Introduction to Aircraft Design
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Lecture - 78
Environmental issues in Aircraft Design

Hello, today we will look at environmental issues in aircraft design.

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As you can see on the screen, there are basically two issues and we will touch upon both of them.

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The two key environmental issues are air pollution and noise pollution. Air pollution essentially means the emissions and the key emissions are the carbon dioxide, the NOx or nitrates of oxygen, carbon monoxide, and particulate matters. The problem is that these emissions contribute greatly to the global warming. As far as noise pollution is concerned, it leads to a negative impact on the health of the people who are subjected to the noise.

The studies have also shown that excessive exposure to noise can lead to cardiovascular issues like hypertension, and increased stress levels. There is also a negative psychological impact essentially in the form of annoyance. Annoyance to whom? To the people who live in the areas near the airports or the airport neighbors.

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So let us first look at air pollution which is the main cause of concern.

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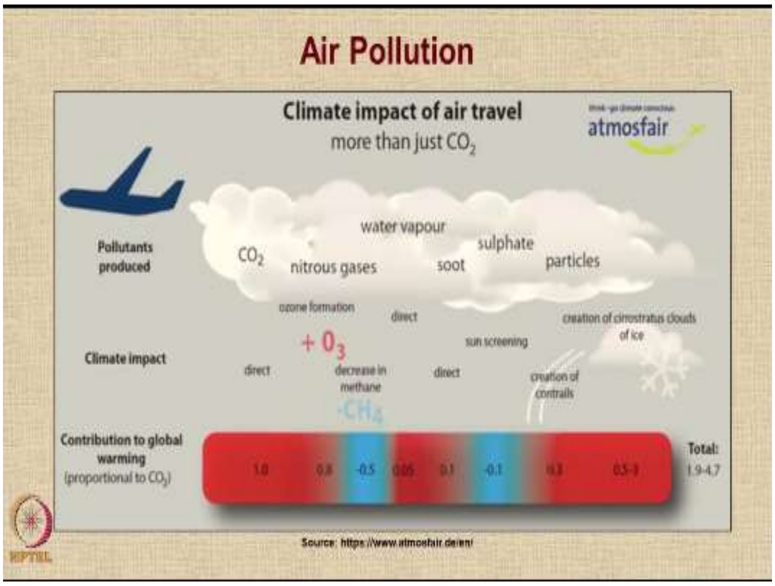

As I mentioned, air pollution due to aviation or air travel is more than just the carbon dioxide. The exhaust of an aircraft contains nitrous gases, water vapor, sulfates, soot particles. All of these create a direct impact on the climate and the contribution to the global warming in proportion to CO_2 is shown. The total contribution varies from approximately 2% to 5%.

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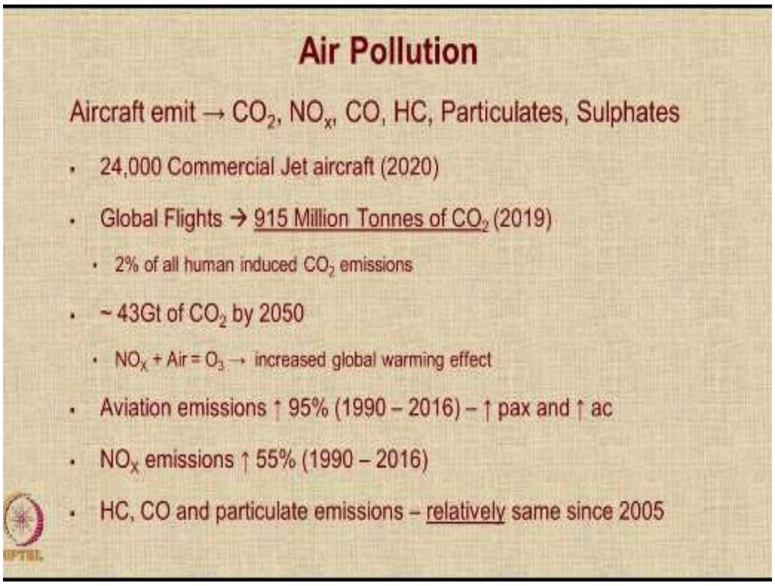

So the emissions of the aircraft which caused problems are as mentioned, hydrocarbons and sulfates. Now in 2020, it is expected that there would be 24,000 commercial jet aircraft operating. Now this is without taking into consideration the effect due to the nCOVID-19 or the coronavirus pandemic. The global flights last year in 2019 they contributed to 915 million tons of carbon dioxide and it is they amount to around 2% of all human induced CO_2 emissions.

So although there is a lot of noise about air pollution being created by aircraft, but actually the carbon dioxide emissions are only just 2%. Other activities like burning of coal, burning of wood and industrial and factory exhausts actually cause much more carbon dioxide emissions and also the automobiles. By 2050 it is estimated that 43 gigatons of carbon dioxide will be released in the air due to air travel.

The problem is that when there are NOx emissions and in the air, it leads to the creation of ozone and that creates to increased global warming effect. Aviation emissions have increased by about 95% between 1990 to 2016. So in around 26 years, we have kind of doubled the emissions. This is the cause of the increased number of passengers which travel and also increased number of aircraft both.

The NOx emissions have gone up by nearly half between the same period and the hydrocarbon and carbon monoxide and particulate emissions they are relatively the same. They have not gone up very much high. This is because of the advances in the propulsion technology, okay. But the NOx and the CO_2 emissions still are a major cause of concern.

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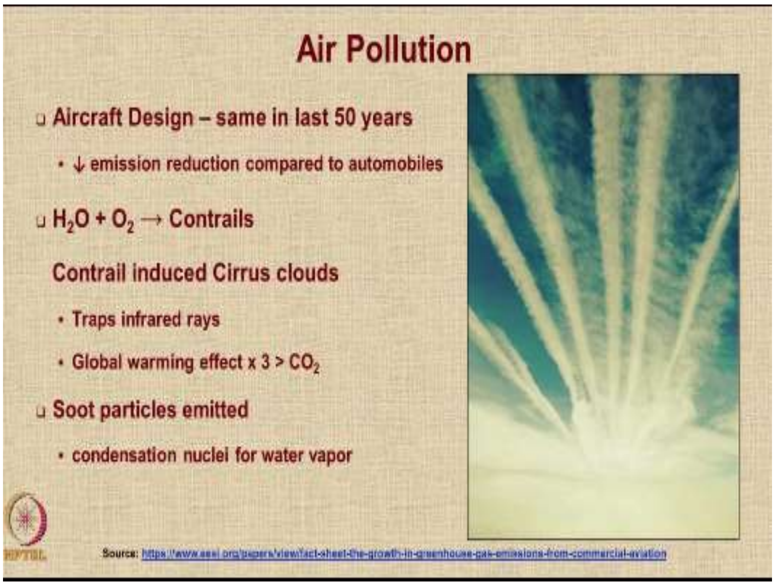

Another relatively unknown form of air pollution is the creation of contrails behind the aircraft. So the aircraft design has remained almost the same in the last 50 years, whereas if you look at automobiles they have done much more in the field of reduction of emissions as compared to aircraft, okay. Now water vapor and oxygen in the atmosphere creates what is called as contrails, or those clouds which we see behind the aircraft.

And these clouds are called as contrail introduced cirrus clouds. The problem with them is that they trap infrared rays. And the global warming effect of these is actually three times that of the global warming because of carbon dioxide. The exhaust of the engine also emits soot particles. And these soot particles they act as nuclei for condensation of water vapor and that is what causes these contrails.

Let us have a look at a video showcasing the effect. **(Video Starts: 06:00) (Video Ends: 06:37)**.

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So now let us see the efforts being taken to reduce the emissions. First is to utilize chemistry to provide cleaner fuels, which can reduce the emissions, okay.

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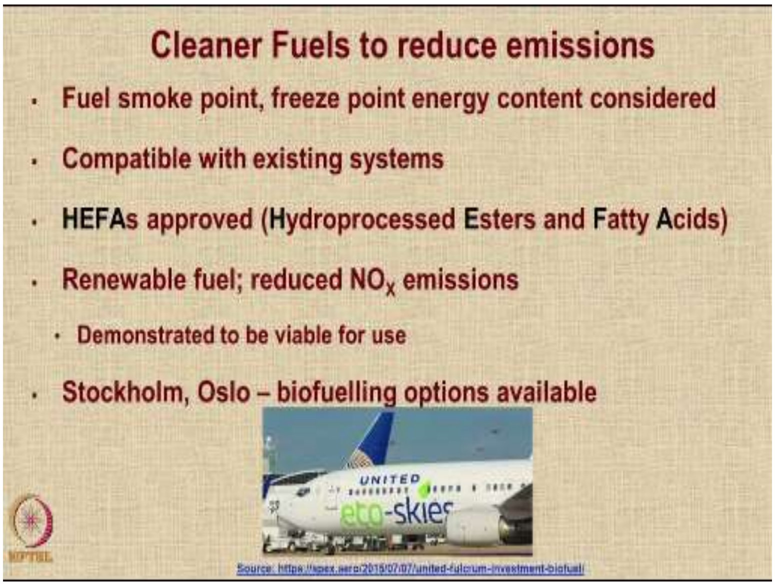

Now it should be kept in mind that the fuel smoke point and the freeze point energy content has to be considered while estimating methods to create cleaner fuel and the fuel that we create should be compatible with existing systems. It should not require new engines or major changes in the existing power plants. And in many cases, it should be possible to blend the fuel that you create artificially with the natural fuel.

Over a last few years, HEFAs which are hydro-processed esters and fatty acids, they have been approved for use on aircraft as fuels. So we when we use HEFAs in the fuel in the renewable fuel will lead to reduced NOx emissions, okay. And it has already been demonstrated to be viable for usage. Several experiments and several flights have taken place, okay. And also there are many airports which are creating bio-fueling options.

For example, the Stockholm and Oslo airports are having such special facilities. So more and more airports are becoming greener now and give a provision for providing the renewable fuels.

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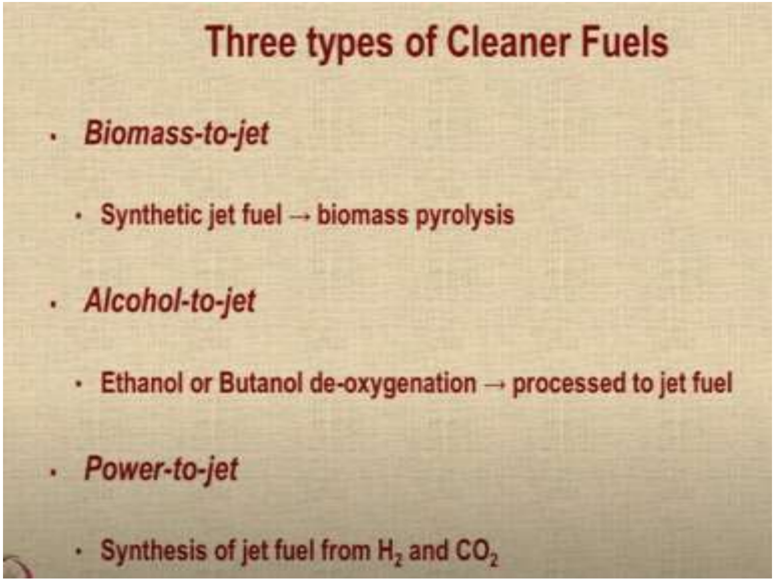

There are three types of artificial or cleaner fuels. One is called as the biomass-to-jet fuel in which synthetic jet fuel is created by biomass pyrolysis. There is also alcohol-to-jet in which ethanol or butanol de-oxygenation is carried out to create the jet fuel. And there is a third one called as power-to-jet in which you use hydrogen and carbon dioxide, synthesize these together and straightaway create jet fuel from there.

So these are the three types of artificial or cleaner fuels which have been attempted by several scientists.

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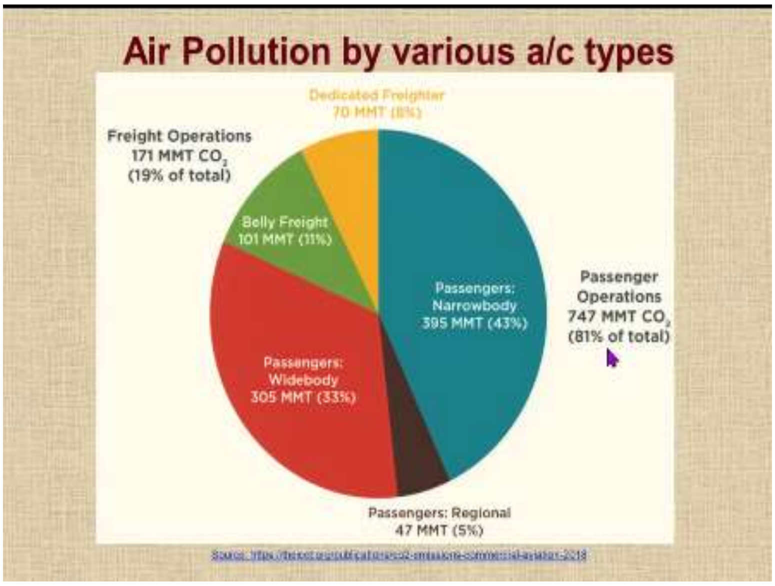

Now let us look at how much air pollution is created by various aircraft types. So we see that the belly freight contributes to only about 11% and the dedicated freighter about 8%. Together, they only account for something like 19% of the total 171 million megatons of carbon dioxide emissions. But the passenger operations the narrow body, the wide body and the regional, in which actually the largest contribution is the narrow body.

The aircraft like Boeing 737 or A320. These are narrow body aircraft. They contribute to 43% and the wide body aircraft because they travel longer distances and per capita they consume less amount of fuel, hence give you lower emissions they give you slightly lower emissions. Together it accounts for something like 76%.

And if you add another 5% because of the passengers in the regional transport aircraft, so a total of 81% of the fuel consumption is because of the passenger operations. So let us have a look at one segment that is a wide body aircraft.

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So we did a small comparative study of emissions by four transport aircraft, okay. All four of these aircraft are shown here. They are all wide bodied aircraft. And this was carried out using a software called as piano X, PianoX. So PianoX is actually a software which is available online and you can download it and use it. There is a trial version available free of cost in which some aircraft are already available. So these four are among those aircraft which are available.

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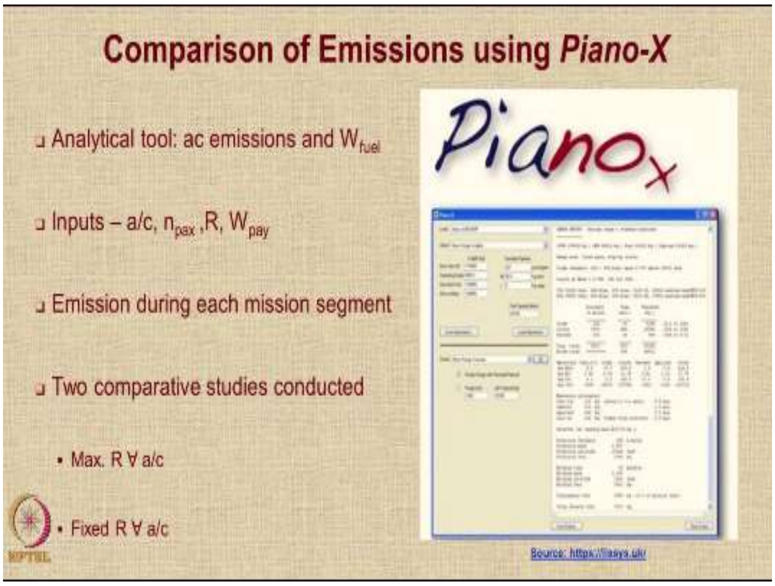

So we carried out comparison of emissions using PianoX. This is an analytical tool in which you get the aircraft emissions and also the W fuel, fuel weight. The inputs to this software are the specific aircraft name so that the correct data file can be taken which contains the aircraft information, number of passengers, range, and the payload weight. And the software calculates emissions during each mission segment.

So we carried out two comparative studies. In one we said that we will allow the aircraft to travel to its maximum range that it can travel and then calculate the emissions. And the other one is for a comparison, we said we will go for a fixed value of range and we will see what are the emission levels created by four aircraft for the same fixed value of range.

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So these are the four aircraft. As I mentioned, all of them are wide bodied aircraft, the Boeing 767 which started operations in 1998. And it is still operating. Although recently I think it has been retired. Airbus A340 which began in 1991. Airbus A380-800, which began in 2003. And recently many airlines have retired their Airbus A380s but some of them are still operating them.

And the Boeing 787-8 a relatively new aircraft which appeared in 2011. So we have taken aircraft which start from 1998 and go right up to 2011 the year of introduction.

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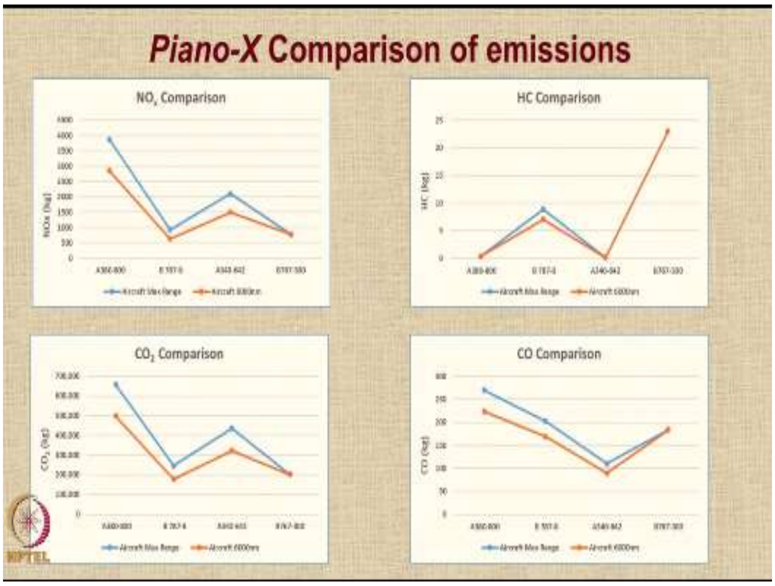

So if we compare the emissions we see that the highest emissions of NOx appear in Airbus A380 okay, and then the next number is for 340. The lowest values are for Boeing 787-8 and just slightly higher than that is Boeing 767-300. If you look at the hydrocarbons, we see that the Airbus A380 has very low values, and also Airbus A340. Boeing 787-8 has little bit high values but very high values are seen for Boeing 767-300.

If you look at the carbon dioxide emissions again, a large aircraft like Airbus A380 does have the highest value of emissions followed by A340. Then 787 and then 767. Rather 767 is slightly higher. And finally, if we look at the carbon dioxide, carbon monoxide emissions, once again the highest values are for Airbus A380, followed by 787-8, then 767-200 and finally the lowest ones for 340-642.

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Let us move on to noise pollution, which basically is undesirable sound. Let us have a look at a short video that explains to us what causes aircraft noise. **(Video Starts: 13:38) (Video Ends: 15:11)**.

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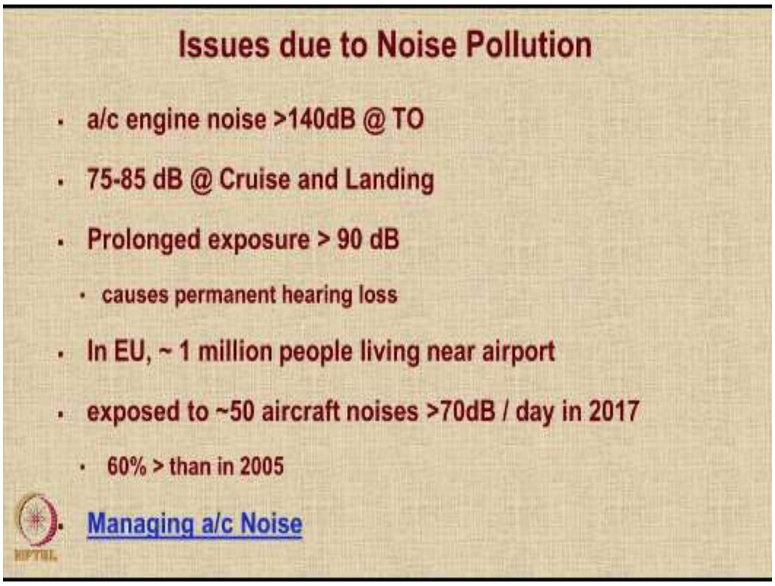

So what are the issues because of noise pollution. First important point is that aircraft engine noise can go beyond 140 decibels at takeoff. And that is very loud, okay? During cruising and landing, the noise levels are much lower, 75 to 85 decibels, okay? Now the problem is that if you have a prolonged exposure to noise levels beyond 90 decibels, it can cause permanent hearing loss and that is very bad news.

In the European Union, a study has shown that nearly 1 million people are living near the airport. They are subjected to around 50 aircraft noises per day, which have a decibel level of more than 70. This was in 2017. Now this number has gone up by 60% compared to 2005. So in about 12 years, we have had 60% higher exposure to noise. So this is the main concern.

Let us see how the aircraft noise can be managed. **(Video Starts: 16:18) (Video Ends: 17:30)**. So that was an example of one airport Brisbane taking proactive attempts to reduce the exposure to the people living nearby due to noise.

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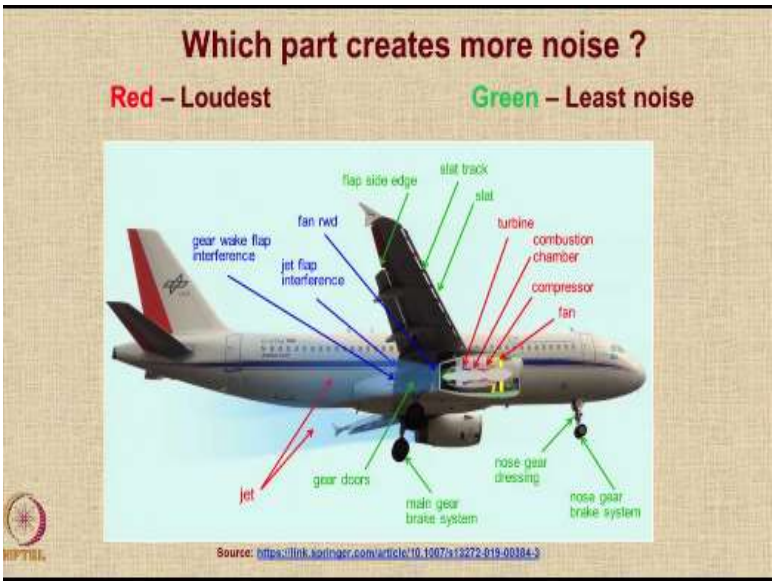

Let us have a look at which part of the aircraft creates more noise. So as you can see in this picture, the one which are marked red that is the turbine, combustion chamber, compressor fan and the jet they are the ones that create the loudest noise and the ones which are green like the wings, flaps, gear doors, main gear, nose gear etc., they create the least noise. And the interference and other things are the in between the two.

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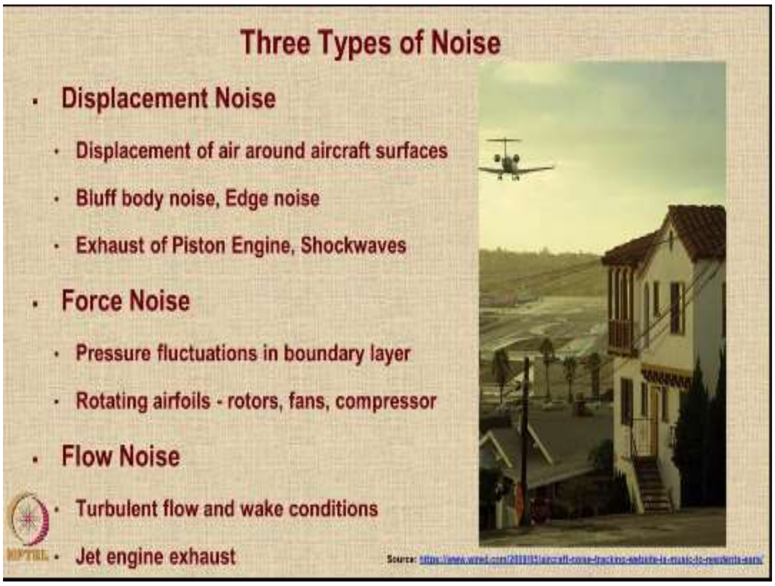

So there are essentially three types of noise, okay. There is displacement noise, which is created because of displacement of air around an aircraft surface okay. So when you have a bluff body or when you have edges, it creates noise because air is displaced. And also when you have exhaust of piston engines and if you have shockwaves they also displace air and hence cause noise.

Then we have forced noise or noise due to the generation of forces because of the pressure fluctuations in the boundary layer. So rotating components or air foils like rotors, fans, compressors, they are the ones that create the force noise. And then we have flow noise, okay. That is whenever we have turbulent flow and wake conditions, at that time there is a noise created because of the flow itself.

So we call it as a flow noise. So among these, the displacement noise tends to be a little bit lower. The largest values are basically the force noise and the flow noise. And the exhaust of the jet engine is the biggest reason for creating the noise.

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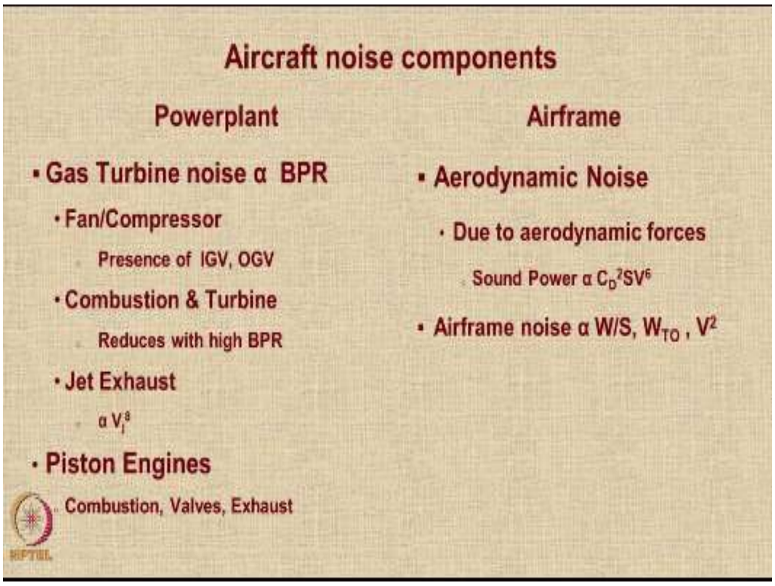

Let us have a look at the components of the aircraft. Essentially you can break down noise on the aircraft either attributed to the powerplant or attributable to the airframe. In powerplant we see that the gas turbine noise is the most important one apart from the jet noise and this is proportional to the bypass ratio. Higher the bypass ratio lesser will be the noise.

The presence of inlet guide vanes and outlet guide vanes in the fan and compressor are a big reason for noise. In the combustor and the turbine, the noise level reduces as the bypass ratio increases. The jet exhaust as I mentioned, which is the largest component of noise actually the proportional to the eighth power of the jet exhaust velocity. In piston engines noise is created because of the combustion, the valves and the exhaust.

Coming to the airframe, mostly the noise is due to the aerodynamics. It is called as aerodynamics noise. And it is caused because of the aerodynamic forces. The sound power can be shown to be proportional to square of the drag coefficient proportional to the area and sixth power of the velocity okay. So if you reduce the velocity there is a drastic reduction in the sound power of aerodynamic noise also as well as the jet exhaust noise.

If you reduce the area and also if you reduce the drag there will be lower noise. The airframe noise is proportional to the wing loading, is proportional to the takeoff weight and proportional to V square.

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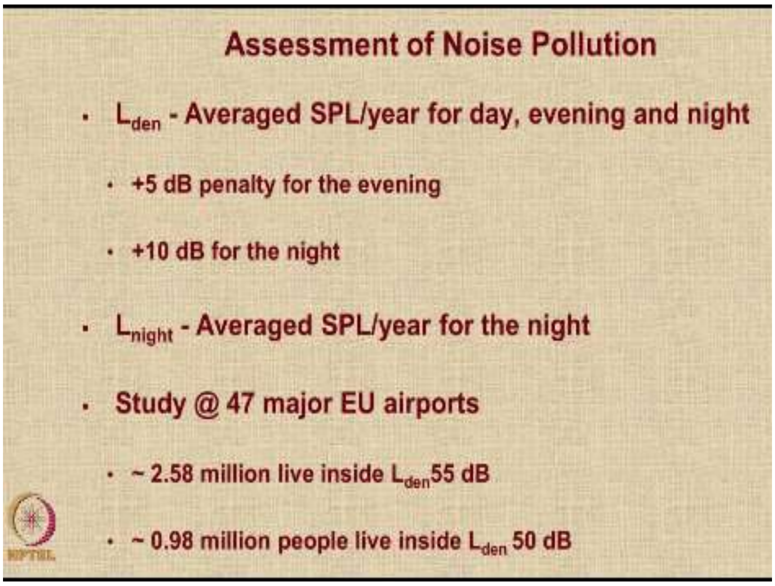

Let us see how we can do the assessment of noise pollution, how is it measured. So there is a one term called as L den which is basically the averaged sound pressure level per year for day, evening and night, okay. However, annoyance created by noise during the day is still tolerable. In the evening it is more troublesome and it is the most troublesome in the night.

Therefore, there is a penalty of 5 decibels on the noise levels for the noise created in the evening. And a penalty of 10 decibels for the noise created in the nighttime. There is something called as L night which is the averaged sound pressure level per year for only the nights okay. So L den stands for L level of day, evening and night. So that is why it is L den. And then you have L night which is only for night.

There was a study carried out at 47 major airports in the European Union. It was found that around two and a half million people or more live inside the 55 decibel zone of L den and around a million people live inside that zone of 50 decibels, okay. So a large number of people are actually living in the you know 55 decibel range.

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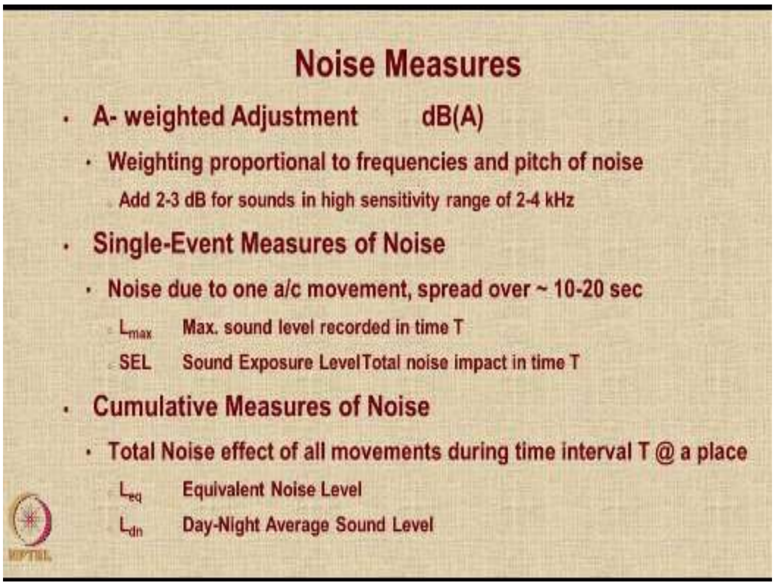

How is noise measured okay? One is called as the A- weighted adjustment or dBA. This is one of the most common the most common term to measure noise is the decibel levels with adjusted with A-weight adjustments. So the weighting is proportional to the frequencies and pitch of noise in this particular measure. So sounds which are in the high sensitivity range of human ear of 2 to 4 kilohertz, we add 2 to 3 decibel for sounds, okay.

Then we also have a single event measures of noise. So what we do is calculate or estimate the noise due to one aircraft movement spread over around 20 seconds, okay. So you can measure either L max which is the maximum sound level recorded in time in terms of the decibel, or you can talk about the SEL or the sound exposure level. That is total noise impact in time T. We also have some cumulative measures of noise.

What we do in this is that we add the noise of all movements during the time interval T at a particular place. So you have L eq which is the equivalent noise level and L dn which is the day and night average sound level.

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So using this information, it is very important to draw noise contours which are nothing but depicting the noise exposure of a particular community over a contour map. So each line on the map corresponds to some specific value of noise exposure level and all, these are ISO noise lines. The data is measured at different dB levels. And FAA has come up with a very interesting tool called as AEDT or aviation environment design tool.

This has got modules both for emissions as well as for noise. So it models noise, emission and fuel consumption and it is a tool developed by the Federal Aviation Administration of USA. It is consistent with ICAO model and database. It calculates the annual noise contours. And earlier there was a noise model called as the INM, integrated noise model. This particular tool replaces that particular tool.

So you draw a noise contour by looking at the noise data, looking at the number of flights, and looking at the flight tracks. Together, superimposing all of them together, you get the noise contour.

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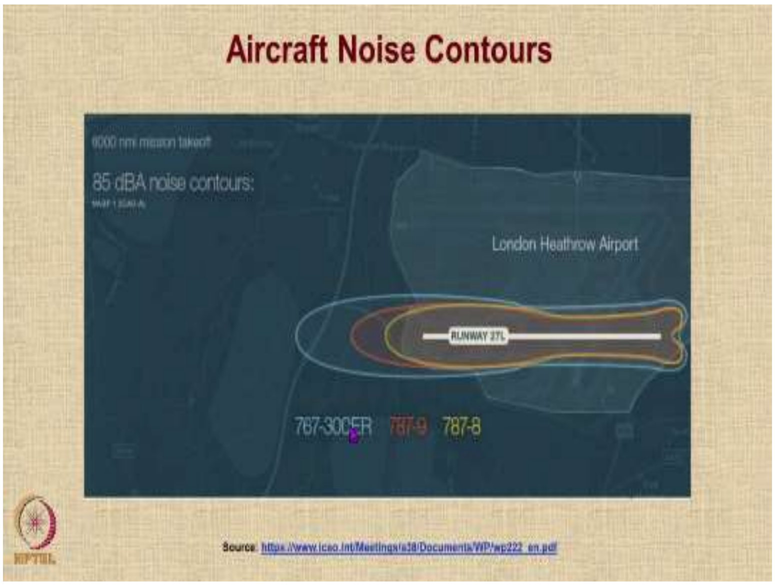

So here is an example of a typical noise contour. This one is recorded at the London Heathrow Airport on a particular runway 27L. So we see here that there is an orange band, then there is a red band, and then there is a blue band. So the orange band or the yellow band corresponds to the noise contour created by Boeing 787-8. The red band, this is for 85 decibel. So all these contours correspond to 85 dBA noise contours.

So we see that much larger area is exposed under noise level of 85 or below for Boeing 787-9 compared to -300ER of 767.

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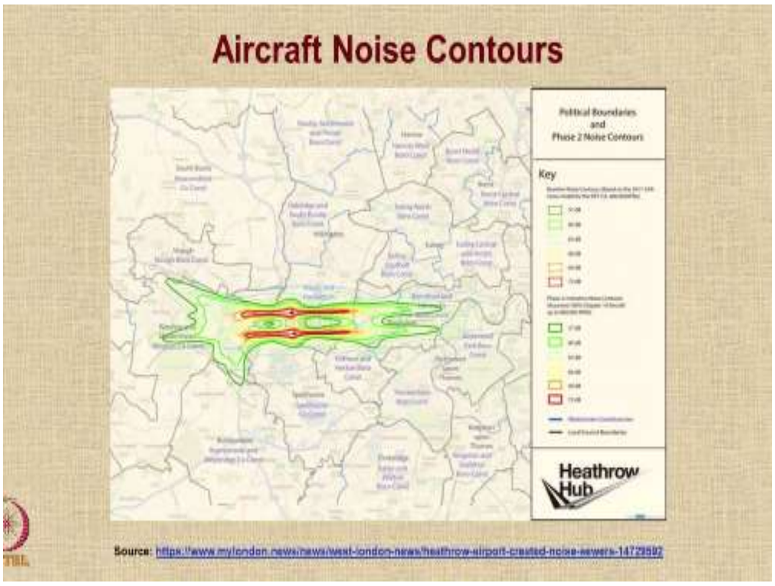

Another way of showing the contour is to map them over the geographical layout. So here you can see that various color schemes are used. The lines which are in red color are the exposure beyond 72 decibels in this case and the lines which are outside the green lines, they are noise level which are more than 57 dB.

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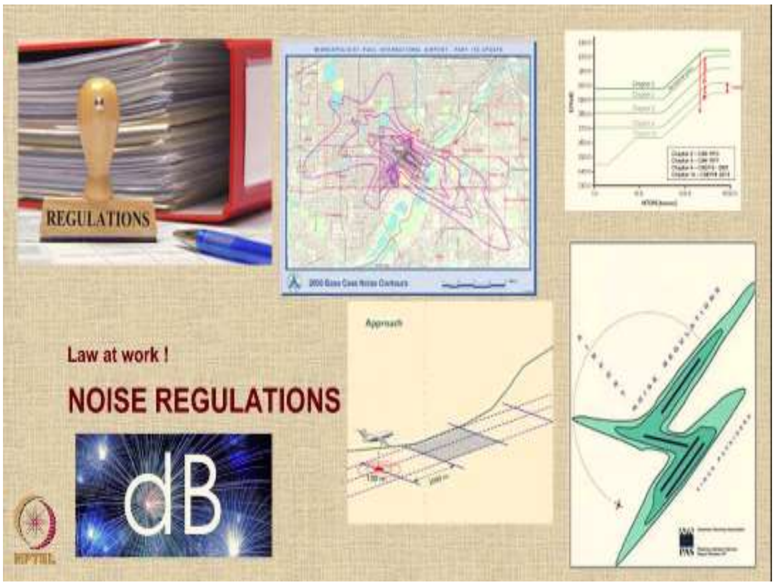

Let us look at some regulations, okay. We see now how law comes to our rescue in tackling and handling the noise requirements.

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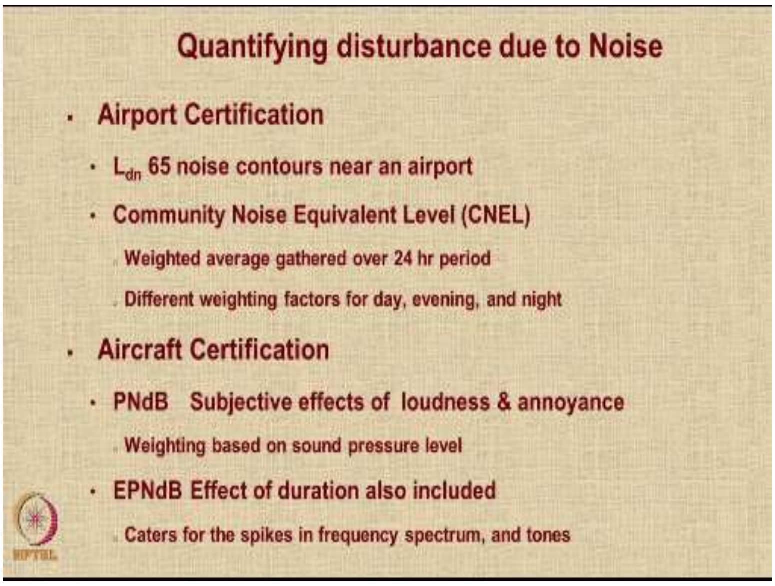

So first of all, in law we have to quantify the disturbance that is caused due to noise. So we use it for either airport certification or aircraft certification. As far as the airport is concerned, what we do is day and night contours of 65 dB are drawn at an airport or near an airport. And there is a term defined as community noise equivalent level. I shall talk about it a little bit in the future.

So CNEL is a parameter which is very important. This is basically a weighted average of noise gathered over 24 hour period. And of course, there are different weighting factors for day, evening, and night. Obviously, there will be less factor for day, more for night and highest, more for evening and highest for the night. As far as you talk about aircraft certification, we define something called as perceived noise level in decibels PNdB.

So what we do here is we do the weighting here on the basis of sound pressure level, okay. So that is how you can get the perceived noise level. Then in EPNdB, this is effective perceived noise level in decibels, the effect of duration is also increased. Because if a noise is sporadic, then it causes disturbance but limited. But if it comes for a long duration, it seems worse. So EPNdB is more important.

Not just a single PNdB value. It caters for spikes in the frequency, spectrum and also the various tones that are created.

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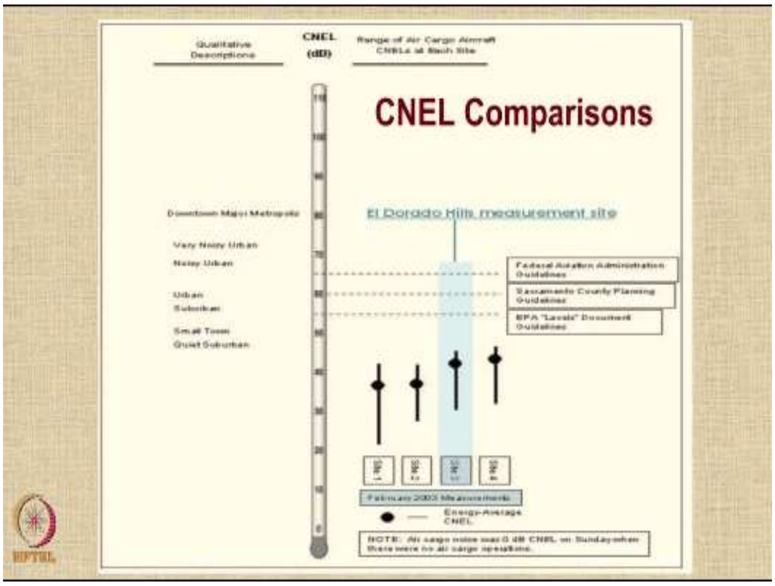

So this is the comparison of CNEL the community noise equivalent level for various activities like urban, suburban, okay on the location. So we see that there is a fairly large band available here for the lower side, right. Okay, so just gives you an idea that there are these four sites at which we measured the sound.

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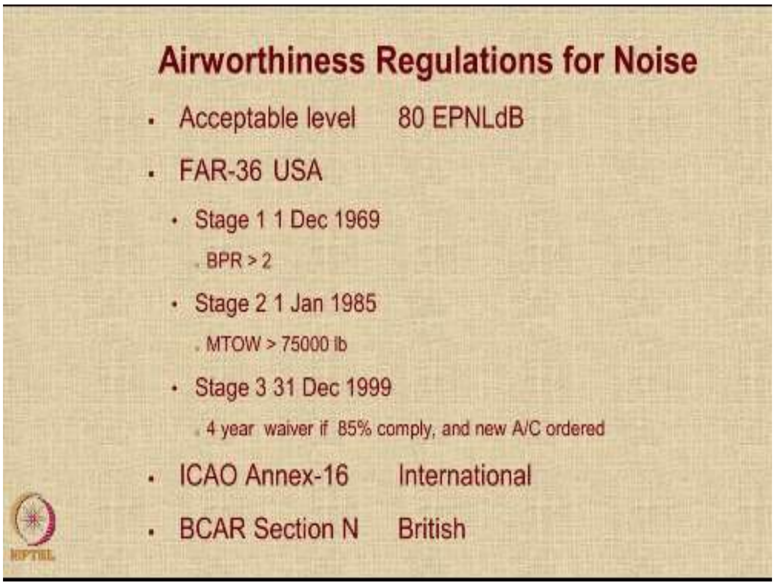

Let us look at the airworthiness regulations for noise. So the acceptable level of noises 80 EPN EPNLdB okay. And there is a federal aviation regulation FAR-36 in the USA. It gave something like stage 1 noise levels till December 1969. This was applicable to engines with BPR or bypass ratio more than 2. Then in January 1985 stage 2 regulations were put into place for aircraft having a max takeoff weight more than 75,000 pounds.

And then stage 3 came in December 1999. So we were told that aircraft which belong to stage 2 will not be able to operate in the US after 31st December 1999, okay. But there was some small point there so there was a 4 year waiver if 85% of the aircraft of an airline complies and the aircraft new aircraft has already been ordered to take care of the shortfall. In that case there is a waiver of 4 years available.

If as far as the International Civil Aviation is concerned, there is an annex-16 which is applicable for the noise levels. And in the UK regulations, the BCAR regulations British Civil Aviation Authority Regulations, section N is applicable to the noise.

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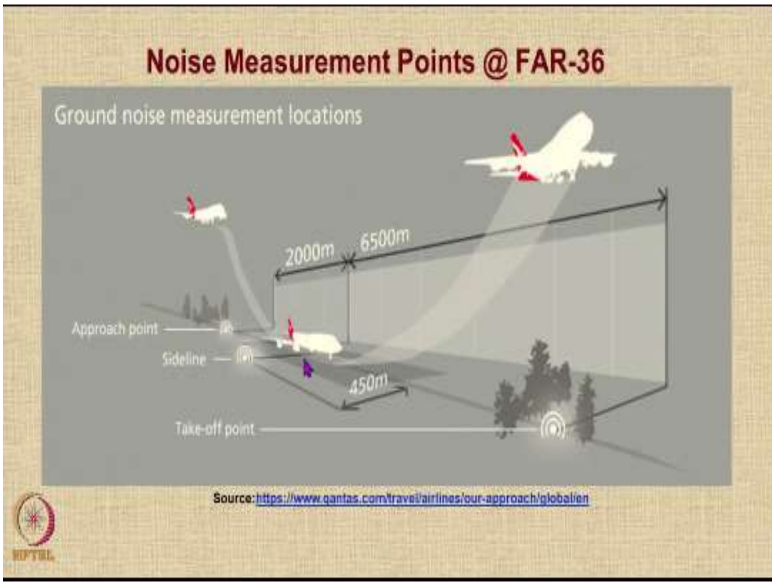

So the most common of these is the FAR-36 and as far as FAR-36 noise is to be measured at three places. There is a takeoff noise which is measured at a distance which is six and a half kilometers ahead of the takeoff point, okay. Right? So it is six and a half kilometers ahead from the point where the aircraft starts operating. There is sideline noise which is measured 450 meters along the side of the aircraft anywhere along the line, preferably just next to the aircraft during takeoff.

And the third is the approach noise. So for that, what we do is we ask the aircraft to come in and approach slowly. And at during approach, we specify the values to be tested for, okay. And the approach point is basically 2000 meters behind the it is measured. The noise level is measured on the ground two kilometers behind the point where the aircraft is normally going to come to a stop after landing.

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The FAR 36 stage 2 noise limits are as mentioned. They are a function of the mass of the aircraft, okay. So during sideline and approach you allow larger noise levels, but during takeoff you allow comparatively same or lower noise levels.

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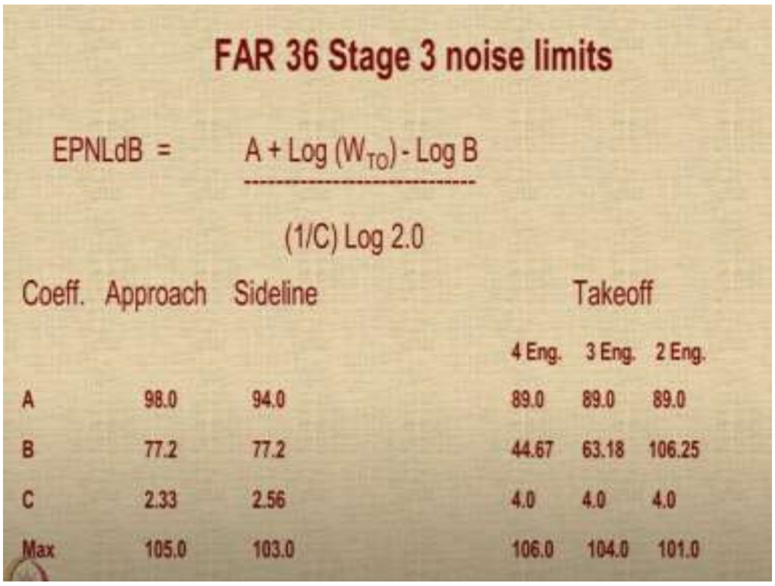

And there is a formula available for calculating the EPNdB as a function of the log of the weight of the aircraft, log of the coefficient B and log of C, okay.

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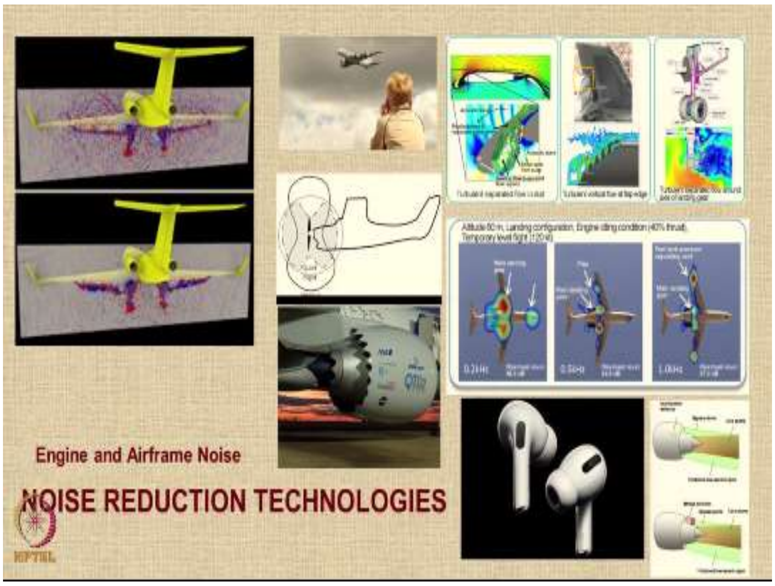

So moving on, let us look at how the noise can be reduced. So there are noises basically because of the engine and the airframe. So of which engine is the bigger culprit. So we will first look at how the engine noise is reduced.

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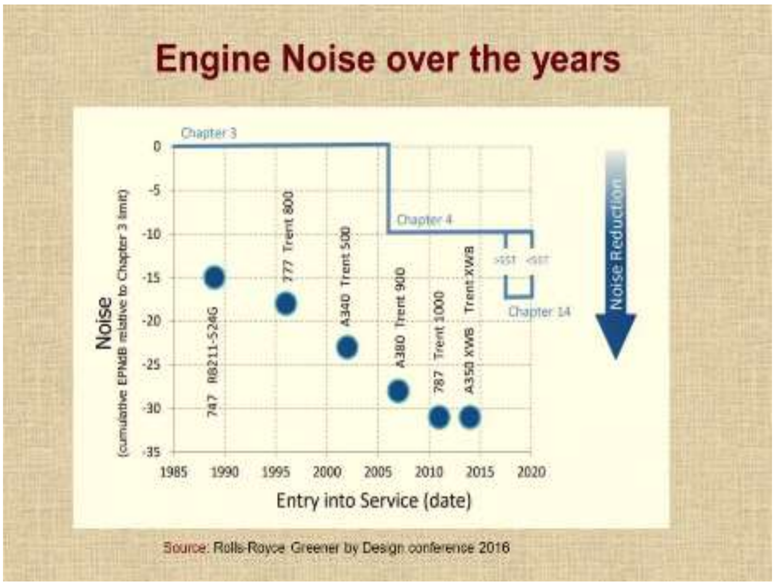

So let us first see how the engine noise has gone down as per Rolls-Royce, okay. So we see that there were chapter 3 regulations till 2005 in which there was some baseline noise level, okay. Then in chapter 4, in the year 2005, we got some new aircraft and the noise levels actually came down by around 10 decibels, okay.

And then there was another stage in which some aircraft such as the supersonic transport were giving the same benefits, but many others were giving around 15 to 17 decibel lower noise levels, which is a quite a large achievement. You can see the noise levels of various aircraft as the designs have evolved, how they are reducing with time. And now we are under the chapter 14 regulations and now there is an aim.

So every aircraft actually becomes a benchmark. It becomes better than previously designed or previously approved aircraft.

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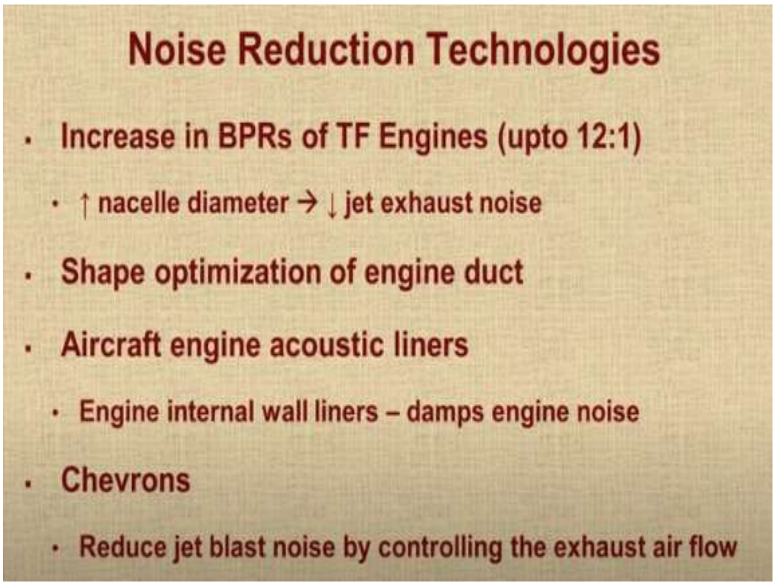

Let us have a look at some reduction technologies for noise. So increase of bypass ratio of the turbofan engines from you know 5:1 etc., to 12:1 that reduces the noise drastically, because with this higher bypass ratio the nacelle diameter increases and due to that the jet exhaust noise decreases and you know that the noise is powered proportional to the sixth power of velocity or eighth power of velocity in the exhaust.

So therefore, immediately there is a reduction in the noise if the nacelle diameter reduces. Then we also can do shape optimization of the engine duct and you can insert aircraft, engine can, you can insert acoustic liners in the aircraft engines. These are internal wall liners which dampen the engine noise, okay. And then there are some techniques like Chevrons which are special treatment of the exhaust nozzle to reduce the jet blast noise by controlling the extent of airflow in the exhaust.

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So here is an example of Chevron nozzles mounted on Rolls-Royce Trent 1000 aircraft for Boeing 787. So Chevrons have been developed by Boeing GE and NASA and the pressure of the airflow through the combustion chamber is to be always kept more than that of the bypassed air, okay. This is always the case. So whenever you have high pressure air and you have bypassed air and they meet together, it can lead to a loud shockwave and that can create noise.

So one example or one solution is enhanced mixing of the exhaust air in the intake or in the engine so that we do not encounter these problems. So if you provide streamwise vorticity then you can enhance the mixing and you can lead to lower jet noise. Here is another example of a double Chevron mounted on this engine. So where is the double? You can see that there is one Chevrons are here and also in the exhaust of the inner aircraft. Here we have not touched the inner aircraft at all, we kept it as it is.

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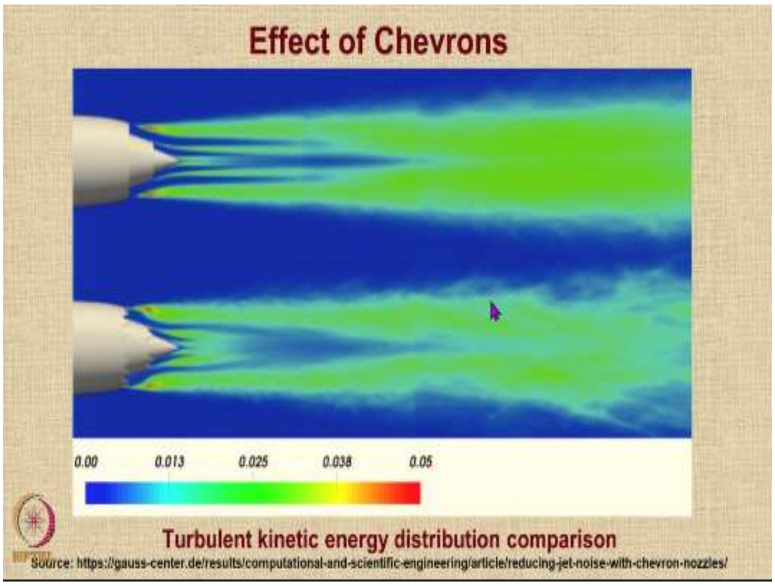

So here is the effect of Chevrons. You can see that in the top figure, there are no Chevrons. So the turbulent kinetic energy is quite large even up to the end. The moment you install Chevrons there is a movement of the boundary here. So it is very much possible that the exhaust can be literally stopped and the exhaust the engine will just take in ambient air and it will be utilized for the entire functioning.

So you can see that the turbulent kinetic energy distribution is far more rapid and disturbed in case of that with Chevrons compared to that without Chevrons.

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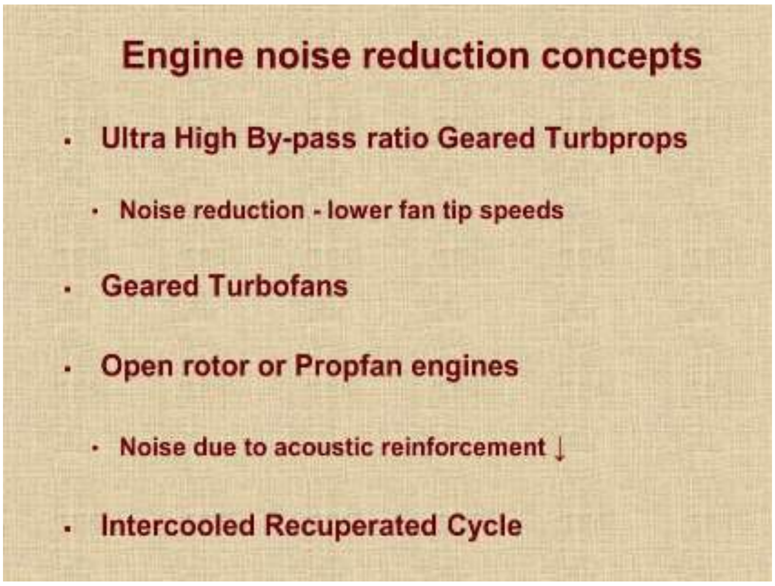

Let us now look at some engine noise reduction concepts. One way of reducing the engine noise is to use ultra-high bypass ratio geared turboprops. So what happens here is that there will be noise reduction because there will be lower fan tip speed. You could go for geared turbo fans also. Or you could go for open rotor or Propfan engines.

And also here what happens is the noise reduces because of acoustic reinforcement and you can also go for intercooled recuperated cycle. So these four techniques can be followed to reduce the noise of the engine.

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So in the ultra-high bypass ratio, this is an example of Rolls-Royce ultrafan. You can notice how large the outer portion of the wing is. So the core air is in very large area and the bypass happens to a very small area above this black liner. So it is a gear turboprop, which has got the bypass ratio of 15:1 and usage of these technology has been shown to reduce the noise by approximately 15 decibels.

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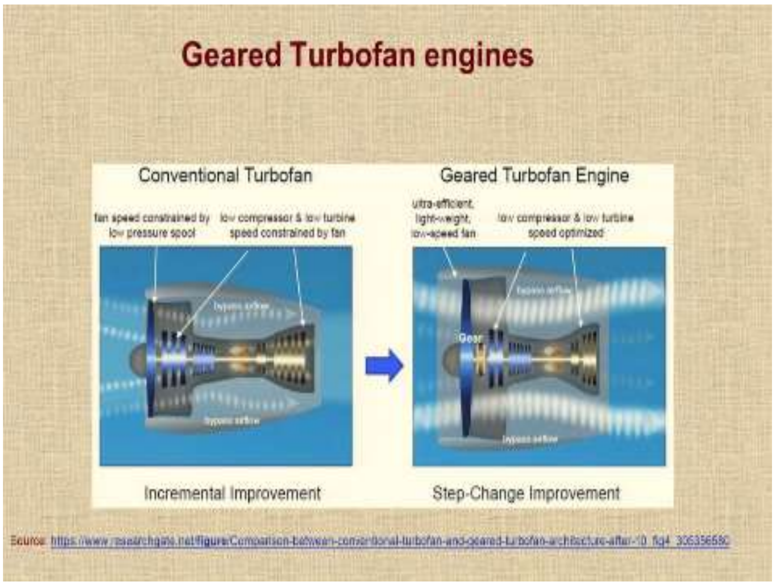

Now we have seen about geared turboprop. Can we apply a similar technique to turbofan? So that is the attempt in a geared turbofan engine. This is the conventional engine, okay. It is a conventional engine and this one is a geared turbofan.

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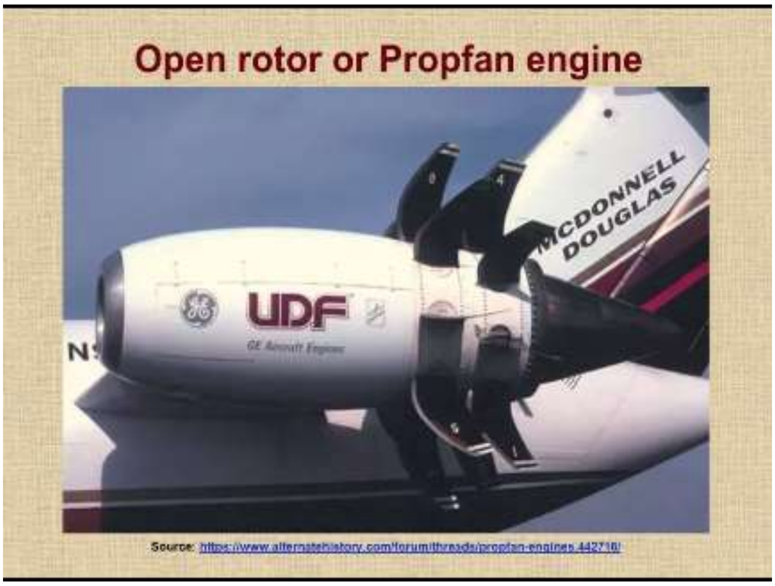

Then we have concepts like open rotor or propfan installation. So here is an example of UDF. So these are two contra rotating propellers which are mounted on the rear side. There is a fuselage and then there is a engine and both of them are firing the same engine.

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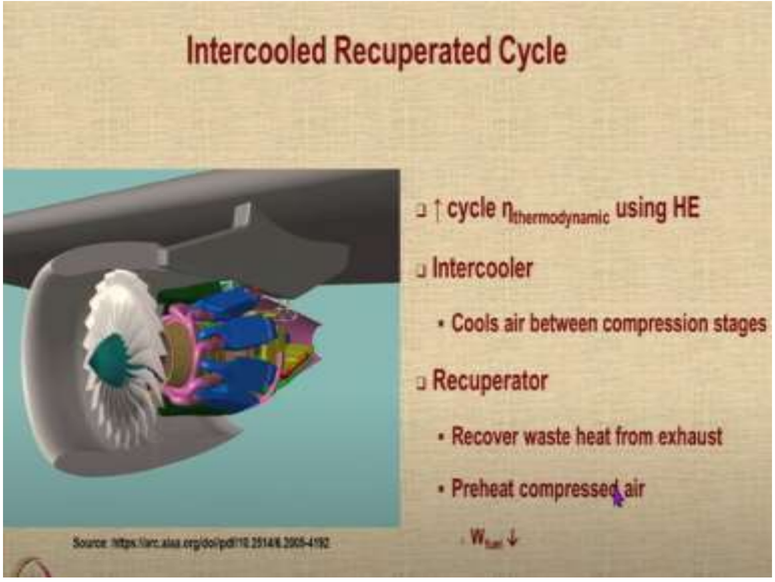

One option is to use intercooled recuperated cycle engine in which we increase the cycle thermodynamic efficiency by using heat exchangers, okay. The intercooler is a stage that cools the air between the compression stages so that the air can be given larger thermal energy. So that is called as a Recuperator. It recovers the waste heat from the exhaust and puts it back so you get preheat, you get compressed air.

Because of that the fuel weight consumption reduces and hence the emission is also reduced.

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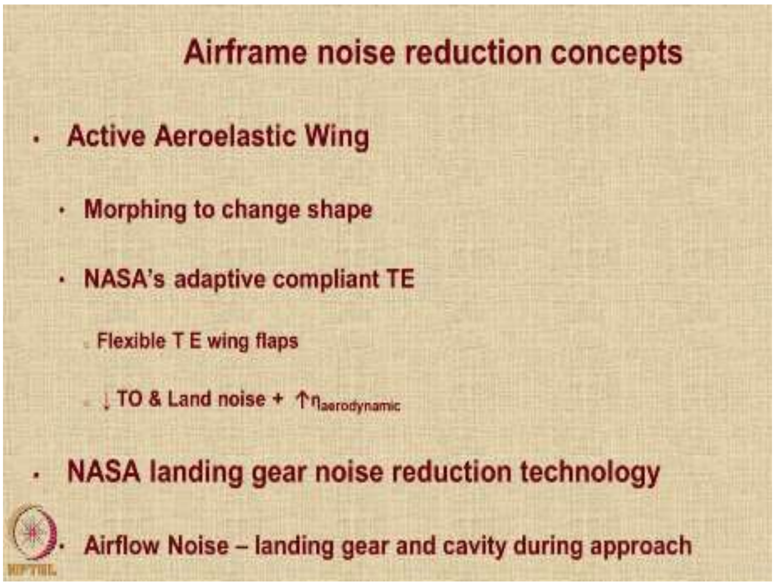

As far as the airframe is concerned even here we can use some technique to reduce the noise. Although the level of noise caused by the airframe is much lower compared to the aircraft noise we can use an active aeroelastic wing where morphing can be used to change the shape of the wing and then control the noise levels. You could for example, use adaptive compliant trailing edge and we will talk about it.

This particular scheme goes for flexible trailing edge wing flaps, okay. So it results in lower takeoff and landing noise and higher aerodynamic efficiency. Or we can also go for landing gear noise reduction technology as attempted by NASA. So landing gear and cavity during approach are the main reason for the airflow noise.

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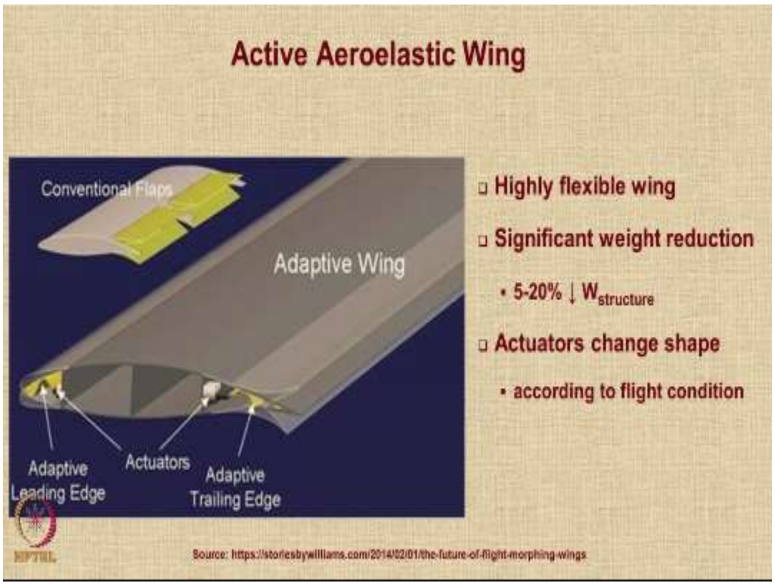

So here is an example of the adaptive wing. Conventional flaps are on the trailing edge and they are deflected mechanically. In the adaptive wing we use actuators which are going to change the trailing edge angle directly and also the leading edge if required. So there can be adaptive leading edge and adaptive trailing edge okay.

So this leads into a highly flexible wing with significant weight reduction because flaps are very heavy in normal circumstances. Usage of active aeroelastic wing leads to 5 to 20% lower weight of the structure and the actuators can change the shape of the aircraft. But these shapes are to be carried out as per the flight condition. However, it may be noted that this is a very tall order.

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It is very easy to say. But to get this thing working is not very easy. One such project was tried out by NASA Air Force you know, at Armstrong Flight Research Center by AFRL and they tried to use this compliant trailing edge to try and reduce the noise levels.

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Some studies have been done to reduce the noise of the landing gear, here is an example of so this video shows the creation of noise at various locations.

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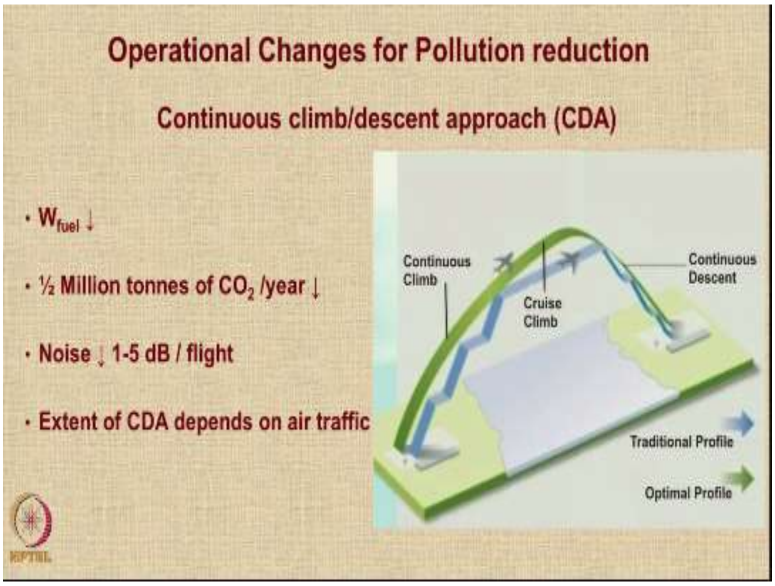

Finally, we can also reduce noise by changing the operational practices. One example of that is a scheme called as the continuous climb or descent approach. It is CDA. In current day operating scenario, the aircraft go into climbs in steps, okay. And even the descent also is in steps. This is for the ease of the aircraft. So the traditional profile is this blue profile which involves flight at these steps.

But if you have a continuous climb profile and a continuous descent profile, then the weight of the fuel consumed has been shown to reduce. About half million ton of carbon dioxide per year can be reduced by using only this CDA approach. During nighttime you can reduce the noise level by about 1 to 5 decibels.

But the extent of the CDA that you can follow depends on the air traffic that you are operating and also it may not be easy to implement it in an operational airport. So at Mumbai airport CDA trials were carried out and finally it was decided that we will not be going to implement this in the near future.

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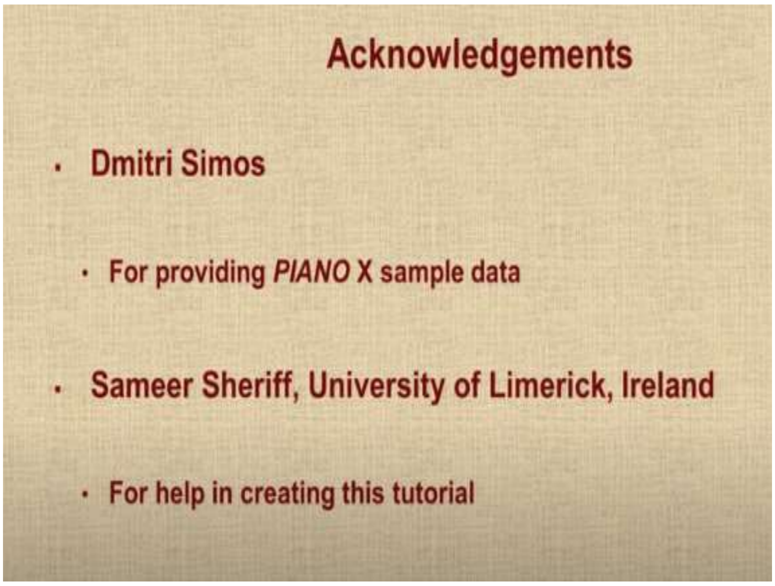

Before I stop, I would like to acknowledge Dmitri Simos for allowing us to use the PianoX software. He has given some sample data for a few aircraft and we have used those aircraft and run the software to generate the values of the emissions as discussed. And also I would like to thank Sameer Sheriff, a student of aerospace engineering at the University of Limerick in Ireland, who worked for me as a summer intern and helped in creating this tutorial. Thank you Sameer. Thanks for your attention.

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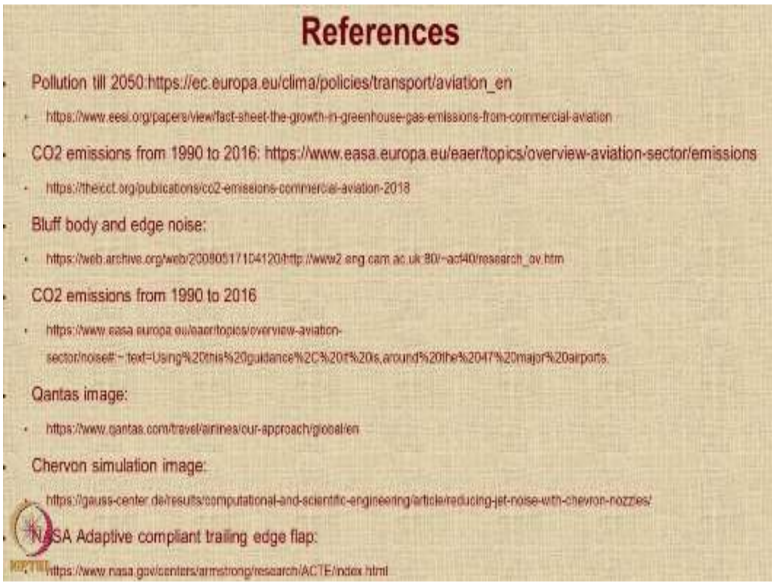

And there are some references which are available. So you can pause the video and look at these references for various specific topics. Thanks for your attention.