Introduction to Flight
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Lecture 07.3
Gas Turbo Engine Types: Part II

Turboshaft, turboshaft is a very interesting engine and this is mostly used in helicopters, because in helicopters you are interested to transfer the entire power that you generate to the rotor which is going to give you thrust as well as lift okay. How do you get thrust in the helicopter? By tilting the plane of the rotating shaft. So the engine is basically only a power producer. There is no function of a turbine here which can give an exhaust. So what we do is the entire power that is produced by the engine is passed on to the shaft and that is why it is called as a turboshaft.

So, very special class of engines which are as I said most common on helicopters. Now, this particular video as you can see it is a commercial video by a company which is trying to sell its engine to a customer. So they are not giving technical data but they are just giving you some kind of an animation about how it is. But this animation will help us to understand the functioning of this particular engine. So once again like a turboprop you do have the intake, you do have the compressor, you do have the turbine okay but the intake is there just behind the engine I will mark it to you with the mouse.

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DEPENDABLE
ENGINES
CDEEP
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TURBOSHAFT
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500 - 1,000 shp class
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PW210
1,000 shp class
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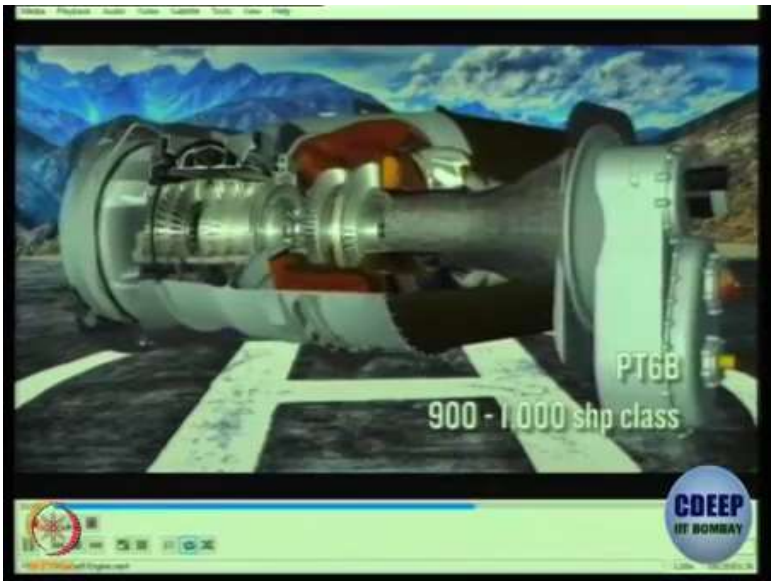
PT6B
900 - 1,000 shp class
CDEEP
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PT6C
1,600 - 2,000 shp class
CDEEP
IIT BOMBAY

So there is the intake, this is a intake. So the air is sucked in and in this case there was a centrifugal compressor because that is very compact okay. You anyway have a large diameter because you are going to use a turbine and you are going to have a shaft. So you take the air in, you compress it but then we are not worried about exhaust here. There is no exhaust thrust you can see the turbine is connected directly to the shaft and that shaft is normally turned 90 degrees and to that you attached your helicopter rotor.

So, it is a type of turbo prop but it doesn't have a propeller attached to it. The power is still given to the shaft but the shaft is turned 90 degrees and used to connect it to a rotor, where you can get the value. So the exhaust here does not give any thrust the exhaust here is just to throw the air out. It's very common for the APUs, the auxiliary power units and for the helicopters.

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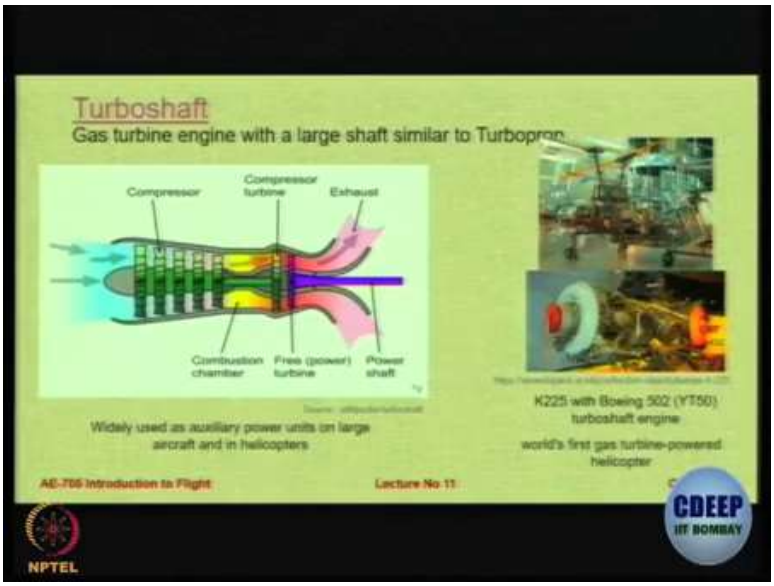

For example this is the world's first helicopter which had a turbofan turbine powered before this helicopters were generally used only piston powered or this was the first one to have a gas turbine in a helicopter and that one was a turbo shaft okay.

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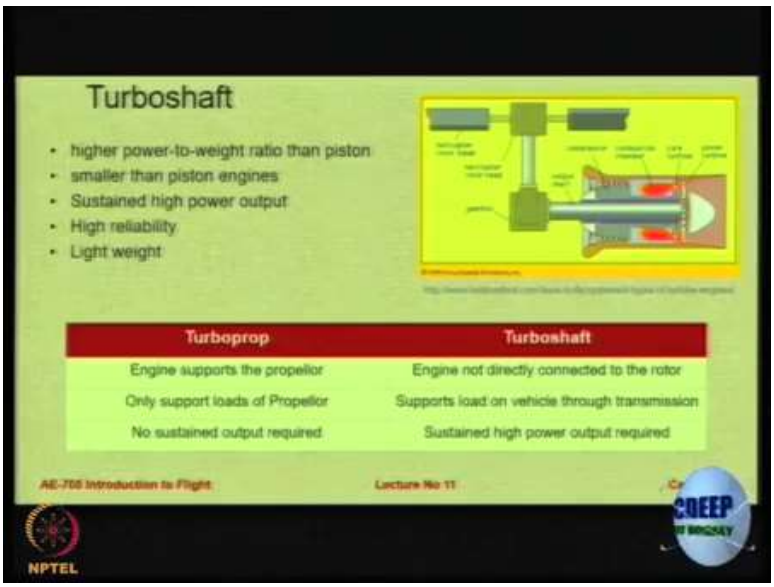

So you get a higher power to weight ratio than a piston because you are not extracting any thrust from the propeller. It becomes smaller and more compact than the piston engines, okay. As you

can see here the shaft is tilted and mounted to the helicopter rotor. So, this is the some difference between turboprop and turboshaft for you to mull over when you have time okay.

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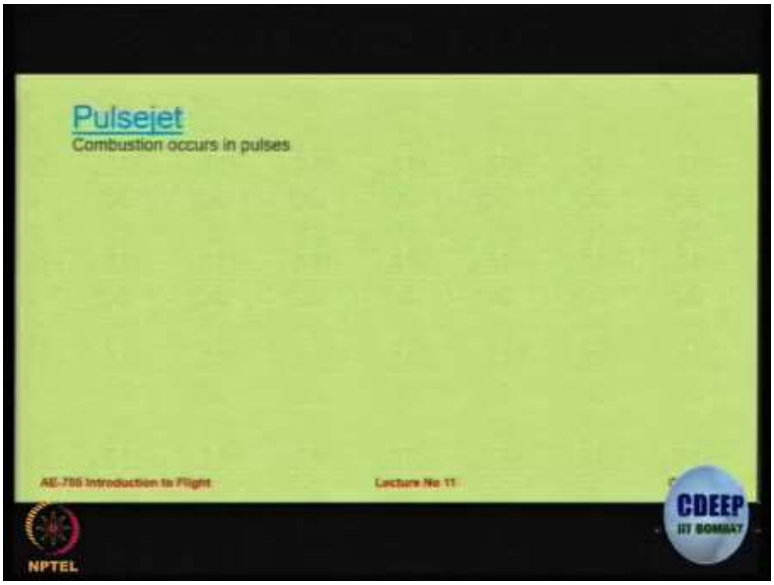

Now, we move on to interesting types of engines which are not so very common but still they have been used one of the very interesting one is called as a pulse jet or a buzz jet. So what is the pulse jet? In a pulse jet the thrust occurs in pulses.

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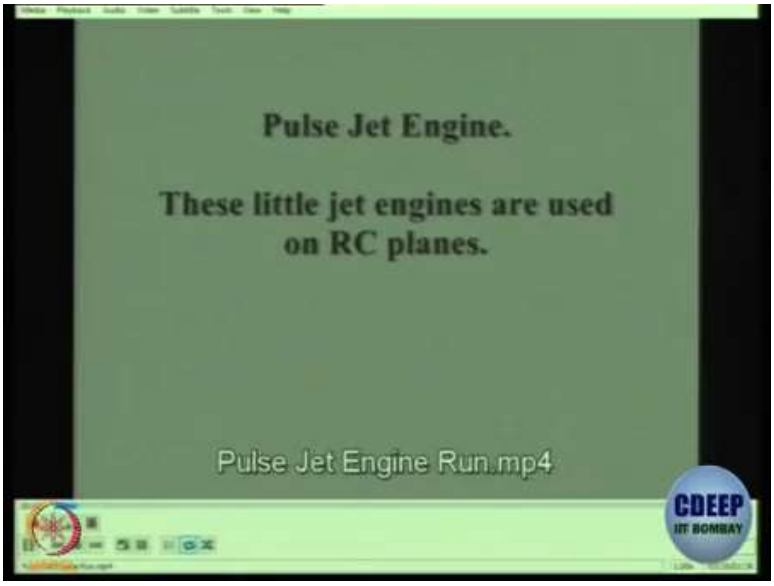


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Professor: So here is an example of a pulse jet which has been designed by an author for use on small remotely controlled aircraft okay.

Video: Okay, if you were attempt light off this pulse jet, make sure you turn down your volume real quick here. Here we go.

Professor: So in a pulse jet you will hear that the thrust comes in buzz okay. What is happening here is that you are injecting fuel in the pipe and then the fuel is ignited and when it is ignited the

back pressure of the combustion is going to open a valve or a series of valve, normally because of the butterfly valve and the butterfly valves allow the air to be exhausted?

But once it is exhausted because of a back pressure they are closed, so that is why the opening and closing at a very high frequency causes this buzz of this particular song. Now this engine you see is red-hot so because it is just an experimental engine but pulse jets are notorious to be also very noisy, huge vibration levels but they are very simple.

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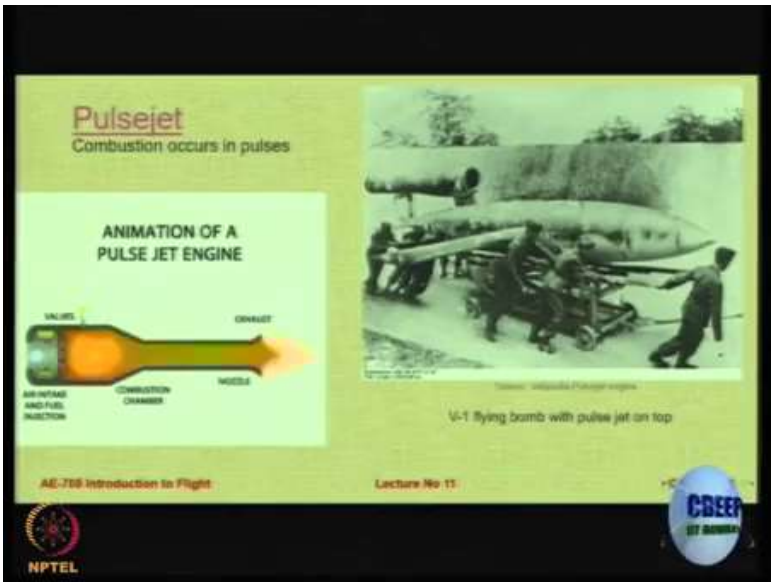

So this is the animation of how a pulse jet works. The key in a pulse jet is the availability of these series of valves in the front, so what do we see here is? If you go in slow motion you will see the air is intake there is an air intake in which air comes in when there comes in because of pressure the valve opens. When it goes inside you ignite, back pressure closes the valve and the reaction throws the product of combustion behind.

When that happens the valve again opens so the valves open-close open-close open-close at a very high frequency and at a particular combination of fuel flow and air speed you might get sustained combustion as you saw in this. It is very simple engine the most complicated part are the valves. If you can get the valves right then it is just a pipe, so that is why it is very attractive for some applications.

For example during the world war II London was bombed heavily by the Germans using what is called as a flying bomb, V1 flying bomb. In that if you notice on the top there is a pulse jet engine mounted and because this was a bomb of a disposable kind of an aircraft and then hence you can build them in large numbers and you can actually power them to give the required thrust values.

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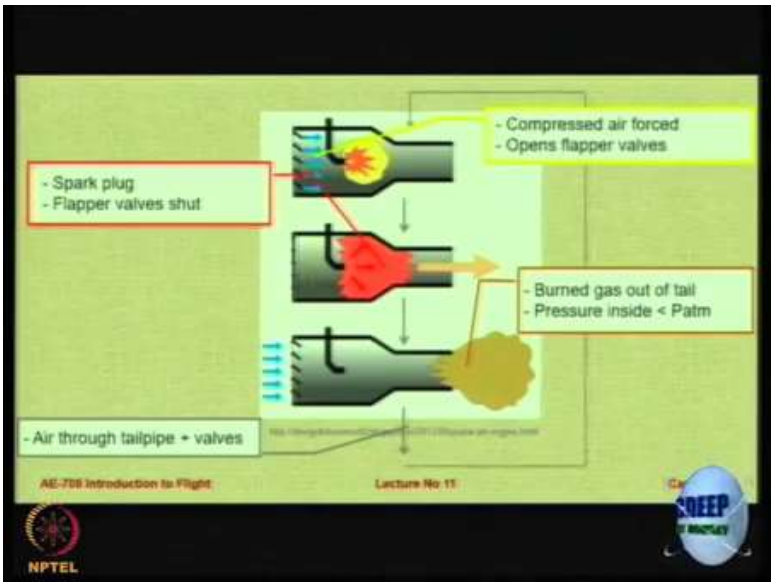

So, here is a working of the pulse jet. The compressed air from the front forces the flapper or butterfly valves open and the timing is very important when you open it at that time only the exhaust the combustion should start. With the combustion the back pressure closes the valves exhaust comes out as it is exhausted out, then air is again sucked in okay. This is what I already told you.

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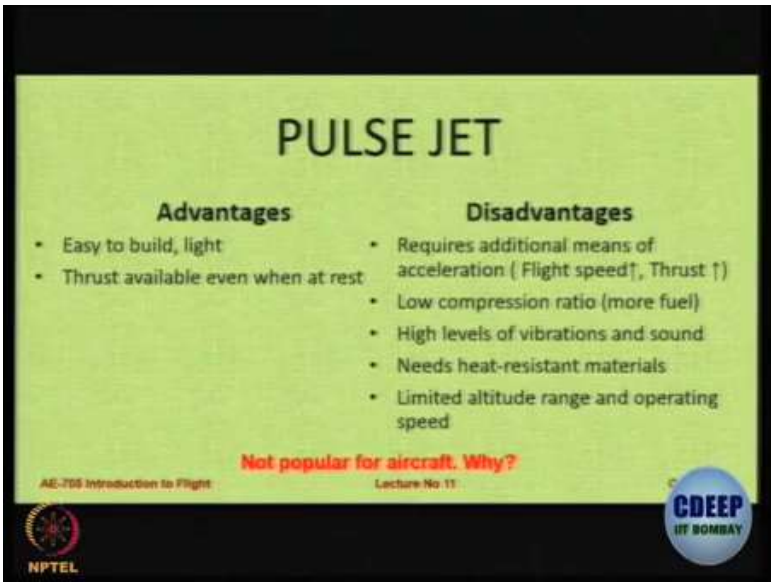

So, it is very easy to build, it is quite light, it is very simple and even when you are at rest, you can get thrust. Because you do not need a very high velocity, very high flight speed. In fact people have built pulse jet which can even power while it is stationary, like the one you saw just now. But there is a whole list of disadvantages with pulse jet and that is why we do not see them very often. So the reasons are given there but still I want you to go to MOODLE and give me more examples of why it is not popular for aircraft? Ok. But before I go ahead I want to show you one very interesting aircraft.

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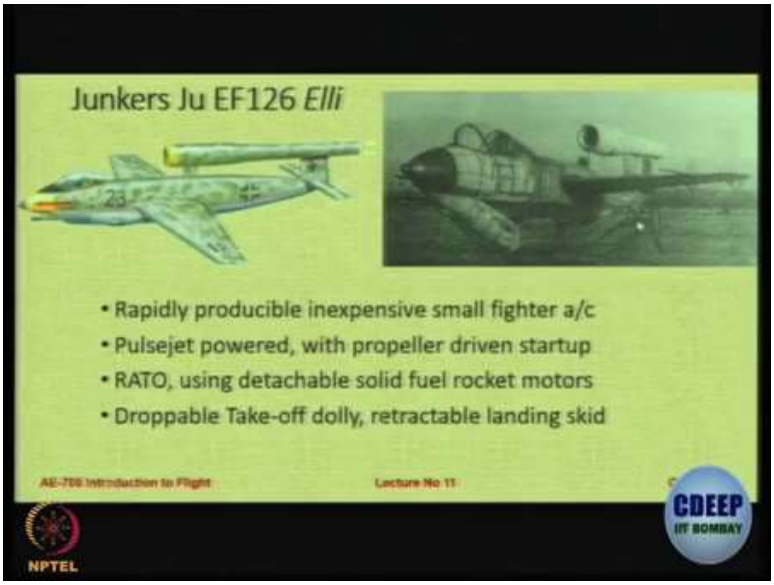

It is always said that, the most innovative designs come up when there is a war or when there is a requirement. History is full of examples of innovations and Jugaad and all kinds of contraptions to meet a particular requirement ok. So, this is one example of an innovation during the war. So during the war Germany was interested to create a large number of disposable aircraft, disposable bombers.

So they wanted to make small, inexpensive fighter aircraft which can be rapidly produced. So they came up with this idea of a pulse jet powered military aircraft ok. So it had a small propeller in the front to give the starting thrust where it starts moving. Once it reaches some minimum speed at which the air can come in it would be firing the pulse-jet and then it would fly with pulse-jet okay.

It had a rocket assisted takeoff using the detachable solid fuel rocket motors on the sides to allow it to given to be given a huge thrust during takeoff and interestingly the landing gear was droppable. So not clear in the sketch on the left if you look on the right it is not very clear, here is a kind of a droppable doll. So you mount it below the wings attach it and as the aircraft moves and the aircraft achieves a particular speed the landing gear is dropped. There is no room for it.

The landing gear is dropped, and interestingly this bottom portion that you see here it is a skid which is used in landing. Because although we wanted to make an inexpensive aircraft we also wanted to come back with the pilot but now there is no landing here so how will you land? So you land on a skid. A skid basically is a device with skids on the runway and it consumes so this is a very interesting design and it is cited as an example of innovation when you would like to go for addressing a need okay.

Moving on let us go to some other engines which are also being very popular. One of them is Ramjet.

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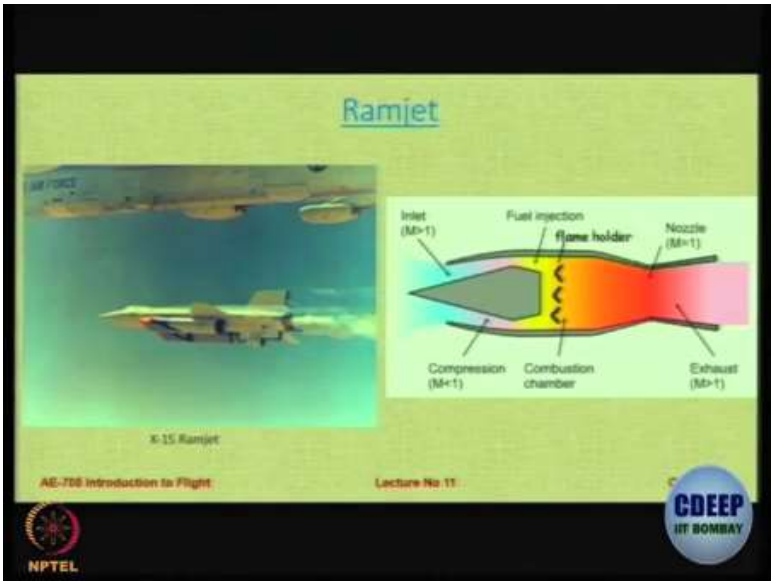

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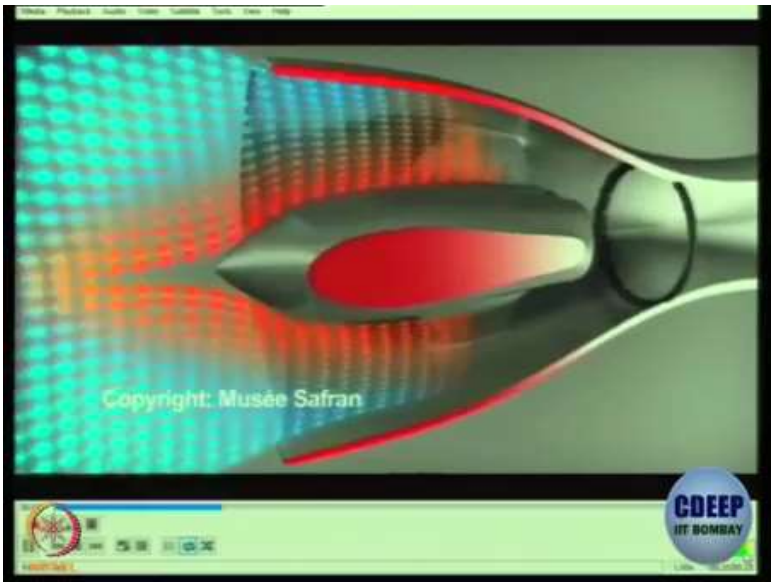

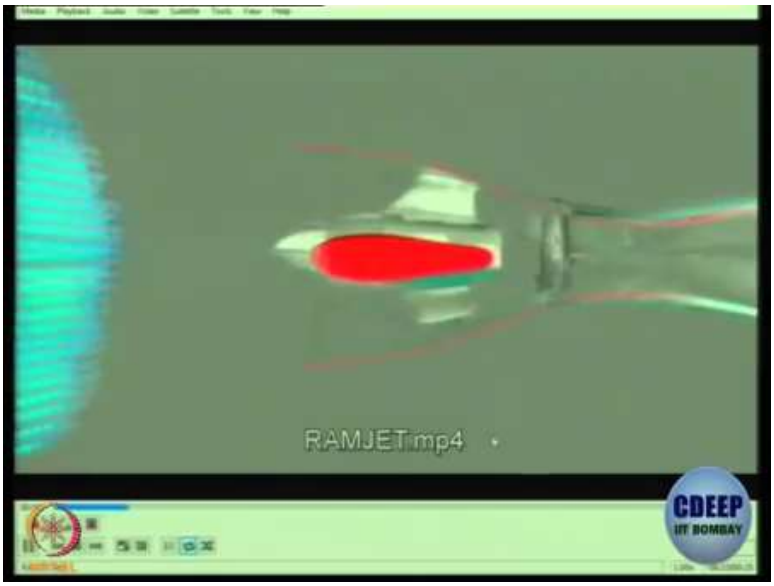

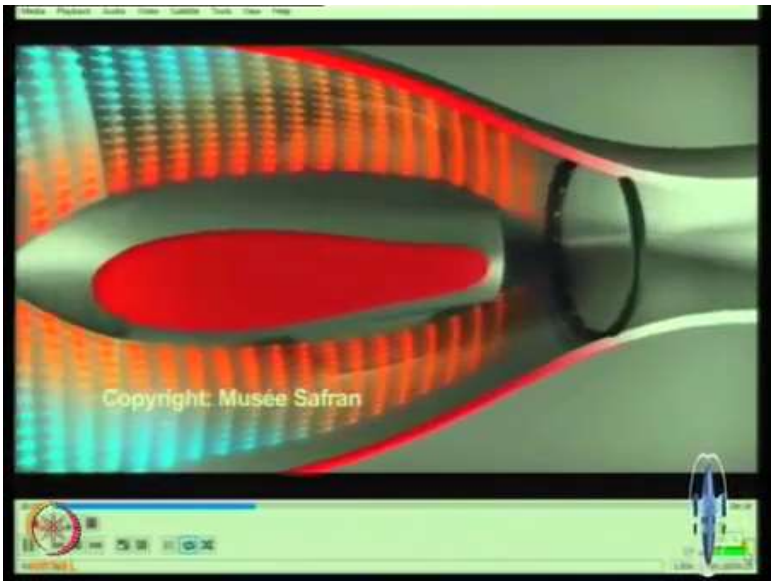
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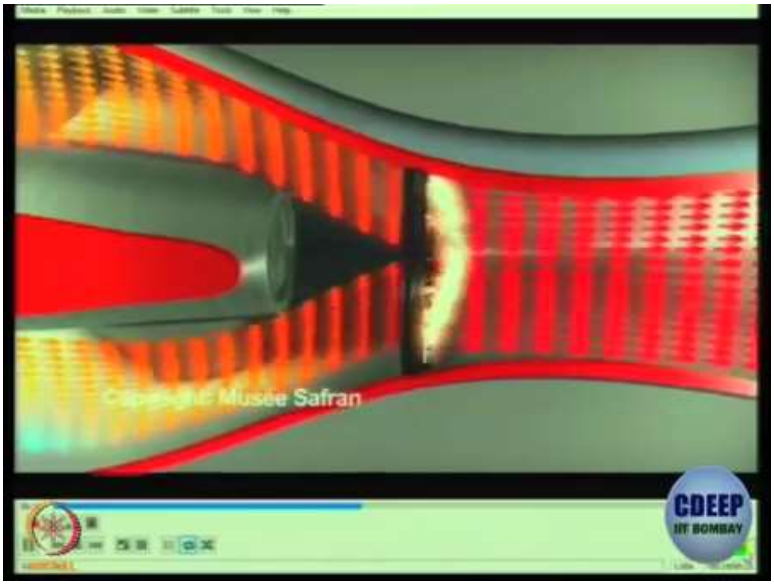
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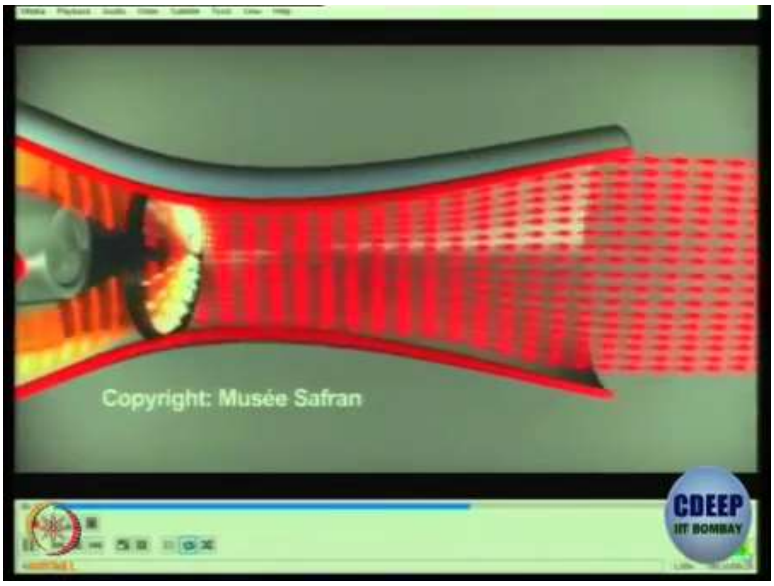
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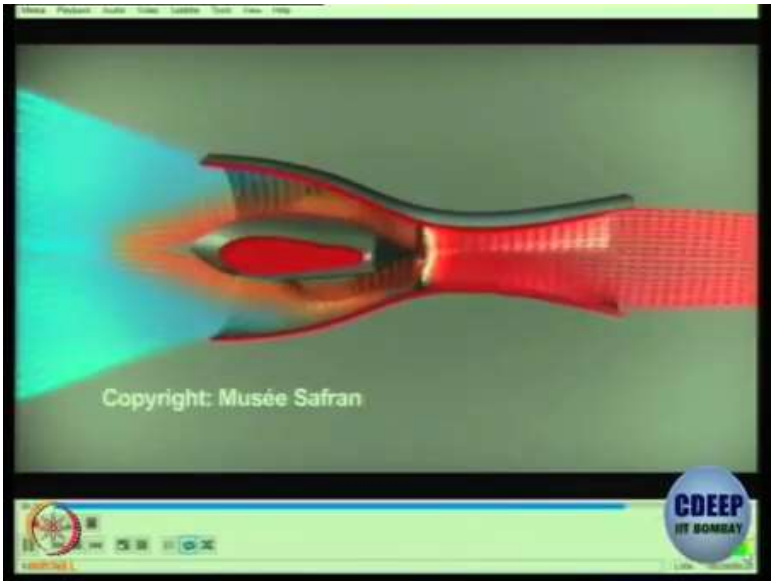
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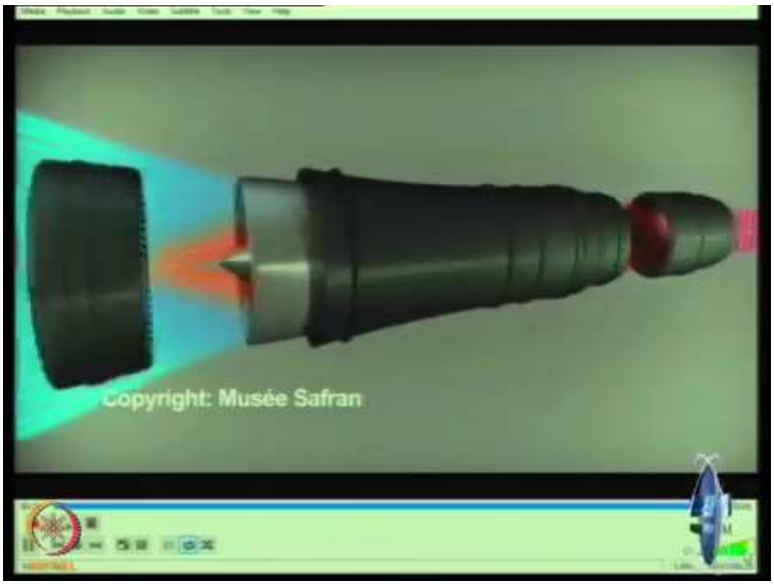

Professor: So a ramjet is actually an engine in which the most…

Video: Air rushes into the air inlet at very high pressure. There it meets with the fuel kerosene that is being sprayed in by the injectors. The combustion produced creates a large quantity of hot gas, which is then expelled from the rear of the motor can only really function at speeds over 500 kilometers an hour. So air rushes into the air inlet at very high pressure, there it meets with the fuel kerosene that is being sprayed in by the injectors. The combustion produced creates a large quantity of hot gas which is then expelled from the rear of the motor.

Professor: So you notice the beauty of Ramjet that is in its mechanical simplicity, no moving parts, no turbo machinery, no oscillations, no vibrations, and no imbalances. So what is it? It is a duct which is given a very appropriate shape and you may put some fixed bodies like this to provide an entry or an intake suitable for creating high pressure air in which the pressure has come only because of the RAM effect and hence you cannot use this at low speeds.

As the video mentioned that minimum speed is 500 kilometers per hour. So somehow you bring the aircraft to that speed. After that you switch on this engine and switch off that engine and if you are able to do it right it is self-sustaining. The air comes in at high pressure sufficient for it to be combusted. Fuel is sprayed on the ready to ignite air. The air ignites; gives reaction and you get thrust and when you slow down and reach a lower speed switch it off and put the other engine on.

So this elegance, this simplicity is very-very attractive for certain applications. For example, missile and rockets in which you might be able to somehow reach the speeds required for the Ramjet to self-ignite.

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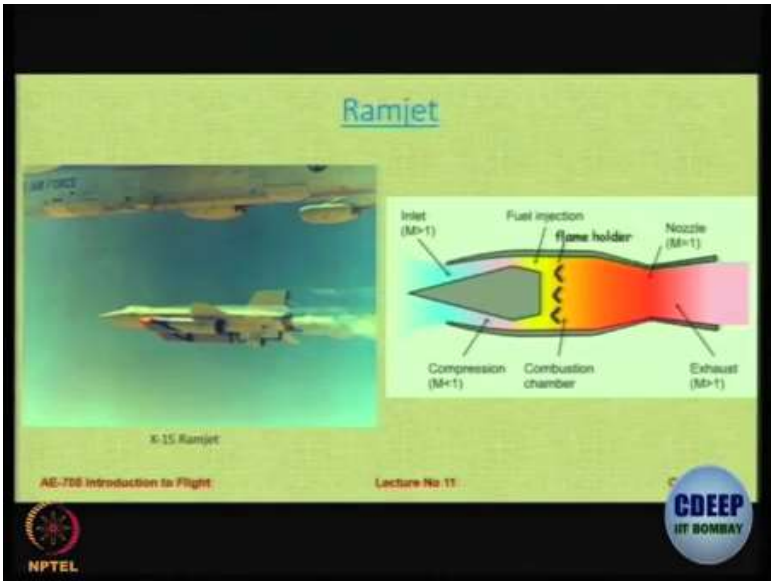

So here is an example of an aircraft X-15 which is mounted below at US Air Force aircraft it takes it to some Mach number okay and then it releases it now it's already at a speed at which it can start functioning okay or there is a rocket motor which gives you the thrust to reach that speed and then Ramjet starts igniting and after that you can get the required thrust okay, very elegant and therefore very attractive.

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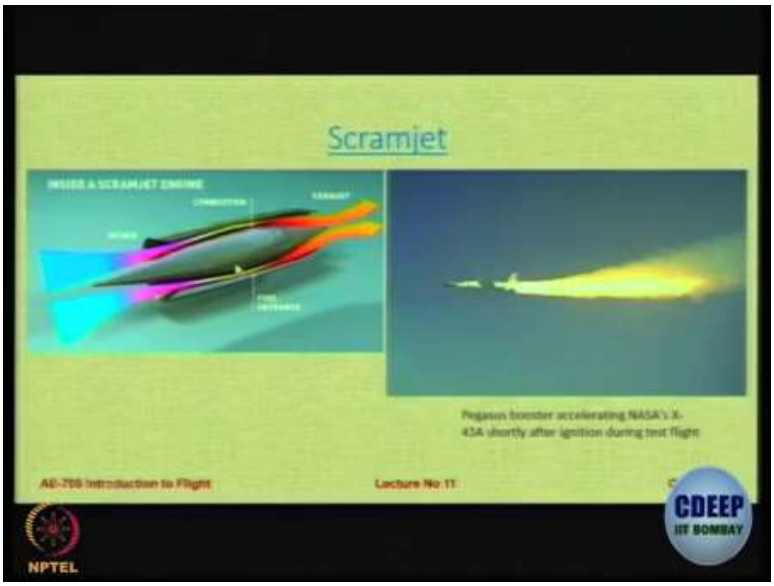

Now, going one step further is the supersonic combustion Ramjet or the Scramjet. And this technology is also under investigation in our country because we are making a vehicle called as the HSTDV. DRDO is working on a project and we are almost near the completion of that particular design. So let us have a look at Scramjet engine and its working.

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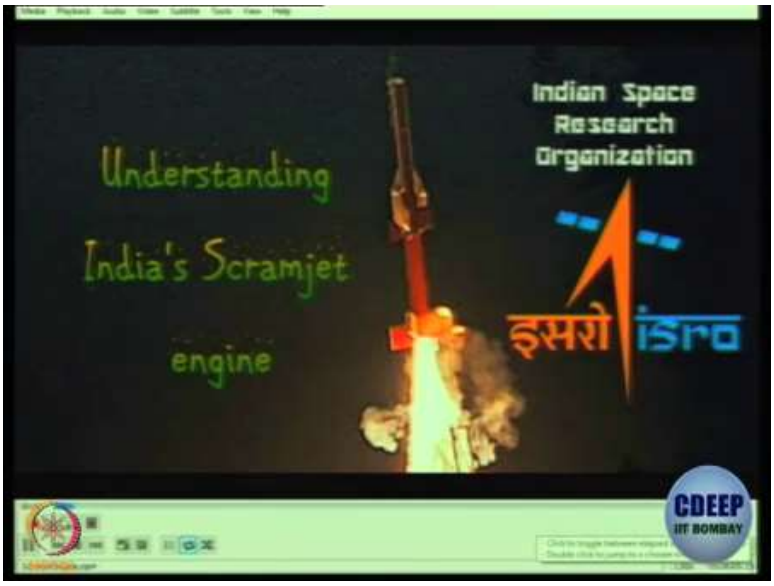
Understanding
India's Scramjet
engine
Indian Space
Research
Organization
इसरो isro
CDEEP
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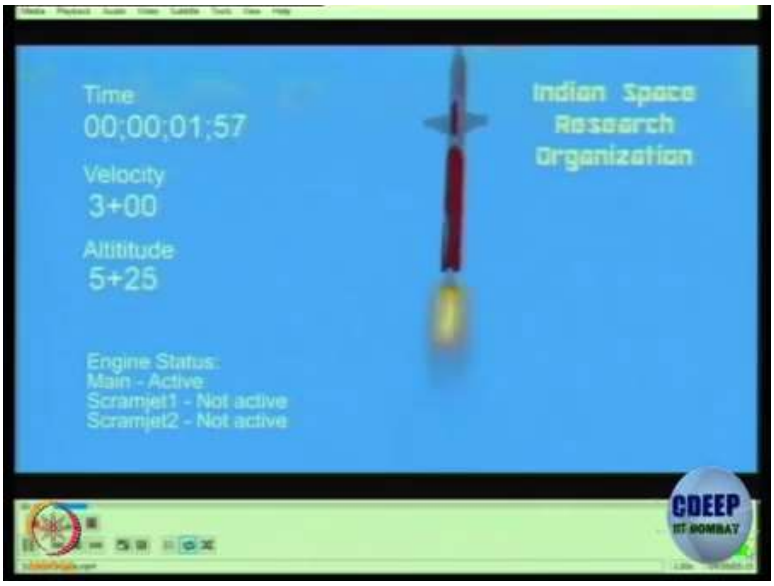
Time
00:00:00:45
Velocity
1+08
Altititude
3+33
Engine Status:
Main - Active
Scramjet1 - Not active
Scramjet2 - Not active
ISRO
Indian Space
Research
Organization


Time
00;00;01;57
Velocity
3+00
Altitude
5+25
Engine Status:
Main - Active
Scramjet1 - Not active
Scramjet2 - Not active
Indian Space
Research
Organization
CDEEP
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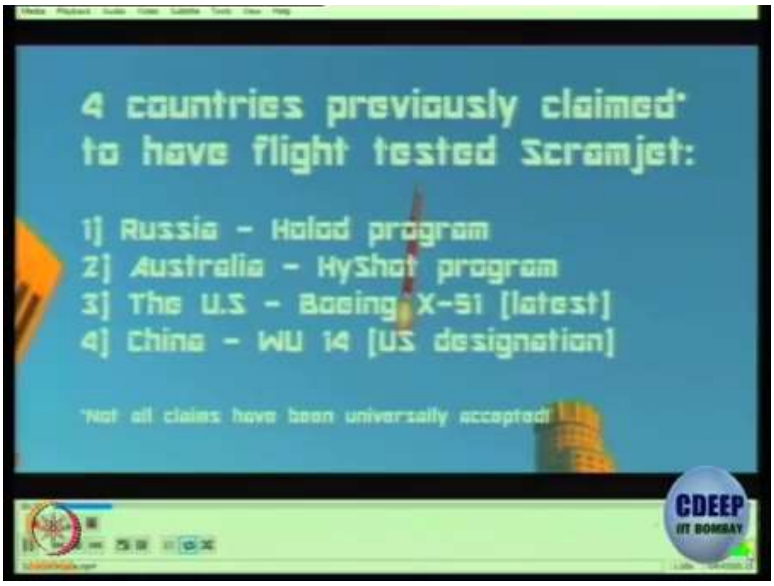

Video: Hi, Welcome to this edition of Tech Update. Last week Indian Space Research Organization or ISRO, propelled India into an elite League of Nations who have successfully flight tested a scramjet engine. So what is the big deal? Only four countries namely Russia, Australia, The US and China have previously claimed to have flight tested this technology.

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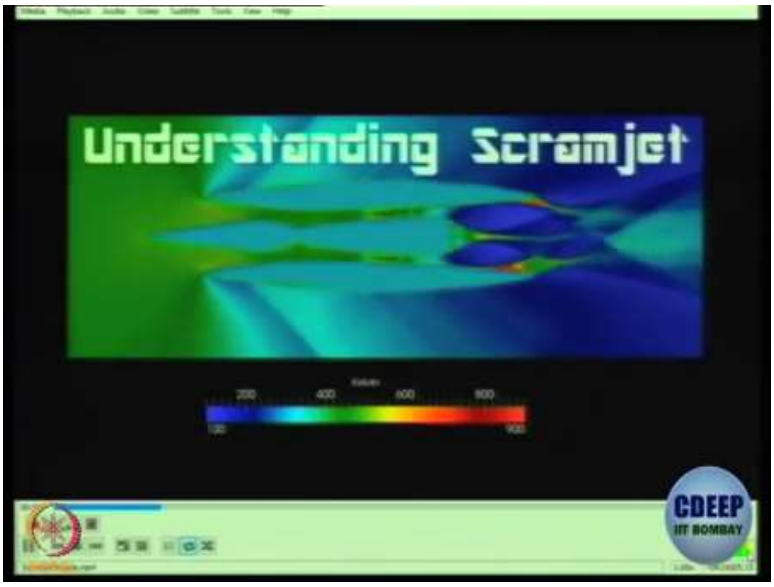
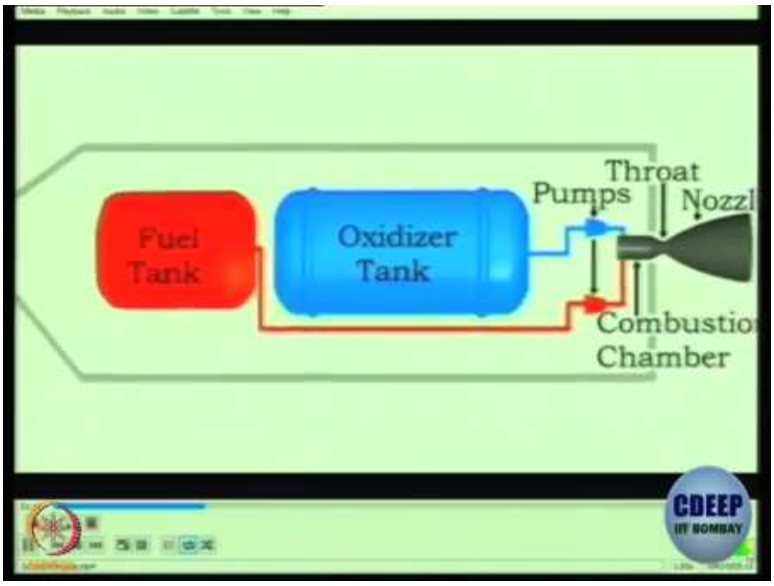
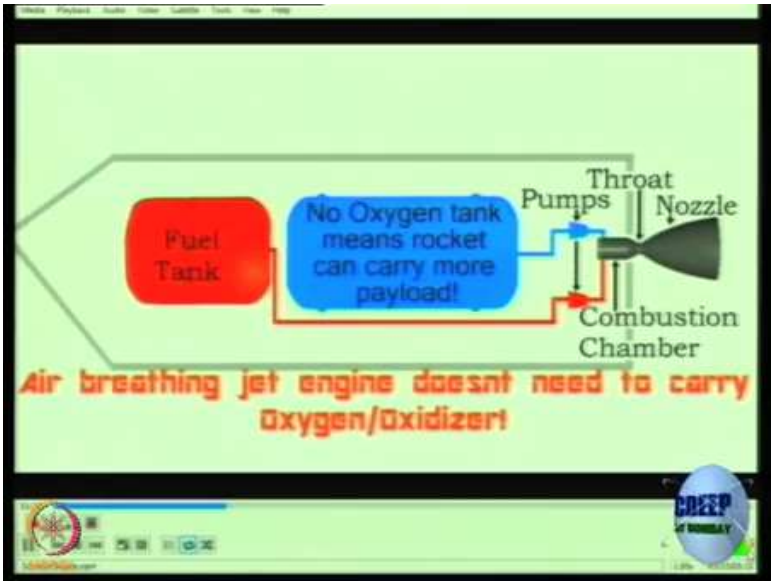
eing [US Airforce] X-51A:
Longest Scramjet flight test ~200s!
CDEEP
IIT BOMBAY


Understanding Scramjet
CDEEP
IIT BOMBAY


OXYGEN
HEAT
FUEL
FUEL + Oxygen + HEAT -> FLAME
CDEEP
IIT BOMBAY


Oxygen
OXYGEN
HEAT
FUEL
FUEL + Oxygen + HEAT -> FLAME





Furthermore it was only in 1991 that the first flight test was performed by the Russians. That is 22 years after man first landing on moon. Also the longest flight test ever recorded by a scramjet was just over 200 seconds by US Air Force X-51A. This show seems to be a complex technology to master. To understand this technology better let us start from basics. As we all know to burn something we need air, more specifically oxygen.

That is the reason why Rockets traveling beyond Earth's atmosphere carry its own supply of oxygen or oxidizers but the present-day Rockets use oxidizers or oxygen even then it is traveling through the Earth's atmosphere considering that almost 50 percent of Rockets weight is oxidizers.

Would not it be great to use atmospheric oxygen during this time? That is exactly what an air breathing jet engine is designed to do.

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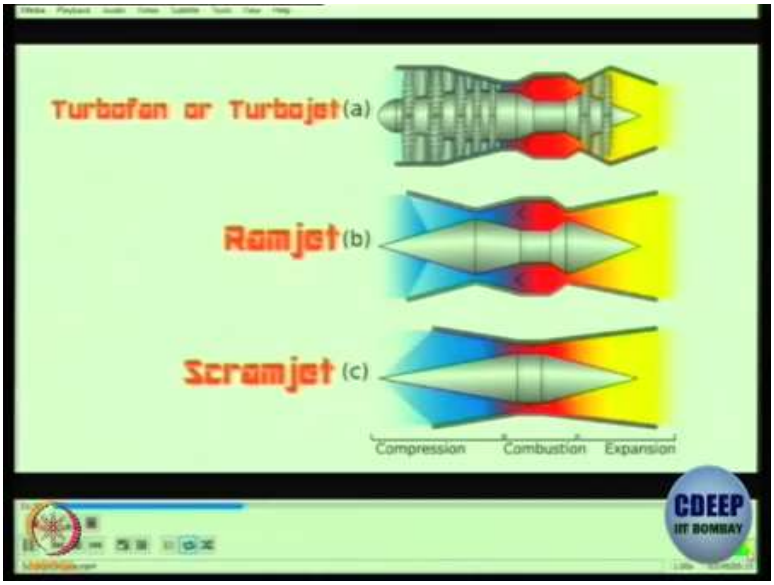
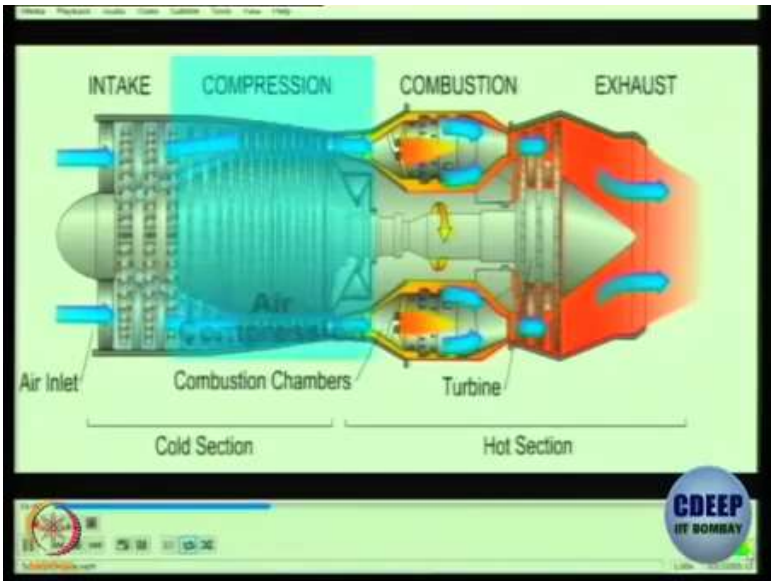
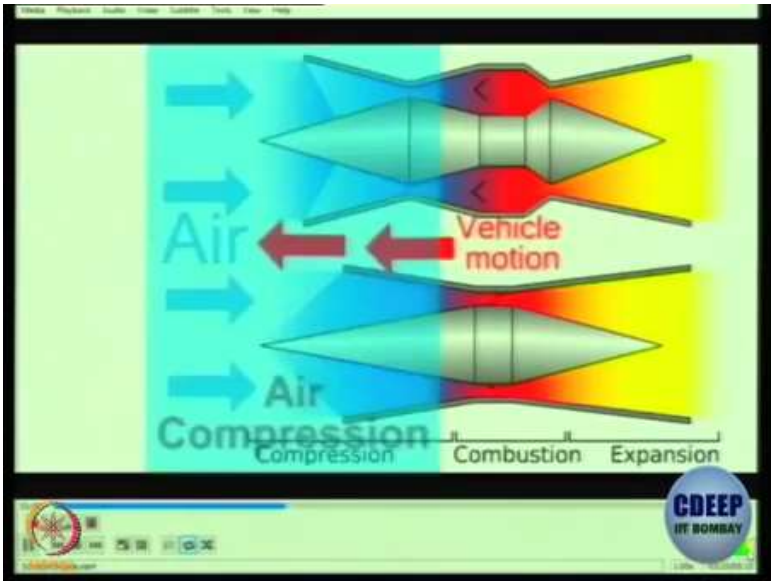
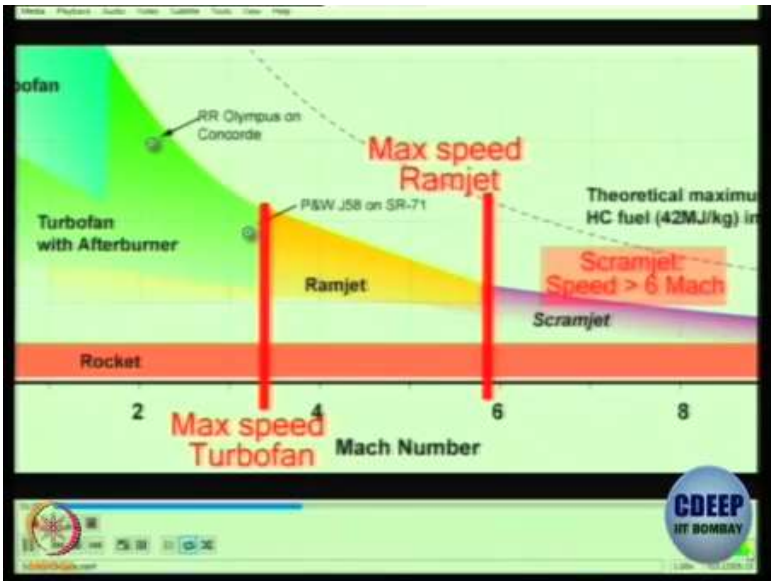
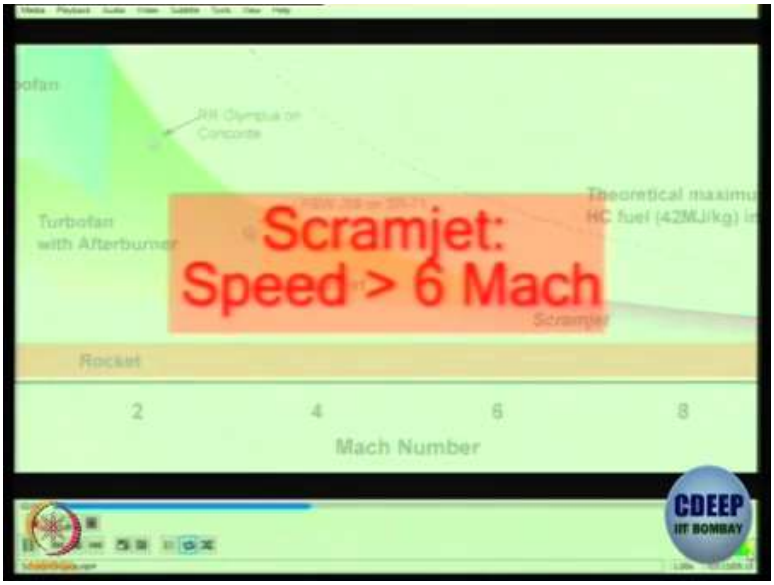



INTAKE
COMPRESSION
COMBUSTION
EXHAUST
Air
Air Inlet
Combustion Chambers
Turbine
Cold Section
Hot Section
CDEEP
IIT BOMBAY


Air
Vehicle motion
Air
Compression
Compression
Combustion
Expansion
CDEEP
IIT BOMBAY


RR Olympus on Concorde
Max speed Ramjet
P&W J58 on SR-71
Turbofan with Afterburner
Ramjet
Scramjet: Speed > 6 Mach
Scramjet
Rocket
2
4
6
8
Max speed Turbofan
Mach Number
CDEEP IIT BOMBAY


Turbofan with Afterburner
Scramjet: Speed > 6 Mach
Rocket
2
4
6
8
Mach Number
CDEEP IIT BOMBAY

There are three types of jet engines, namely turbofan or turbojet, ramjet and scramjet. All these engines work similarly but differ in the way how air is compressed before being burnt in the engine. The Turbofan is the familiar aircraft engine where a gas turbine based compressor is used to compress the air. On the other hand both scramjet and ramjet engines do not have a compressor but utilize the high speed forward motion to compress the air. This chart compares the performance of different air breathing jet engine and shows the speed at which they can operate. It is evident that scramjets are the fastest among jet engines. That is the reason why there is a great deal of excitement about scramjet engines.

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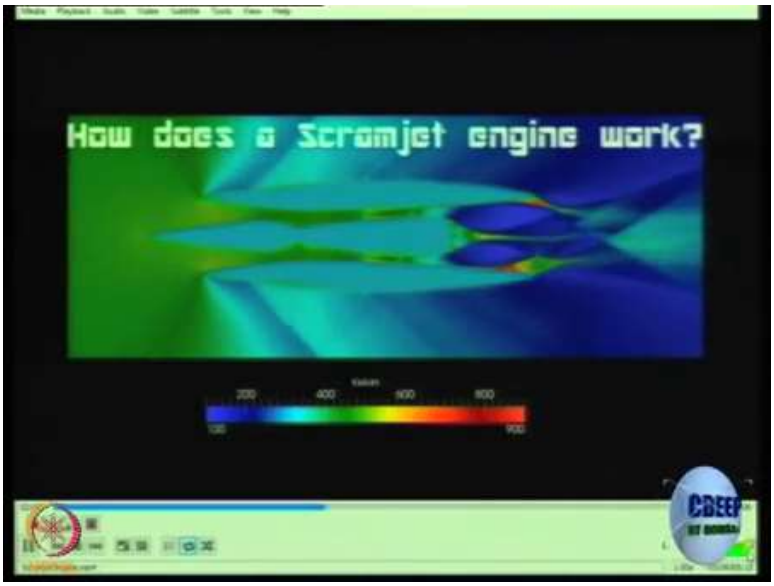
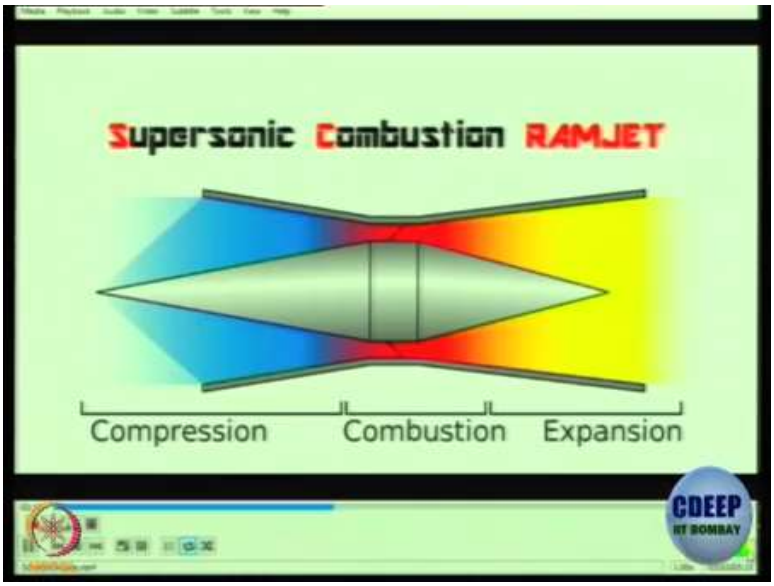
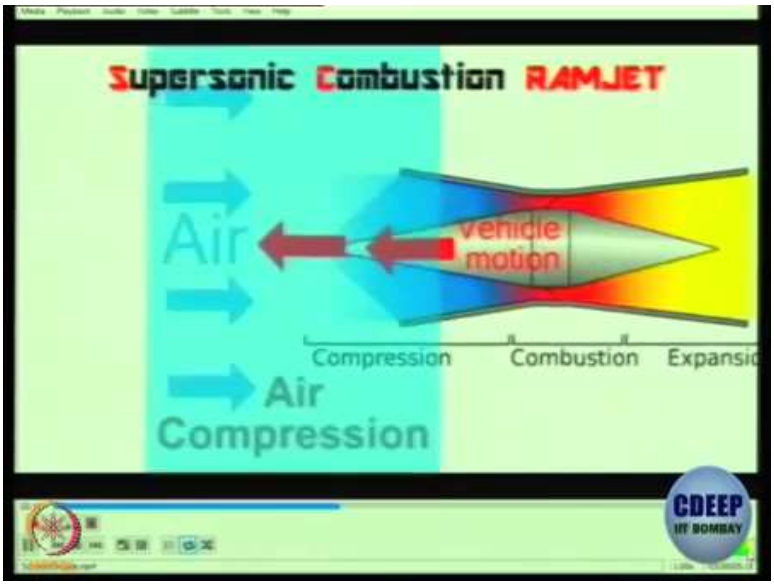
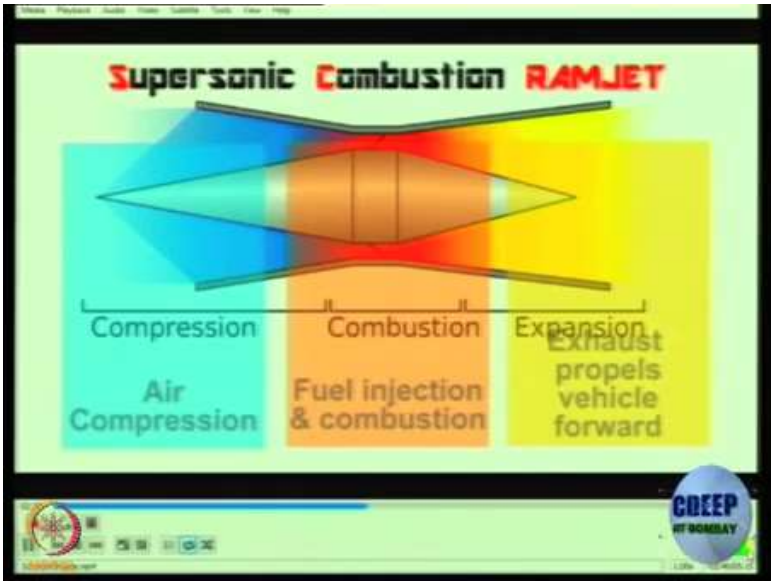





Supersonic Combustion RAMJET
Air
Vehicle motion
Compression
Combustion
Air Compression
CDEEP
IIT BOMBAY


Supersonic Combustion RAMJET
Compression
Combustion
Expansion
Air Compression
Fuel injection & combustion
Exhaust propels vehicle forward
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High vehicle speed needed
to activate scramjet engine!
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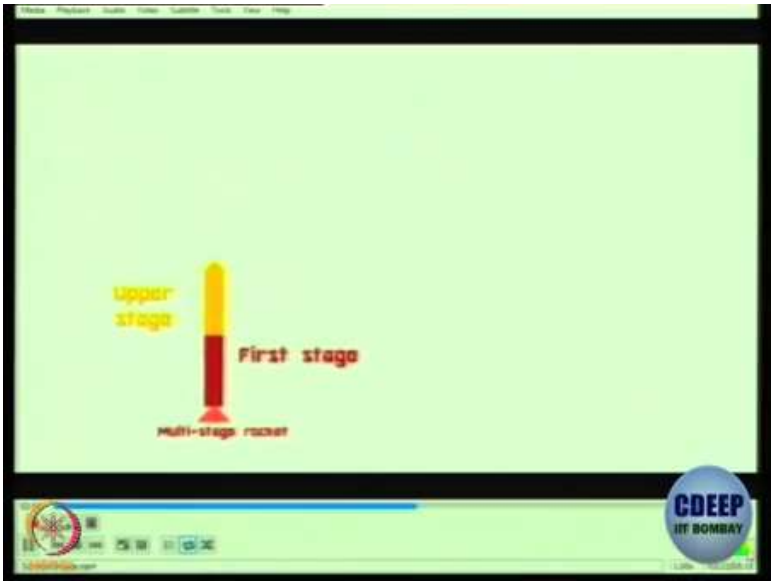
upper
stage
First stage
Multi-stage rocket
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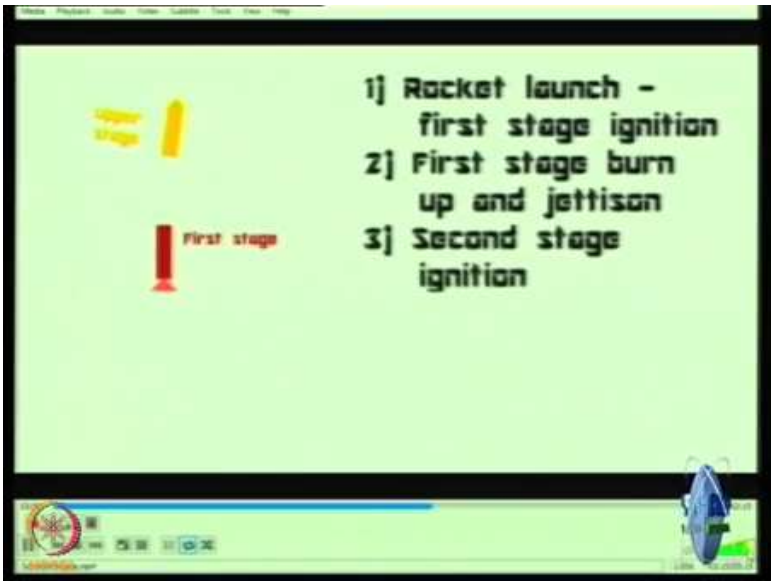
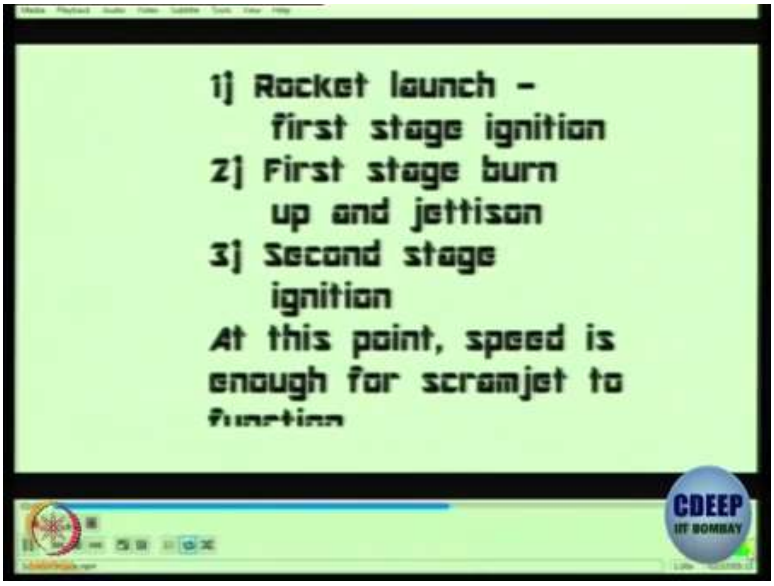

1] Rocket launch –
first stage ignition
2] First stage burn
up and jettison
3] Second stage
ignition
First stage


1] Rocket launch –
first stage ignition
2] First stage burn
up and jettison
3] Second stage
ignition
At this point, speed is
enough for scramjet to
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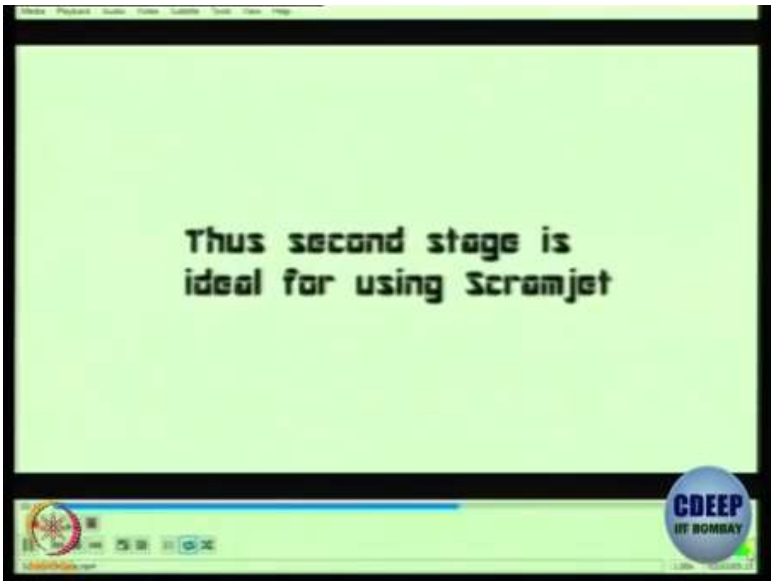

So how does the scramjet work? Scramjet stands for supersonic combustion ramjet. As I said earlier scramjet engines utilize the high-speed forward motion to compress the air. Fuel is then injected in combustion chamber where it mixes with the hot compressed air and ignites. The resulting jet of heated exhaust gas propels the vehicle forward. However, since the scramjet engine cannot function till the vehicle has gained enough speed it needs a different engine such as a rocket engine to get it to the required speed.

Thus a scramjet engine cannot function independently which is its main drawback. However there is an intelligent solution to this which is exactly what ISRO did during the flight test. A launch vehicle usually has multiple stages each having its own engine. Usually the stage is jettisoned after the fuel burns out. This is done to reduce the weight of the launch vehicle. So when the second stage begins to fire up the launch vehicle is already traveling at a high speed. Therefore using scramjet in second stage would be the best way to overcome its drawback just as it is rotates.

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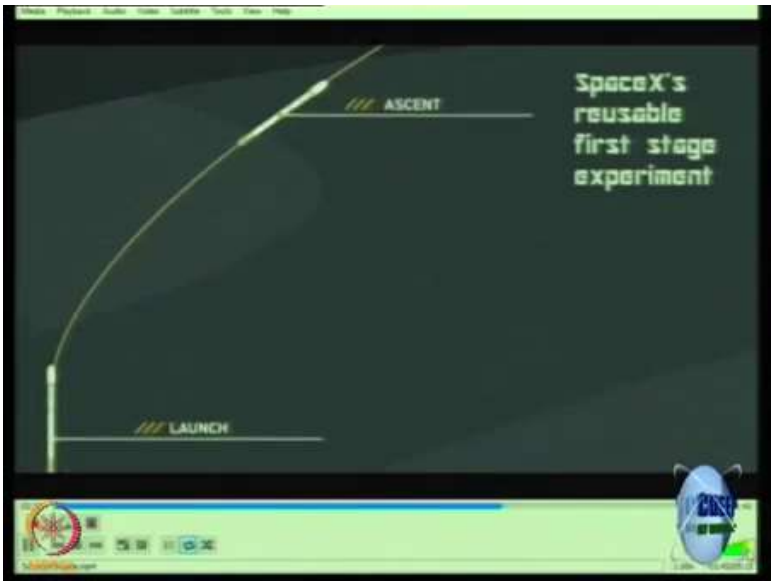
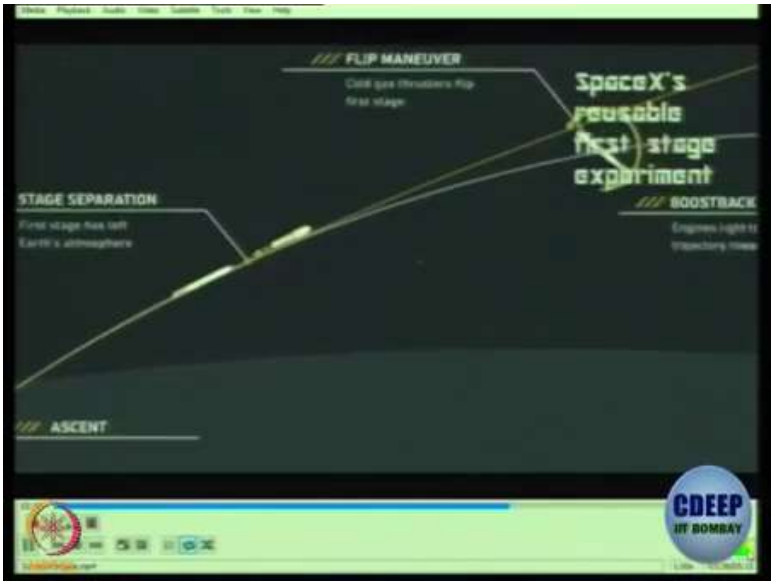
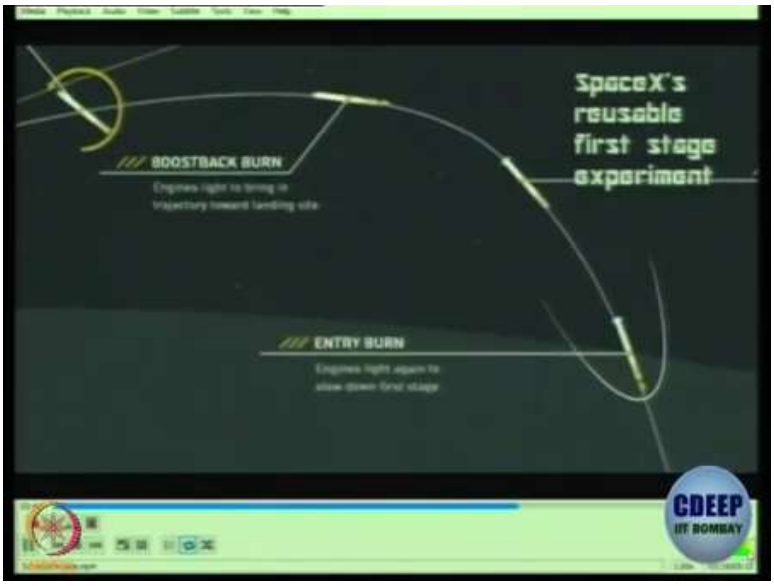
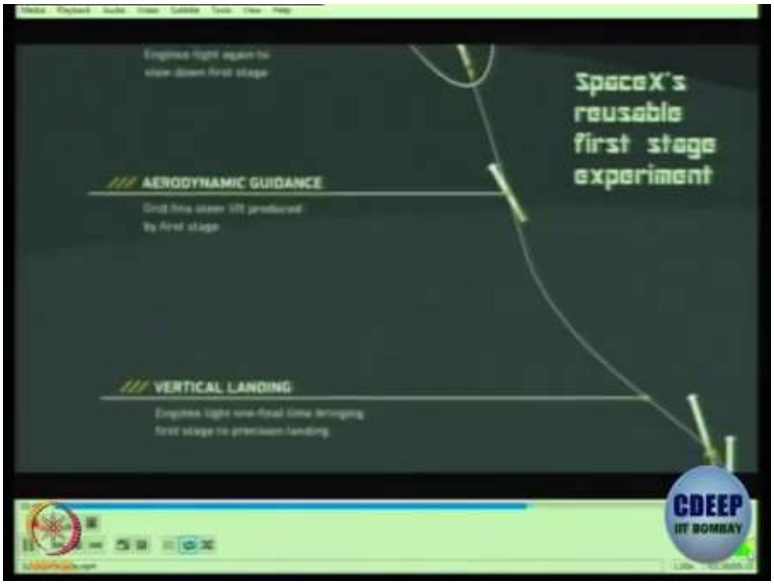

ASCENT
SpaceX's reusable first stage experiment
LAUNCH


FLIP MANEUVER
SpaceX's reusable first stage experiment
STAGE SEPARATION
BOOSTBACK
ASCENT
CDEEP
IIT BOMBAY





So why is ISRO working on this technology? The satellite launching business is valued at billions of dollars and companies such as SpaceX are aggressively using new technologies to compete with the market leaders. ISRO already has one of the lowest price for launch and charges just 60 percent of what the market leader Arian space charges. By incorporating new technologies such as scramjet and reusable launch vehicles ISRO is trying to be more aggressive to gain a bigger pie of this huge business.

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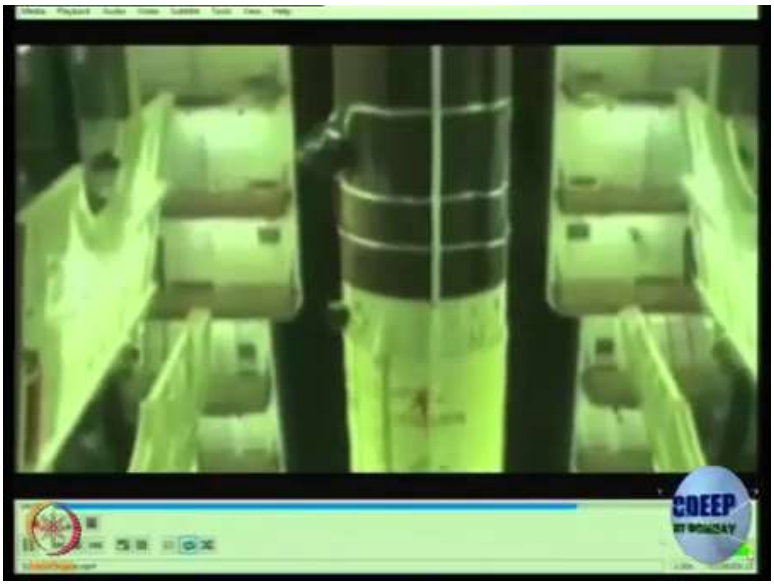

Furthermore Indian government can do more with its limited space budget all right. Almost at the end of the video let us take a quick look at what ISRO has achieved. The flight test of scramjet lasted for five seconds reaching a speed of Mach 6 which is six times the speed of sound. This test has validated all scramjet systems developed by ISRO, such as mixing and compressing of air at high speeds, igniting the air fuel mixture and sustaining the flame.

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8 सितबर को श्रीहारकोटा से किया जाएगा लान्च


8 सितबर को श्रीहारकोटा से किया जाएगा लान्च
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अब मिलेगा मौसम का बेहतर जानकारी
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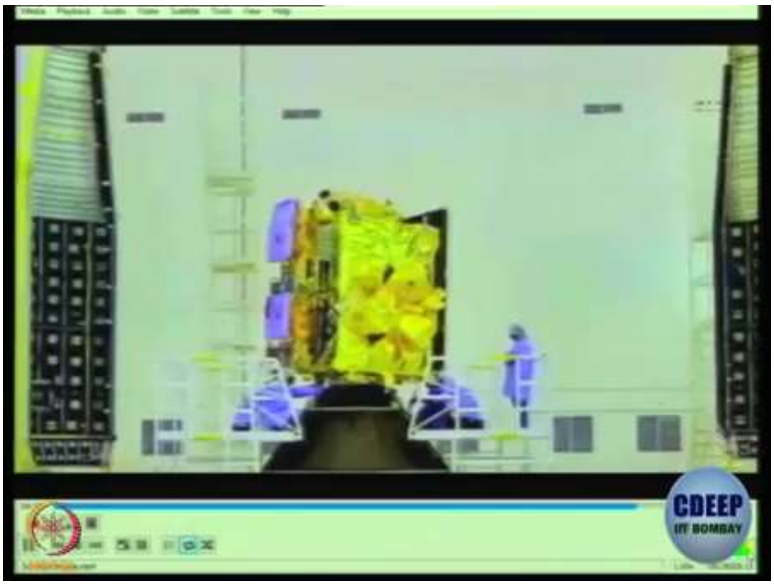

ISRO claims that scramjet would significantly reduce the cost and increase its payload capacity of its launch vehicles. ISRO has achieved all these by spending just 5.3 million dollars compared to over 250 million dollars spent by NASA for its X-43A project. This is what ISRO chairman had to say after the launch.

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It is a very significant development for the country and the efforts of long-duration R&D well. See, right now we have been able to demonstrate for five seconds now we have to do it for a longer duration and also we also have to work out a way of using this effectively in our launch vehicle.

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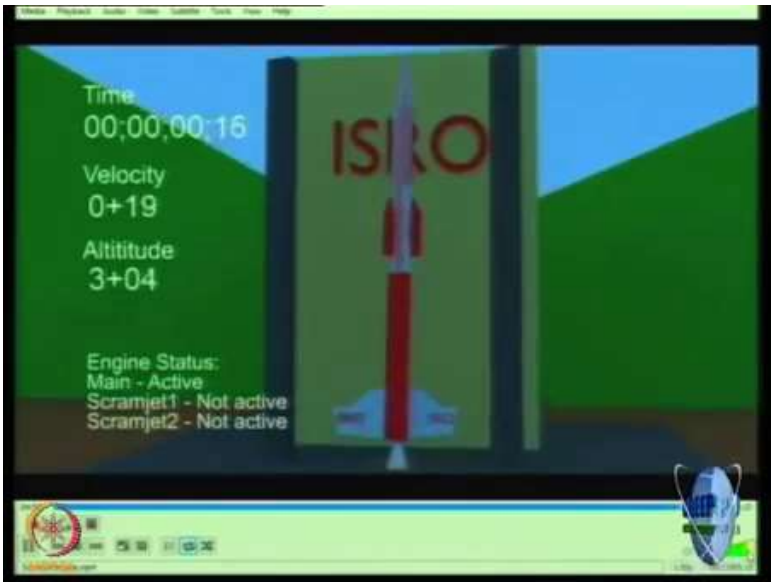

Video: In conclusion even though this technology is years away from being actually used in a launch vehicle this is nevertheless a small but significant step by ISRO. What do you guys think?

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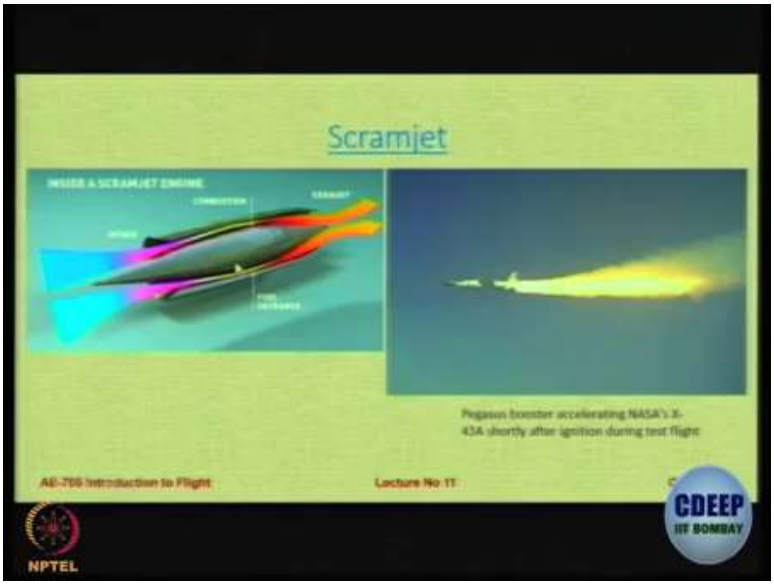

Professor: Okay. So this is an example of how the scramjet engine can be used to generate the required thrust at higher Mach numbers.