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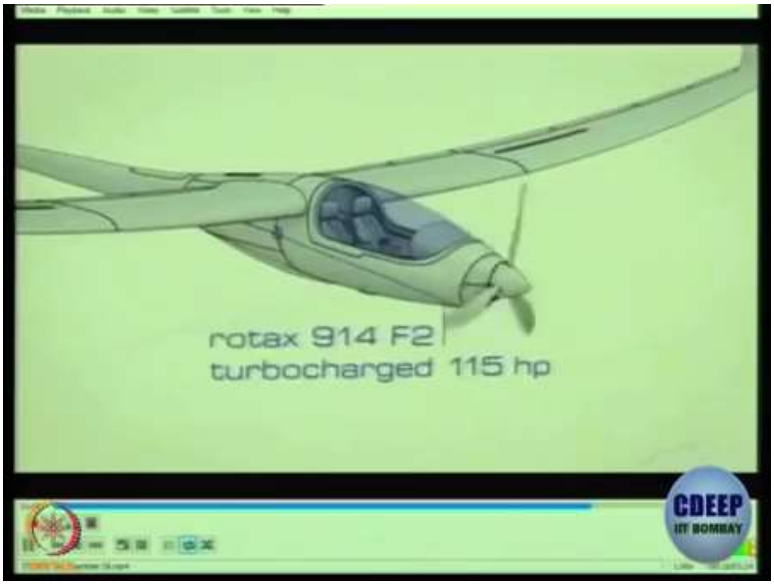

So this is the engine 115 horse power. So this makes you independent of either an Aero Tow or the Winch. Okay so these are the three ways in which you can launch a glider okay.

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Now let us say you have an aircraft which has got an engine or multiple engines and it fails if you have two engines both of them fail, if you are one engine that engine fails okay, so what do you expect is that there is going to be a crash, is going to come down, but that does not happen okay.

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Let us see what else can happen and aircraft can also glide because an aircraft without engines is a glider, this happened in a very famous incident. This is a very interesting video and also when you come to the end, you will know the reason why it happened and I am sure you will have a big laugh. Okay so this happened to a flight brand new aircraft, Boeing 767 purchase by Air Canada okay.

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Let us see what happened so I think this video is only a recreation we do not have the original video obviously, so it is called as a Gimli Glider. Let us see we can get quickly what happens.

Video: It is a Flight 143, it is a routine flight one which have flown many times before. But this time no one on board knows they have only enough fuel to reach half way. Boeing 767 recently purchased is on a flight, everything is fine. Captain Bob Pearson and First Officer Maurice can tell believe I have 22,000 kilograms of fuel when in reality they have only 22,000 pounds. A miscalculation with the fuel while converting volume into weight has gone unnoticed. Compounded? I noticed it on few occasions, catastrophic failure.

So they think they have 22,000 kilograms of fuel but actually they have 22,000 pounds of fuel and a pound is basically 2.204 pounds is 1 kilogram. So they are carrying 2.2 times less fuel which means they are nearly half. So they planned a mission in the filled off fuel and they only carried half the fuel needed. So obviously, the other engine is now inevitable. They are about to run dry. Not just the pilot the person who fills it the person who reports it everybody goofed up, so left engine dies first.

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So one engine failure is not a big problem ok many aircraft experienced, at an altitude of 41,000 feet and only one engine decided to make straight to Winnipeg So this is important, so the altitude is 41,000 feet and one engine is not working now, it has just no fuel so it has become shut down. So what they decided, they decide that they will go to Winnipeg straight, normally an aircraft is flown along a particular route. So that is not a straight line that follows the air routes, they will ask the ATC give us our direct routing to Winnipeg as a safety measure so that we can reach there as quickly as possible because one engine is not working.

Landing at 767 on one engine, it is difficult enough, so now Captain Pearson is in a deadly race against time, barely able to accept the situation they are in and against all hope their right engine finally dies so second engine also gone. Winnipeg, Air Canada, 143 Air Canada, 143 go ahead, we have just lost both engines. Holy cow! That brand new twin engine jet has suddenly become a glider. But this glider unlike any other weighs 95 tons and has 69 souls on board. The plane is now descending 1000 feet for every 3 miles it moves through the air, knowing its distance from the nearest…

1000 feet is a loss for every three miles in the air. So you can work out the sink rate now okay, this is a question you can do in the tutorial, it is going to sink now. So at 41,000 feet they have started their glide and they are losing 1000 feet for every three miles. So how much can they go if it is continues? 20 miles? Ok that is it.

Video: is therefore essential. With no engine power the aircraft has only basic instruments working and these would not give them the information they need.

Because there are no engines, there no instruments now only the mechanical instrument which I taught you vertical speed indicator, air speed indicator

Okay how far are we from the field now? You are 35 correction make that 39 miles from Winnipeg. So 39 miles away is Winnipeg, so with an altitude of only 8000 feet. The news from

Professor: So now they have come to 8000 feet, from 41,000 feet they have come to 8000 feet. Winnipeg is 39 miles away, they were losing 1000 feet for every 3miles. So they can go 20 miles max (wait-wait) you are ahead of time.

Video: The co-pilot is not good.

Professor: But ram is available but what will ram give you not ram but RAT, what will it give you? It cannot give you power to fly, RAT only gives you power for lowering the landing gear, flight control system that was there, otherwise they would have not really worked. Because even do glide properly you need to control the angle. So yes, they had RAT. It came down. It worked. But it gave power for landing gear etc let us see, it comes in the end.

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Wait unless maybe another 20 miles.

Right, so now the pilot calculated that we can travel if we fly in the optimum condition, we can travel 20 miles Winnipeg is some 30 miles away, 43 miles away so we cannot make it to Winnipeg. So then they ask, where do we go? We are not going to make Winnipeg. The only chance now is to land it Gimli, Gimli is a decommissioned air Force base with no control tower. But it is only 12 miles over. So 12 miles away, there is a disused Air Force runway, called as Gimli. Now because it is disused there is no air traffic control, there is no safety equipment nothing. In fact, to their horribly realized that they do not know it. But when they go there, they realize the Gimli is now becoming a drag race hub and they were people below running cars on the runway, and there were two cyclists on the runway when they came in to land just see the fun now.

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The problem now is not reaching the runway but overshooting it that too high and the coming in too fast. So now they are beyond the range.

Normally, a pilot can slow down his airplane by operating flaps, but without full hydraulics they do not have any. They perform now what is called a gravity drop.

Professor: So understand the problem now. Earlier, Winnipeg was far away, so you cannot reach now Gimli is nearby but now you will overshoot because you are gliding and you will travel 20 miles is only 12 miles So you now have to redeem, now how do you change the sink rate by control surfaces? They are not available because flaps are not working so they will do a gravity maneuver.

They have to rely on the weight off the landing gear itself to lock it into place. The gear's air resistance will also help to slow the plane down increase the drag but I mean, copilot notices that the nose gear is not there, he decides to kill people.

Nose gear was 50 percent jam.

It is no good but still too high and too fast because I have to slip it Captain Pearson now employs referred to as side slipping, he banks the plane fully left while stepping hard on the right rudder pedal. This is called crossing the controls.

It turns the plane slightly sideways against the direction of travel offering greater air resistance slowing the plane down [the runway is Gimli] however alarming this may have seen to all on

board. He knows it is their only hope of getting down in one piece. That is one more surprise for Flight 143 they have an order.

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The air field is not empty as they hoped, it is being used as a drag racing strip, there are people on the ground, there are cars on the ground so their sides slipped gone this way and then gone this way.

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Captain Pearson has never been so focused. He holds on for their life, waiting for that sickening crunch. As his plane skids down the runway Captain Pearson realizes he still has work to do. He pushes hard on his differential breaks in an effort to stay on the plane away from two boys straight in front of him, they are cycling. At last, he wrestles the mental giant to a hold. There is no fuel, no flaps, damaged landing gear and no emergency equipment it was only the decisive actions and the superb skill of the flight crew of Air Canada 143 that turned a potential tragedy into a triumph. Thankfully, everyone was able to walk away from Air Canada flight 143 and many things have happened to them since then. But they can be sure that they will never forget the day they flew the Gimli glider.

Okay, so now interestingly, what happened after this? So you might think that it is a very heroic act by the pilots. But both the pilots were suspended why were they suspended? Because they did a stupid thing off making mistake in units okay. They loaded fuel they are from Canada okay but the aircraft is now working, so they think it is in kilogram but actually it is in pound. The aircraft came from USA, in US they still work in a FPS system. So the indications are all in FPS for the fuel indicator. So when it says 22,000 they think it is kilogram actually it is pound. Should not they know, they are supposed to read the manual they are supposed to be prepared.

Now the people who fuel the aircraft, they also goofed up. So everybody goofed up and the emergency happened so both were suspended, the licenses were cancelled and then there was an enquiry, after sometime they were reinstated and then they went on, one of the pilots actually only passed away in 2015, okay.