Fundamentals of Aerospace Propulsion
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Lecture - 03

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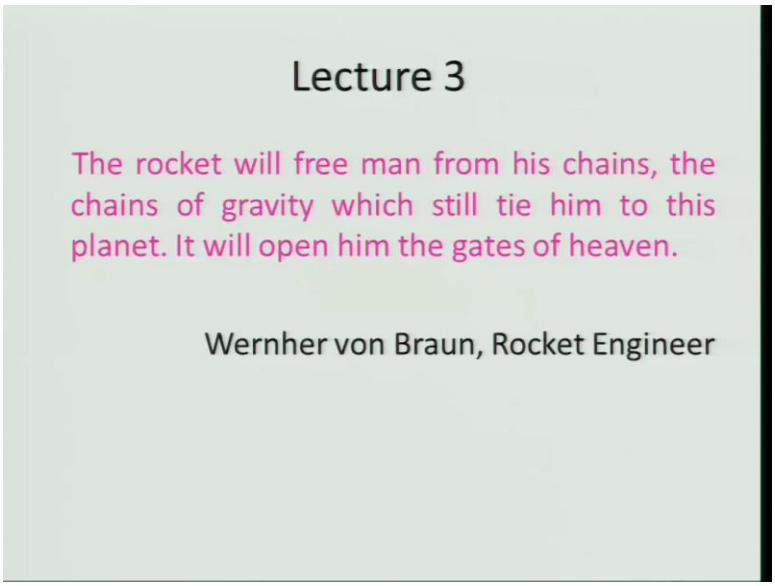

Let us start, this lecture with a third process given by a rocket engineer Wernher von Braun, and he says that the rocket will free man from his chains of gravity, which will still tie him to this planet. It will open him the gates of heaven is it, really true that what he says is right or wrong? That I will leave it to you, and let us recall what we discuss in the last lecture? And first we discuss about how this history of propulsion evolve and during that time we learn three things, which I would like to draw your attention one is that engineering need not to wait for the science to evolve. So, also the science.

So, of course, they can complement each other that is the one, we should learn the other thing you must learn that. This aerospace propulsion and also other technologies are being driven by the war mongering people, which must not be done for the development. The third aspect one has to remember that what I am emphasizing the sensitivity of individual for the flight of the people.

And mankind is very essential for developing any new technology that will be congruent with the all the ecological needs, requirements and also the human being needs. So, with this, we moved into the various classes of the aerospace propulsive devices, we broadly

divided in two categories. One is air breathing engine other is non air breathing engines under the class of air breathing engine. In which air will be taken to be the reacting with the chemical fuels for producing a thrust power under that categories.

We are discuss about turbo jet turbo fan, and turbo prop engine apart from piston engine, which is being use rough usely even today, from the starting of the aircraft engine. The aircraft propulsive device and beside this, we have discuss also about what you call the non air breathing engines. In which category we concentrate on the rocket or the chemical rocket engines, and it is I have classified into broadly into three categories.

One is solid propylene rocket engine. Other is liquid propylene rocket engines, and combination of both solid and propylene, what we call it as a hybrid rocket engines today, what will be discussing is basically about, how we can combined this air breathing and non air breathing engines? And I will give you a very, what you call glimpse? About it birds I view about that, and then we will move into the non chemical rocket engines.

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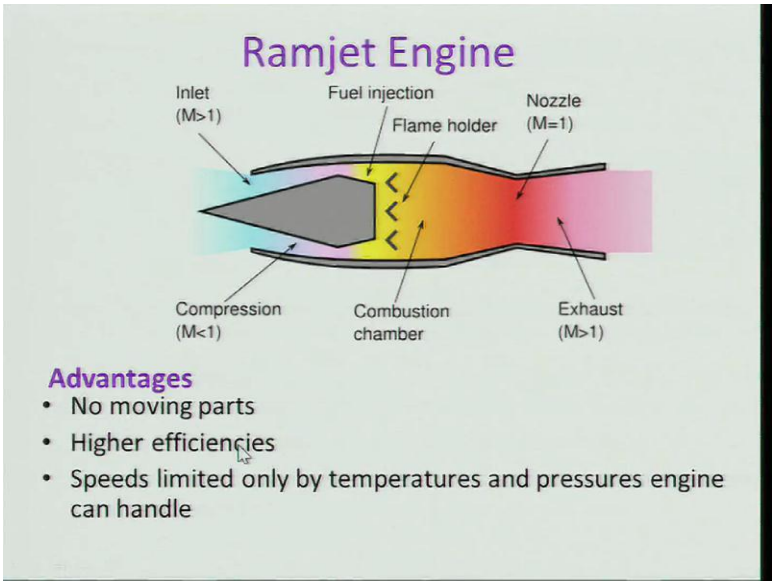

If you look at, this is a ramjet engine, which I have shown here in this case it is not having any rotary components. This is having a air in take here, and this is your combustion chamber, and the this is a nozzle and if you look at, the air will be entering at a very high speed. The aim stands for mach number; that means, it should be greater than one, and it will enter and decelerated in the air intake, and then you will have to have a

fuel, which is injected into it such that you can have a combustion in the subsonic regime, and then it will be expanded a nozzle to have a trust.

And it is having several advantages over the other turbojet engine categories, because it is not having what you call? It is not having any rotary if parts, and it is quite lighter as compare to others like and it is having higher efficiency, and speeds of course, limited only by the temperature , and pressure of the engine that can handle; that means, material problem can be avoided, but it is having disadvantage that it cannot start of its own right. Particularly in the initially take out take out trust it cannot provide.

So, therefore, that is the big problem, which you as you go along will see how it can be solve? And this is being use in the missile system.

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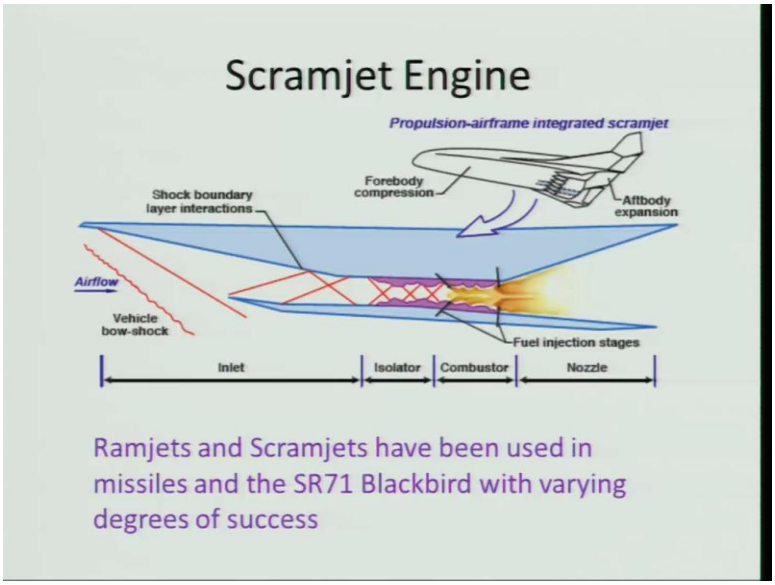

As of now, and there is a another exotic engine, which as come up is known as scramjet engines. Unlike in the ramjet engines here the combustion will be taking place in the supersonic mode, and keep in mind that this is a quite exotic and interesting engine, which people are trying from the starting from nineteen fifty's till date; however, with a very very limited success.

And india is having a program of a very ambitious program of developing scramjet engines. Lot of money has being pumped into it two organizations particular d r d l and v s c c or working on this moment, on this concept development engines and this is having

several application apart from the air breathing, you know like apart from the missile application. It can have a what you call terrestrial application as well particularly, whenever the vehicle will be moving in the atmospheric region.

So, let us look at a schematic of that. If you look at your air intake region will be starting from here it is a quite high, because the flow we will be at a very high speed it is a basically hypersonic vehicle for, which it can be used and therefore, the fluid or the flow has to be decelerated, but; however, you cannot really distillate to subsonic, because if would decelerate to a higher to their lower velocity from the very high velocity.

Then naturally there will be ionization, and if ionization will occur then you cannot really produce any trust rather, you will have to you cannot added any fuel to produce a trust. So, in order to avoid that the this is being decelerator till the supersonic speed, and then combustion chamber. In which the fuel is added and of course. So, that it can be release in this case, which is quite difficult part because the time requirement for the combustion to take place is quite small, and then it has to be ignited, and also burnt completely such that efficiency will be higher.

So, this is the changeling part, and beside this flame stabilization another very important aspect, which is being address I mean like at this moment with little success or may be to some extent their successful in devising, but; however, there is a lot more to be done in further, and it will be inject it will expanded the hard gas will be expanded in a nozzle to produce a trust.

So, if you look at one cannot really isolate the engine for say from what you call body? Therefore, this is a propulsion air from integrated scramjet engine; that means, the propulsion device must be integrated with the air frame properly, otherwise it will be not successful to half this flight, and it has been use in some of the recent what you call s r seven one blackbird with of course, varying degrees of success and in future people says that it will be having.

What you call lot of possibilities of developing a better systems propulsive devices, and not only india, but there is several other countries like u s a, australia and other countries their working we mightily, but I am having a one question ask you people to be really need to have this engine, because it guzzles a large amount of money and the material, and other aspects are also as to be looked at it. So, particularly from the indian

prospective, whether we could look it of course, lot of the young people are excited about this engine, because of our icon that abdul kalama. Who is a you know? What you call icon for the students to follow that? And we should look at this aspect, and see how it can be use for the common human being then that of winning a war or for a limited war, limited number of people.

So, beside this we will be discussing about that how this engine concept both the air breathing and non air breathing can be combined together, because each class of engine is having their own advantages and disadvantages like. If you look at a human being each individual will be having certain good qualities, and certain bad qualities, but when you combined together, and work in a group.

We try to maximize the good qualities. So, that society or a system can run unfortunately. It is not happening in india, but that is the desirable and it is more natural to be that. So, therefore, in the same process is being utilize while developing engineering system or component. That you combined try to see, whether you can optimize. What you call performances? And optimize the process such that you can get the maximum benefit of development.

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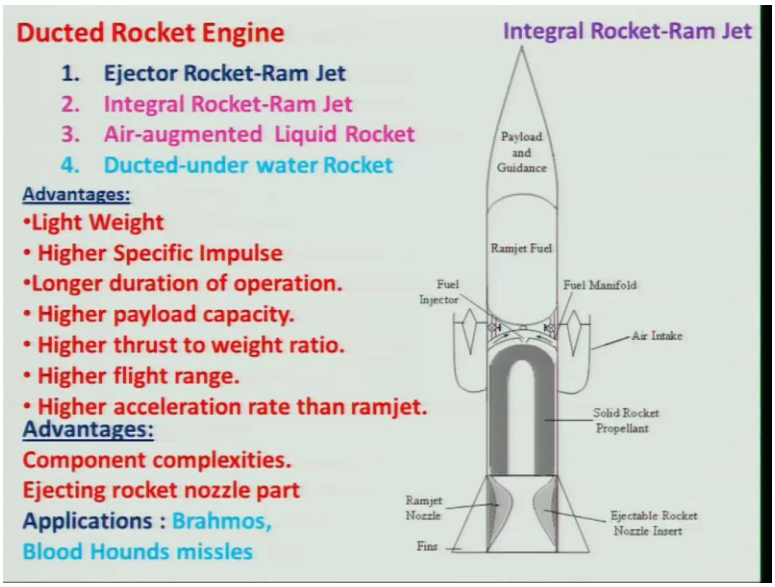

So, there are several combination, one can think of like one of them what I have discuss is the ram rocket engines. And their might be also this is known as what you call combine cycles rocket, combine cycle engines, and turbo combine cycles engines kind of

that; that means, in one class their will be rocket and the ramjet combinations, and in other case a turbojets and ramjet combination. So, what will be a discussing about this a ducted rocket engines in this generally rocket is being used to start with right, wherever the initial trust is required at take of trust is required, which this advantages for the ramjet engine.

And then in this case the rocket will be working on the reach condition, and you would take some air from the atmosphere, and then burnt with the reach fuel, which will be remaining, and then you will be injected out of that engine nozzle to get the trust, and there are several class kind of thing this is the basic idea that is known as ducted rocket engine, but there are several class kind of things like ejector rocket ram jet engines, and in this case it will in the initial started with the ejector, and the rocket will be acting will be working till the mach number two, and after the it reaches the mach number two that ram jet will be taking over. So, this is known ejector ram jet engines.

We will be there are several other classes like integral rocket ram jet engine, air augmented liquid rocket engine, and ducted under water rocket engine, which I would not be discussing, we will be discussing basically integral rocket ram jet engines, and in the next slide will be discussing air augment liquid engine.

If you look at advantage there are several of them. It is having light weight higher specific impulse, which will be discussing and defining you can say that it is having a better performance parameter longer duration operation, because of like rocket engine it can be operated for limited time, but whereas, if you are breathing the air, and then it will be operate for longer time, and then higher payload capacity, and higher trust to weight ratio, which is a quite good as compare to the rocket or the solid propylene rocket engine. Higher flight range and higher acceleration rate than the ramjet engine and as.

So, I told you it is having several advantages. Let us consider, its disadvantages its component complexities, and eject a rocket nozzle part kind of things I will just let us look at, what is this integral ram rocket jet engines? If you look at it is having a. What you call a ram jet fuel, which is having here and it is to start with it is having a solid propellant rocket engines having a separate nozzle to start with this rocket solid propellant rocket, which will be fired, and then a once it is you know high pressure, and high temperature gas is being generated.

In this it will be ejected through this nozzle, and he will get the trust initial trust, but after that once it reaches the mach number of two kind of thing then this whole rocket propellant or the grain the rocket engines along with the nozzle will be ejected; that means, this is eject able nozzle insert, which will be going out ejected out, and then it will taking the air and fuel the ram jet fuel and it will be working like a liquid propellant ram jet engines and you can take a very longer path.

So, it has been use in our brahmos the missile system, which a being you know being developed by d r d o, and russian federation, and beside this it has been use in blood hounds missiles in u k, and several other places as well.

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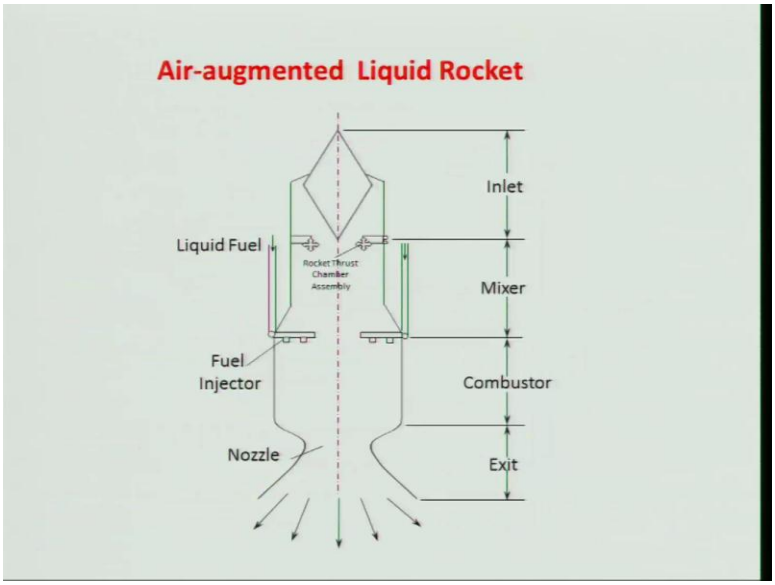

So, let us look at the augmented air augmented liquid rocket engine in this case it will be similar in nature, but; however, there is a little difference there will be a rocket trust chamber, which will their, which is not being shown in this diagram, and you will take the air all the time.

Which will be continuously feeding to the start with, and then is a liquid fuel inject as, which will be working; that means, you need not to put this what you call eject that rocket engine, because it is a liquid fuel rocket engine itself, but to start with you will start with the rocket engine, because in enough air may not be their to start with after that you will be going to the mode of ram jet engines.

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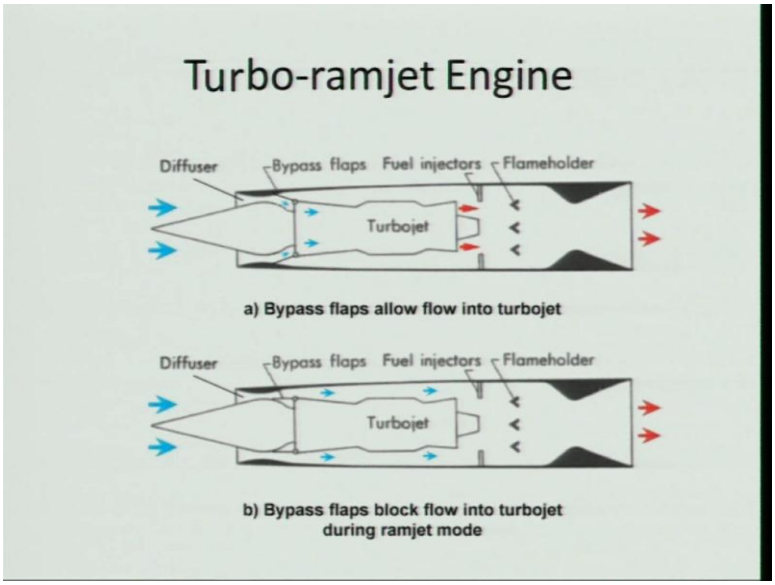

So, which we will be looking at basically turbo ram jet engine why all this engines are coming to pictures? Because of inability of ram jet engine to give a initial take of trust, and in this case that is a turbo jet, which is having shown here and to start with the air will be coming through the diffuser or the air end in take into the turbo jet engine, and it will be having various component as I told in the last lecture. I have shown you some pictures that is having a compressor and it will be having a combustion chamber, which is not shown here and turbine of course, there will be a gas in this case nozzle need to guide it will be expanded in that other nozzle and a, but in the this is basically bypass flaps.

Which is their allow the flow into the turbojet engines, this is there is a bypass flap, and in the whenever you move into the resume, where ram jet can be operated you can put this turbo jet half by putting this bypass flap, which can block the air not entering into turbo jet; however, it will be entering into the ram jet components, and you will get the trust. So, and there are good thing is that you can always start the engine whenever you can; that means, it can be reusable a you can land it and again take of that is a good thing, but the bad thing about this turbo ram jet engine that you will have to carry the weight of the turbo jet along with you.

So, sometimes you know you will have to find out what I am like? What is the requirement? What is the machine requirement rather? And whether you can use or not,

and it has been use by the missile applications, and some other kind of things other application as well. So, if you look at now we will be moving into the non chemical rocket engines, and before getting into that what I told you that I have given you a birds I view of the new combine cycle engines right, and it is several varieties are there and you can look at it if you are interested in, but; however, I would not be discussing now

We will be moving into the non chemical rocket engines, in which case I will be discussing about nuclear power rocket engines, and then solar power rocket engine, and electrical power rocket engine. I will be giving a very very you know sort view or a small are the birds I view of the old concept.

And then, I will be moving into the other things and concentrating only on the chemical a chemical propulsion devices. So, if you look at this nuclear power rocket engines why you one has to go? For a nuclear power rocket engines, why not chemical propylene, which is being use from the time memorial can be utilize for the rocket propylene engine can anybody tell me. Air rockets are higher first vibration on that to chemical logics.

But why what is the region? Why higher trust weight ratio will be their, because it is having a limitation; that means, the chemical rock propylenes are or the fuels is having limitation of energy being produce for unit mass of fuel.

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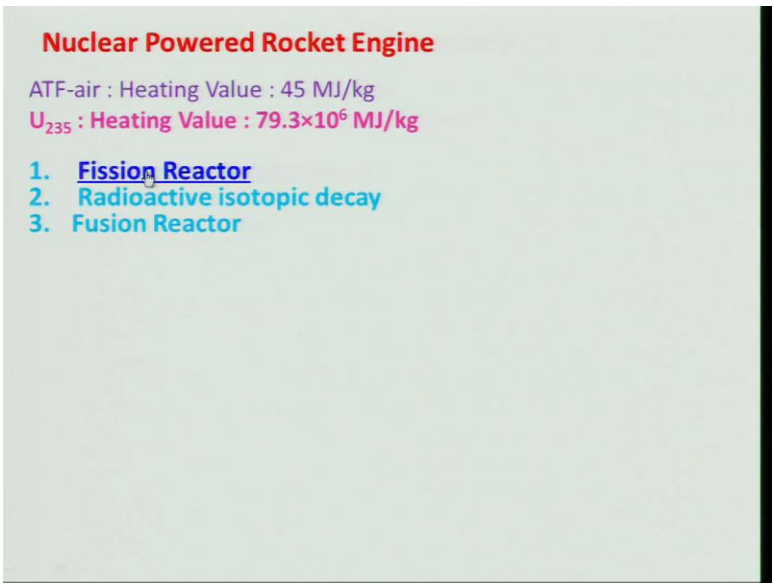

For example, for hydro carbon if you take ATF that is aviation turbine fuel, which is nothing, but a refined kerosene right. And air if I burnt I will be getting the heating value will be 45 mega joule per k g right, whereas if I use the uranium 235 and bombard it, and such that nuclear fission can take place then the heating value will be 79 what you call 0.3 into 10 power to the 6 mega joule per k g; that means, you can use the higher amount of what you call energy for producing a higher trust and higher other things.

So, therefore, there is not much limitation; however, it is not that easy to use, because of several problem associated with it, and you might be aware that recently in Japan. There was a catastrophic accident, which cause a lot of damage to the people and environment as well; however, let us look at.

That nuclear power rocket engine can have a three kinds of reactors one is your what you call fission reactors, and other is your radioactive isotopic decay fusion reactor, and in the fusion reactor what happens is that? The nuclear will be of uranium 235 will be absorb by a neutron right, and as a result what will happen. So, what we are discussing about the fusion reactor.

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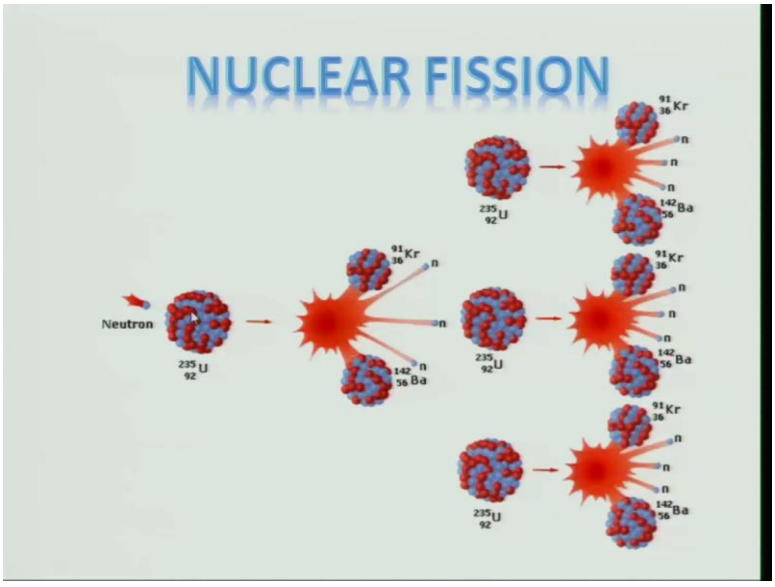

And a during the passes of fission what happens is that the uranium 235 will be observing a neutron, and when it absorbs it will be having energy level will increasing, and then it will be separated or splited into two nuclear. One is krypton and other is

barium, and it will be also generating a large amount of energy beside this the gamma raise

Which contains a small amount of energy, which will be generate. So, this kind of energy is basically due to the nuclear fission, because the nuclear being separated into two smaller what you call nucleus? And in the process also it creates three more neutrons, sometimes it is two also need not to be three and this neutron became potential for two, we observe by other uranium nuclei such that this reaction will be continuing. If you look at in this figure I have shown here. It became a more number of you know krpton's and barium bring generated and more number of neutrons are being also produce; that means, each became potential and this is a chain reaction no.

If it will continue like that then what will happen it will be kind of explosion or a it will be very difficult to contain it. So, therefore, wherever we are talking about this nuclear fission to be used for harnessing the energy, we need to contain or observe this neutrons; that means, we control what is the number of neutrons being generated, otherwise it will be beyond our control. So, it is very important to keep this in mind, and this is the one way of generating the larger amount of heat as compared to the chemical rocket. It is a may be 3 4 order of magnitude as I told in the last. Why three poet is a six times you know 6 order of magnitude the then that to the chemical energy that can be evaluated due to chemical reactions.

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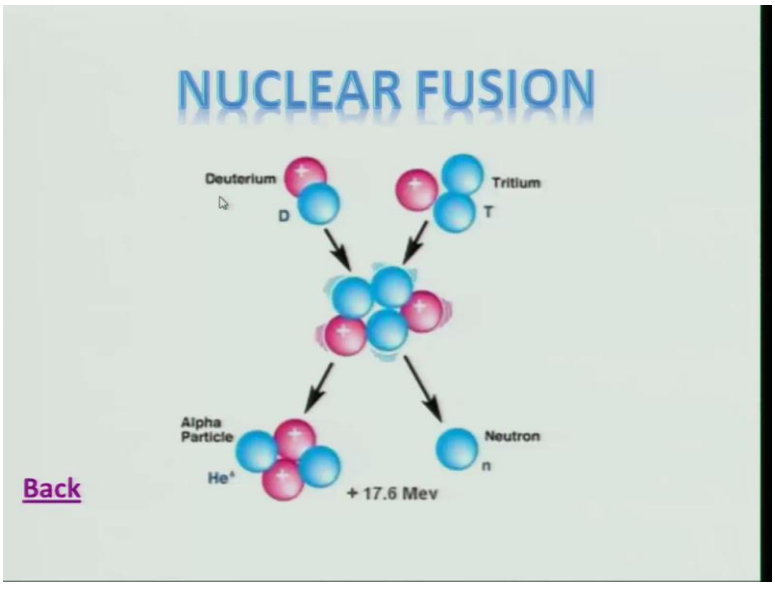

And there is a another process, which is just opposite of that, where this deuterium nuclei will be combined with tritium nuclei, and as a result it will be generating a helium 4 and a alpha of course, raise and a neutron being generate in the passes, and it gives 17.6 mega electron volt, and this is being you know being utilize a large amount of heat or the energy can be generated, which can utilize unfortunately we are not very successful till not to do in a control manner and most of the stars, and then what you call like sun, and others cosmic entities.

They do involve this kind of nuclear fission, which will be going on for several you know years it is the infinite source of energy almost to say. So, and this energy can be utilize for the rocket propulsion, but unfortunately till now no work or it is not successfully when in civilian forget about this application, which is military and other planetary applications. So, and radioactive isotopic decay, which is a very very you know general it happens, but it would not having much applications.

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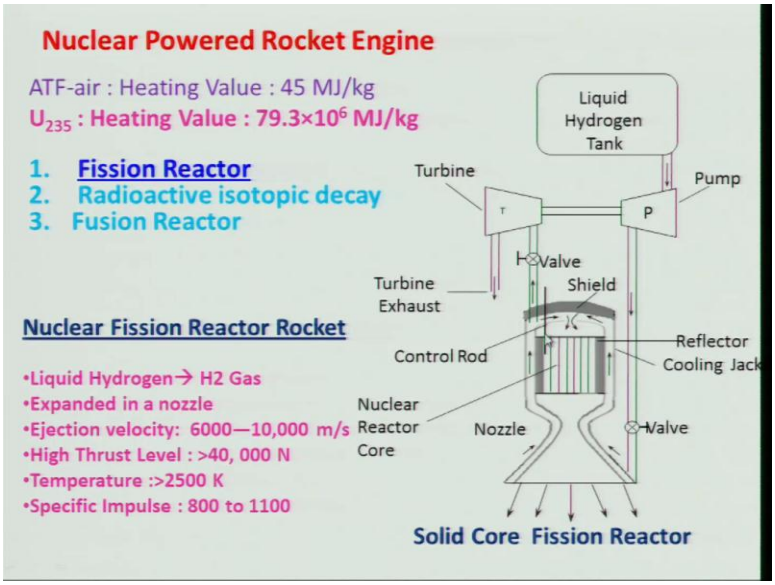

So, for rocket engineers concern. So, which will be I will be giving you only one example that is solid core fusion reactors. The schematic is being shown here, and here you can use any other propellant like kind of thing.

Which will be having a good physical properties of or rather heat capacity a to observe the heat generated in this nuclear fission reactors, and here hydrogen being use, and it is being pumped at a high pressure. It will go through the nozzle to look at outer casing of

the nozzle, and also the reactors this a typical, which is being use in liquid poplin rocket engines the hydrogen will be flowing though it will observe some amount of heat.

It will be converted into gas, and then it will be entering into the what you call the nuclear reactor core? And keep in reminder this is having a control rod as I told you that we need to control this generation of neutron. So, this will be controlling that and this will be absorbing the heat of course, there is a reflector of cooling jacket and other things will be there to contain the reactions kind of things, and beside this some of this hydrogen also use to run this turbine, otherwise you cannot have a pump and after that it is a typical chemical rocket engine. Kind of thing this high pressure and high temperature hydrogen, which will be expanded in a nozzle and you will get a trust.

So, if you look at very high trust label around 40000 newton or 40 kilo newton's even higher than that one can get easily, and temperature is restricted to the 2500 kelvin; however, higher temperature one can use provided better material is available right, and high specific impulse you will be getting as compare to the chemical rocket engines, and ejection velocity you can get a very higher values.

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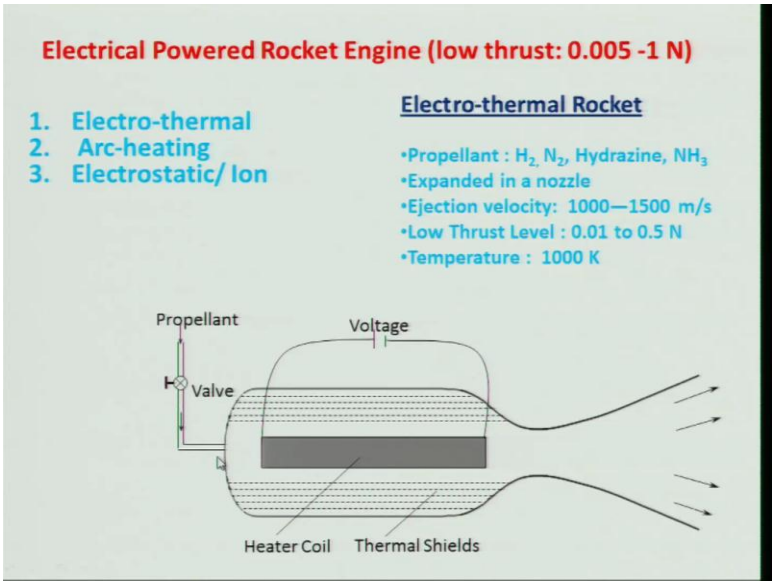

And we will be looking at the electrical power, which can be use for producing a trust and of course, this engine is having a limitation of getting lower trust; however, it can be utilize in a space particular outer space, where trust requirement is not really very much and there are several ways. One can think of electro thermal and arc heating, and

electrostatic or the ion information, and you look at I have taken only a electro thermal rocket engines, and where electrical energy is being utilize to generate some heat, you must be aware that heat can be generated by basically several means; one of the easier way is doing using a resistance right, you can have inductance.

You can have other way of generating the heat converting electrical energy into in this case what I have shown here? It is a basically heating coil. What we people use during the winter season to heat the room or our food preparation other thing it is as simple of that, but; however, it has to be little more energy you know density; that means, the amount of energy release per unit surface area must be higher, because it must be compact one, and then you can use what you call the various propellants? Propellant can be hydrogen. It can be nitrogen, it can be ammonia, it can be any other things one can be use it, and even some cases you can use as well as some kind of mono propellants.

We are it can be reacted, and cannot can release also energy of course, some of you may think of using there is several ideas one can think of using for augment the trust. In this case, but; however, to have a voltage or the electric power you need to provide various systems like you know I can have a solar systems as such to produce some electricity.

Now a day's fuel cell is coming into pictures may be some people can use that or you can use some kind other energy like storage energy one can use, but problem is that it can only provide the very low trust is a 0.01to 0.5 newtons, and you should not restrict about that, but there might be better ways of doing it, and temperature being limited 2000 kelvin, and one can go for little more, but the energy density requirement will be higher and it is a usual rocket engines.

Where the high temperature a gas, and at high pressure is expanded through a convergent divergent nozzle to produce the trust. So, I mean this is the basic thing about electro thermal kind of rocket engine there are several varieties, we would not be really looking at all of them, but some of you are interested you can look at it leisurely.

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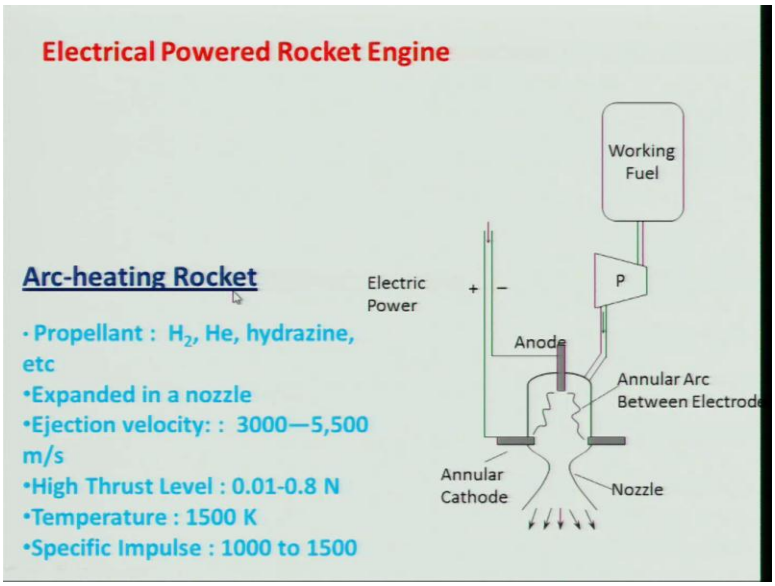

So, let us look at arc heating rocket engines, and in this case arc is being use having a in this schematic a annular cathode, and anode is being use to produce a arc, and you know that arc can be produce when the high voltage, you know will be across this cathode and anode will be there, and which will be creating a kind of a plasma as such, and because that will be broken out and a spark will be produce.

Whenever spark is produce very high temperature is being generated, because we know that in the case of simple electrically heating. The high temperature cannot be achieved for that you need to give a very large amount of heat, but whereas, here you can get a what you call high temperature very easily, and higher temperature higher will be the pressure, and also the it can be expanded,

And to get a higher trust and there are several varieties, which has can be one can thing of, but in this case I have show in very simple one the this having a working propellant or the fuel, which you can use basically. It is a propellant as I told you it any propellant can be use like hydrogen helium, and hydrazine kind of things and it has to be pumped. So, that you have a higher pressure generated here, and it will be come through that it will be acting like a medium for the spark walk. That is very important, and it will be spark will be produce.

Whenever you know voltage high voltage being applied here, and it will be although the high temperature will be during the spark will occurring, but average bulk temperature as

not really being increase. Unless otherwise you go for a little better design, and what people have done till now is 1500 kelvin, and when this will be expanded in a nozzle you will get a little higher specific impulse as compared to the chemical rocket engines. So, this is one varieties of the what you call arc heating rocket engines, but there are several other varieties as well. So, which you can look at in the literature

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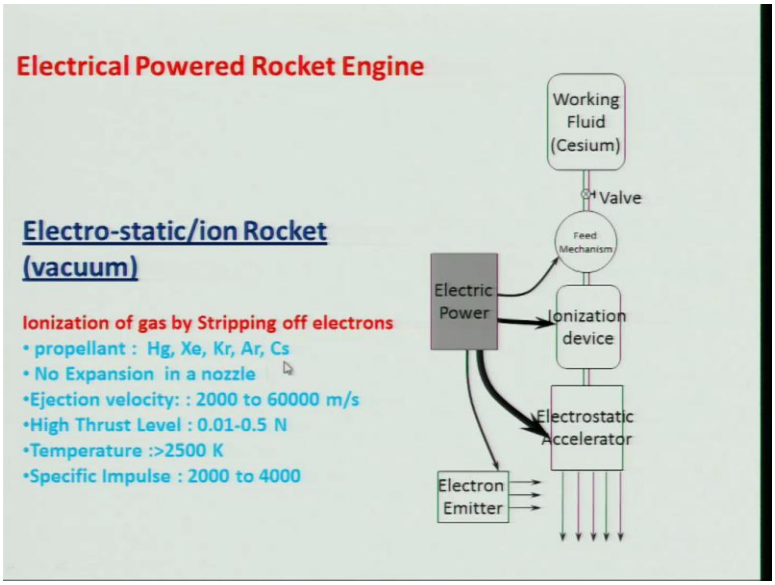

But let us now, move into a another varieties of engines, which you will be discussing is electro static or ion rocket, and it will be different then what we have discuss in this case there would not be any rocket nozzle will be there in other words gas need to be expanded in a nozzle to get the trust rather, in this case the ionization will be use; that means, the gas will be ionize by stripping of electrons.

I have shown a, what you call a flow chart kind of things, where you can see the working fluid working fluid or the propellant can be any gases like mercury. Then what you call krypton's organs cesium and kind of gases, and which will be basically feed from the tank with a feed mechanism will be there, and you will use electrical power to organize it right. And then this organize particles will be accelerated by the electric static force it can be electromagnetic forces you can apply, and when it is accelerated you can accelerate to a very high velocities like 2000 to 60000 meter per second, and generally the kind of velocity is what is being use in particle system is around 25000 to 32000 meter per second and you will get of course,

What you call a little lower trust, but it is having no nozzle and it is a very compact. And smaller systems except you need to have a high voltage source that is the kind of things, and which is being use by Russians in the outer space region for this electro static.

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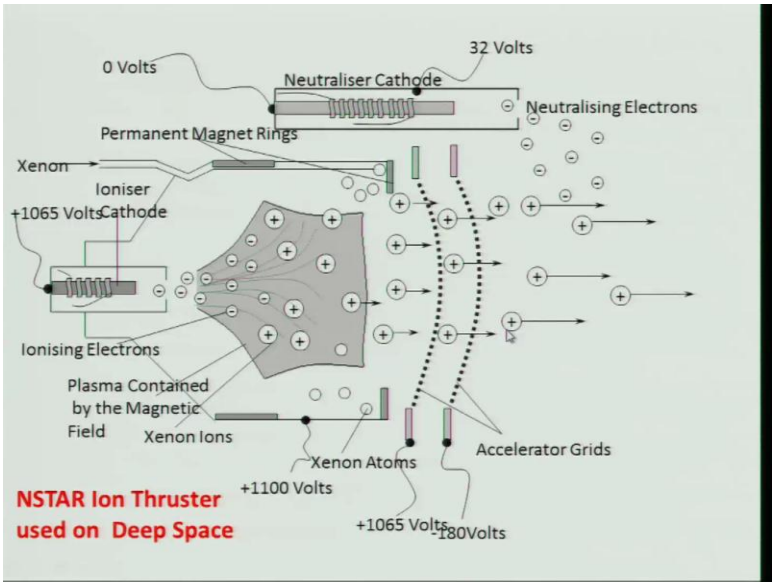

Let me, what you call look at actually one, which will be like n star ion thrusters use in deep space as I told that. If you can it is having a two components. One is your ionization sections, the other is your acceleration sections right, if you look at.

What is being done here is that there is a cathode, which is being use it is having a higher voltage such that it can produce some electrons, and this electrons will be moving towards this chamber, where the xenon gas are any other propylene can be passing through this, and it is what you call the there will be a magnet you feel along with the actually direction. And also the radial direction such that these electrons should be coming in contact with the, what you call the propellants, otherwise you cannot really strip those neutral gases and generate an ion.

So, therefore, this will be moving in a spiral manner right, in a spiral manner it will be rotating. So, that all are most of the, what you call this propellants molecules should come in contact with the electron to be stripped up. So, that ion will be created once ion is created. It will be moving at a you know certain velocities of course, it will increase, but; however, there is a acceleration grid, which is create in by the voltage like here in this design. It is 106 by volts and there is a negative as 108 grids volts are their.

So, that it would not be going as strain and the objective of this grid is to import a higher velocity accelerate the velocity of the ions, and in a particular direction; that means, it should be not moving here and there; that means, the vectors or the direction of the velocities should be in actually direction.

So, that is the two function of this kind of accelerate grid, which is you can say that. It is as good as a your nozzle. It is working like a nozzle, but it is not having any physical kind of thing and this is the gap between this two accelerate or the two grids. This accelerate, the grids is very very small in order of m m kind of thing. So, that you need not to carry a very bigger, what you call the nozzle to have a requisite trust for getting good expansion ship, and the optimum expansion apart from that. It is very important that there is a neutralizer cathode.

Which must be produce in some electrons are the, which will be absorb by this thing; that means, the trust which will be acting on this grid right. The trust will be because of this moment, the trust will be acting on this grid, and it will be transport to the rocket chambers or the what you call trust ion thrusters, but after that after the grid you can have this neutralizing electrons, which will be combined. So, that it will be neutral and it is not having a detrimental effect on the trust bring produce by the rocket engines or the ion thruster. So, this is about what you call the electrical rocket engines.

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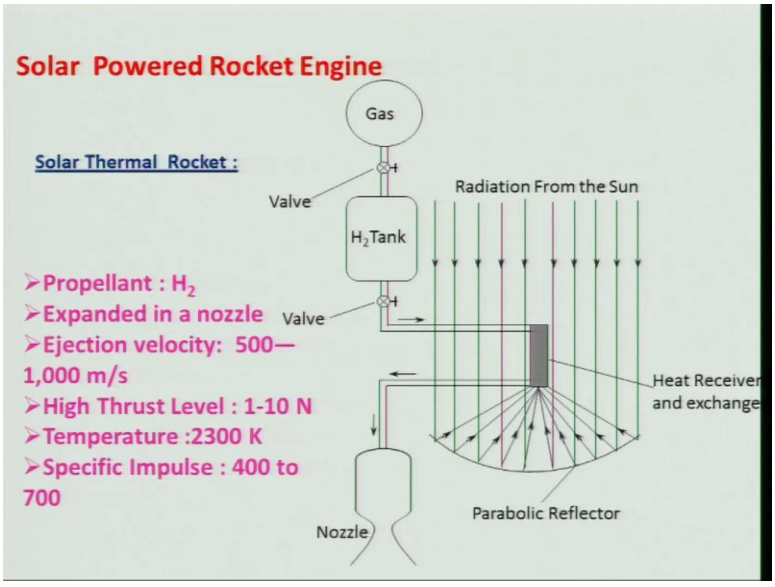

Now, we will move into the solar power rocket engines when you talk about this solar power rocket engines. There are several kinds right, but I will be discussing about solar thermal rocket engines, you might have seen in the satellites there is a solar panels right, you might have seen it is having a solar panels to give some energy, and that can be utilize to propel as given right, because we have seen already the electrical rocket engines will be their, where you can use that either in any form either in a ionization thruster or some other thing particularly in the deep space, but those things are having limitations, what are those limitation, because of efficiency of solar cells and panels or quite low.

It will be around something 10 to 15 of some people or claiming it to be 20 kind of things not more than that. So, therefore, there is a lot of challenge to improve that solar panel efficiency of solar absorption by the solar panels solar cell rather solar cell efficiencies, and which will be beneficial for the land use as well, because in after may be 100 years there will be hardly any fossil fuel to be left to be use.

So, if some of you could you know take it as a motivation and do work on that and improve the efficiency of the solar cell. It will be great boon particular to india, where we are having a large amount of solar you know energy available so, but what I will discussing about the thermal solar rocket engines, which is being shown here, and it is having similar to that like is a gas rather gas cannot be use, because having limitation you can use also the liquid fuel particular liquid hydrogen then when you take about liquid hydrogen. You need to have a cryogenic that is another problem, but; however, if you go the deep very deep space may be you will overcome that problem, but then this gas you know tank you can have this thing it will go to a parabolic reflectors.

It can be there are several reflectors no like, which can collect this solar radiation, and then in this example I have taken as parabolic you say a reflector, which will reflect the solar radiation and put into this kind of heat receivers or exchanger, and you. In which there will be exchange of heat will be taking place between the propellant and this tank, and then as a result there will be increase in pressure and temperature right particular at temperatures, and then it will be expanded in a nozzle and keep in mind that the temperature of course, is limited to 2300 kelvin, and that depends upon the you are panel design.

Sorry, the parabolic reflected design, and also the heat exchanger design, and material also the rocket engine materials, and the of course, the ejection velocity is limited to low velocity, because it is a similar to that your chemical rocket engines unlike you are ion thruster electrical engines. So, this is being you know very really being use; however, lot of research is going on to have this comparable.

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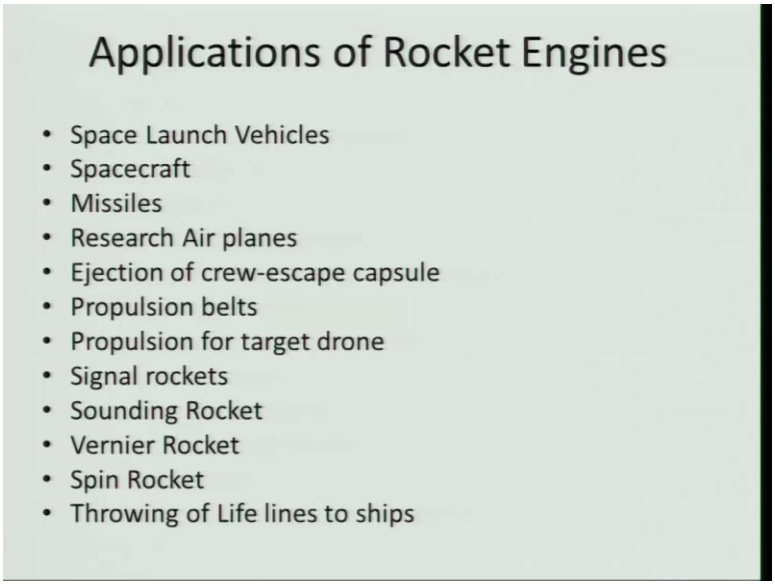

And. So, if you look at the applications of the rocket engine are having several. I have just jotted down here some of them like a space launch vehicles, which all of we as know that we are having a you know space launch satellite launching particularly vehicle know as PSLV, GSLV kind of things.

And spacecraft of course, it is being use by apollo and other you know engines, and the most you know places, where rocket being use or the all the development I always feel is being motivated for winning a war that is a missile, but I feel that war we should avoid actually I always feel that war lies in the mind of the people must be removed such that, we can have a peaceful existence in the war, and beside this a lot of research you know air planes. It is being us rocket engines might be knowing for the conducting research like your recently the scramjet engines, what are being it was being fired from a an aircraft very we use aircraft you might be looking at in video's, now does it have a level in tube you tube.

So, the ejection of q escape capsules that is for, which the engine can be use and of course, a propulsion belts like if you look at one who was a you know Chinese fellow. Last is life kind of thing for making a rockets sled similar, thing people are talking about even some companies has come up to have a feel the gravity 0 gravity affect on some other things, you can have a propel this imagination of the human being will propel how you can use a concept for the you know for use. So, beside this their propulsion for target drone you know again. It is for the of course, military application, but you can use for some other applications as well civilian applications, but generally it is use for the military applications say like signal rockets.

You know we want to give some signals and other things that can be use, but there is good application about you know, where we need to work for rocket engine. Sometimes I feel why should I teach a rocket engine, which is not good for the you know mankind, but; however, whenever I come to the sounding rocket engines that is a quite good, because you can talk about this atmospheric you know measurements and weather forecasting, and other thing it can be use that sounding rocket, and there is one year rocket, where you want have a some kind of course, corrections and other things.

You can use and the spin rocket, where you can use try to spin something, and then you can use it for some other purpose and throwing life lines to ship, you know this is a very important applications. I feel from the civilian point itself for example, there is a storm in the sea and to sea ships are there, and they want to interact they want to supply the food are something exchange you can use a rocket engine to have a connect the life lines between the two big ships, which you cannot really move in a very adverse conditions.

So, this kind of things you one can think of using applications of rocket as I told you engines is depends on the imagination of the people and once your mind is being more benign , and then more humanistic you can find more application for rocket engines with this I will stop over and in the next lecture, we will be discussing about the various fundamental aspect, which is required for the rocket engines right do you have any question to be ask. Possible to convenience in a if nuclear rocket

We are using a nuclear energy to heat hydrogen, and converting it to means in the accelerating it. Is it possible to directly convert it thermal energy to accelerate the rocket thermal energy, you how you can do that like you are saying as a electron basically.

What it gives a large amount of thermal energies. So, whenever it is there you can use that itself to basically a to expanded in a nozzle right do have any other idea by which one can do that thermal is a only one way of doing. It not like your ion thrusters of course, there is a plasma thruster, which I did not discuss right. So, what is the coming into picture my mind is the only the thermal is the way of course, there might be several other means of doing that, but I think I have aware it right any other questions. So, if you do not have any question we can stop over here.