Jet and Rocket Propulsion
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Lecture - 4

Welcome back everybody to the second lecture of this course on Rocket and Spacecraft Propulsion.

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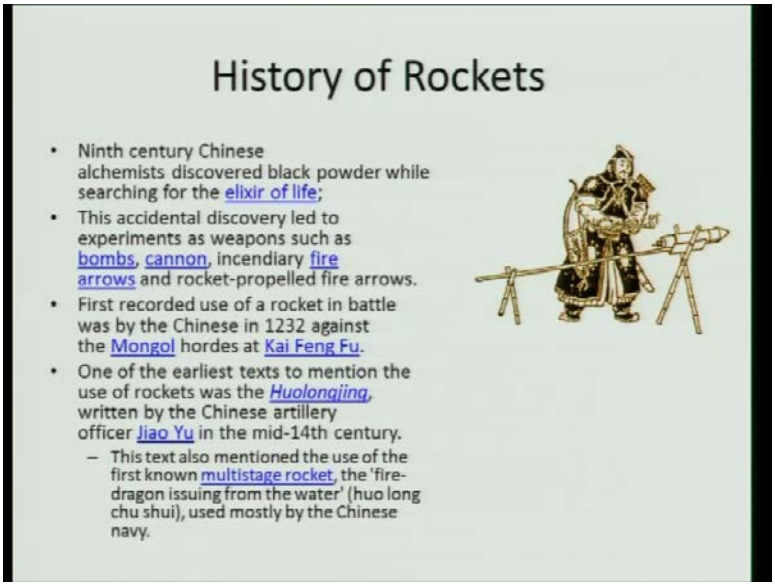

So, yesterday we discussed what are rockets, what are the different applications of the rockets and where are they used. Before proceeding further first let us look at a little bit history of rockets. The invention of rocket was actually older than the aircrafts or aircraft engines, and it all started with the invention of gun powder or a black powder by Chinese, some time in 9th century.

Actually the Chinese alchemists were searching for the elixir of life and by mixing some concoction or other, they came up with black powder, which is an explosive which can be burned in a control manner. And that started the development of rockets, so this was initially an accidental discovery, but then the Chinese realize in potential and started experimenting with it for different applications, including many military applications, like development of bombs, cannons, then fire arrows, the rocket propelled fire arrows, etcetera.

So, the first use of rockets actually were apart from say some fire crackers and all, first for military applications. And the first recorded use of rocket in battle gets back to as far back 1232 AD, when the Chinese use the rockets against the Mongol hordes at Kai Feng Fu. Now, one of the earliest text, which mention the use of rockets was Huolongling, which was written by a Chinese artillery officer Jiao in as far back as mid 14th century. So, you can see that it is quite old as a practical application, now in this text he mentions the use of first known multistage rocket as well.

So, multistage rocket is not something unique, Chinese have already thought about it had use it and the fire dragon issuing from the water that is what they used to call the multistage rocket. It was mostly used by Chinese navy and they had a profound impact on the geo political history. Now, after the Chinese after the china was taken over by Mongols and during the Mongol wars or the Mongol invention.

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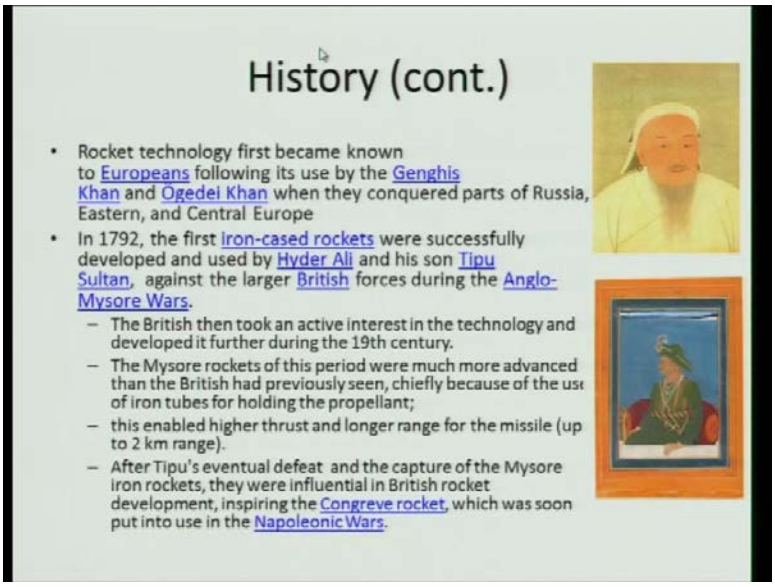

The Mongols took this rocket to Europe, so rocket technology was first known to Europeans by the invention of Genghis khan and Ogedei khan. Because, they conquered part of Russia eastern and central Europe and they use rockets also to their advantage particularly for military application. But, till that time the casing of the rockets were usually wooden or bamboo or paper something like that, and for above 200, 300 years it remained like that it was essentially just use as a military weapon, but with not much of advancement in it is technology.

But by 1792 we see the rocket reappear in it is more refined form in iron cases, and this was successfully developed by Hyder ali in of Karnataka of Mysore and his son Tipu sultan. So, Tipu sultan and Hyder ali started using this iron case rockets and initially they were very, very effective because, they use to scare the cavalry of Britishers or there advisories because of fire wall coming towards the horses, horses used to get scared. So, they were more efficient than the cannons and they used it during Anglo Mysore wars quite extensively.

But, there was a massive flaw in this rockets and that is this accuracy or controls because of that it did not have such a profound impact on the war that can change the history. So, therefore, it had the potential, but because of his inefficiency and the inaccuracies, it was not very I would say effectively could be used in a military application. But, the British's saw the potential of it, and they took them active interest in this technology to further develop it. And the Mysore rocket of that period were much more advance then the what the British's has been seen before.

So, therefore, they took an clean interest on that and primarily the advancement was because of the use iron tubes for holding the propellants. So, first of all by that you can pack in more propellant, born longer and born without burning the entire body because, if you are using bamboo, then is a chance or if you put more propellant it will start to burn the body, instead of providing the propellant propulsive force. But, using the iron tubes were essentially able to provide thrust in the intended direction by not burning out the body.

So, this use of iron tubes enable them to get higher thrust and also the longer range, this rockets were capable of going up to 2 kilo meter that was huge in that period we are talking about 18 century. But, after Tipu Sultan was defeated and captured this Mysore rockets, where influential in British rocket development and this were inspiration for the development of Congreve rocket, which we are going to talk about later, which the Congreve rocket are after this is see 1792 is what we see the rockets emerging again in the iron tube and Napoleon wars were some time at about 1815.

So, about 20, 25 years there was a massive development and from that point order what particularly in the Napoleonic wars we see rockets having an substantial influence on the

outcome of the war because, now the accuracy have improved and they are now much more effective.

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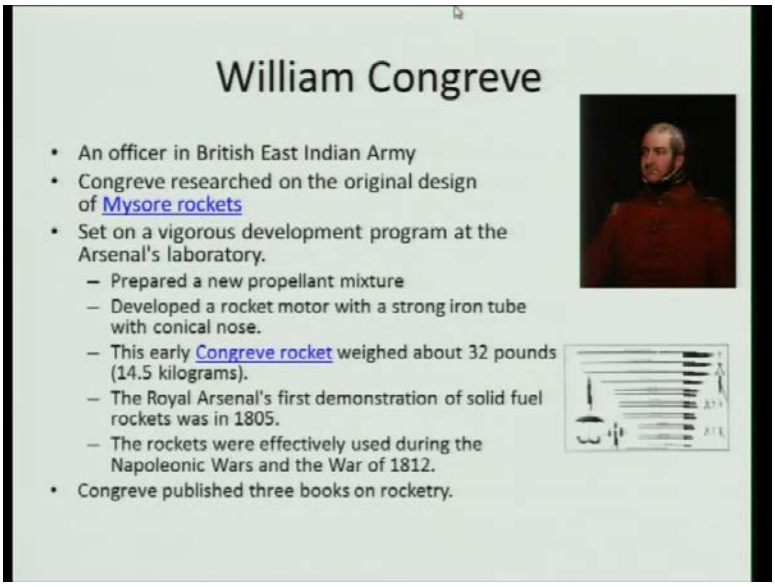

So, as I have just said that the British's took clean interest in Tipu Sultans iron case rockets and one person who was in the for front of his development was William Congreve, he was an officer in British east India army. And after he saw the use of this rockets by Tipu Sultan forces, he started researching on the original design of this Mysore rockets, this rockets were called Mysore rockets, as you can see there are some pictures here of the Mysore rockets. Now, he essentially started I would say scientific program in development of this rocket technology as a viable technology for military applications.

So, he started a vigorous development program at the arsenals laboratory, he prepared new propellant mixtures; which can provide the higher thrust enlarges range. He developed a rocket motor with strong iron tube and with conical nose, this is another development having a conical nose that reduces the drag. This early Congreve rocket weight about 15 kilogram, 14.5 kilogram, 32 pounds, which again was quite substantial if you are talking about in early 90 century. And the royal arsenals first demonstration of the solid fuel rocket was in 18 of 5.

So, essentially the beginning of solid fuel rockets are can be considered to be 18 of 5 when it was first demonstrated. These rockets were effectively used in Napoleonic war

and the war of 1812, now best on his experiences with the development of this rocket technology, Congreve actually publish three books on rocketry. So, there has been substantial improvement, but once again starting from say 1800, which is early 19 century, till the beginning of 20 century, there was not much of substantial development in the rocket technology it remain where it was…

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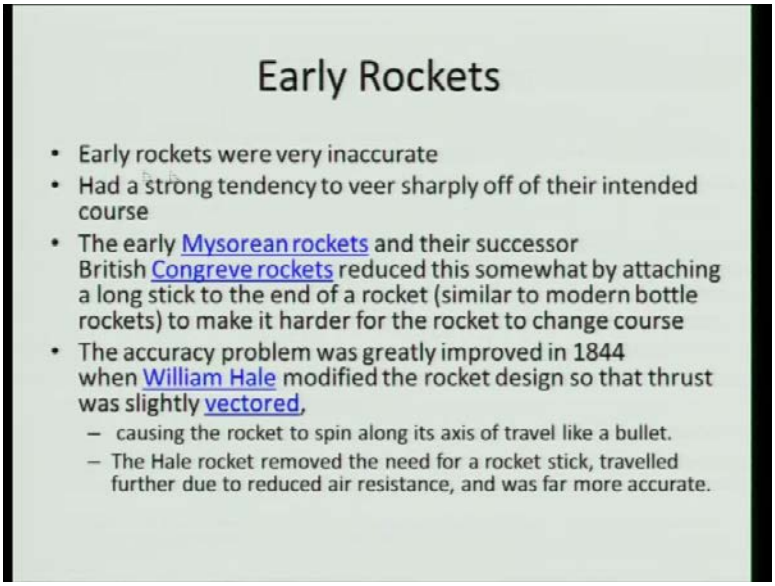

So, the early rockets, if you look at still there were very inaccurate, they had a strong tendency to veer sharply off of their intended course. Because, they were no control and stability they were in unstable, the early Mysore rockets and their successor at British Congreve rockets reduced this instability somewhat by attaching a along stick it was end of the rocket. As you can see here, there are long sticks added for stability, but still they were not able to remove this draw back completely.

And if you look at was rockets they look very similar to the fire crackers the bottle rockets that are ((Refer Time: 10:09)) use now a days. Now, essentially by putting this stick what they are doing is they are making it, so stable that is difficult for the rock to be a out of the course. But, still the accuracy or I would say marks man ship of the rocket has not improved, the accuracy problem was greatly improve now a days most of the rockets the thrust is slightly vectored and by doing, so it produces half access force; which then pills the rockets.

Particularly is useful for missiles is pills the rockets and provides the stability, so this slight thrust vectoring or half axis thrust causes the rocket to spin along it is axis, when it struggles. So, it is struggles like a bullet because, it is spinning, so it has more stability, so the hale rocket actually removes the need for a rocket stick, and because of that its overall surface area reduced. So, the overall frictional forces reduced, so they were able to travel further the range was increased and were more accurate.

So, as what we are seeing now that the coming of control technology into rocket slowly, now let us not come to the modern day rocket and space flight. The modern day rocket development started at the early 20th century, and after that actually if you look at the history of modern day rocket, whatever was proposed by the pioneers I will come to the pioneers in 1903 to 1905 or 1915. Still we are following the same, we have not done any new invention all the basic principles were proposed at that time and formulated at that time rocket enlarge is still works on those principles.

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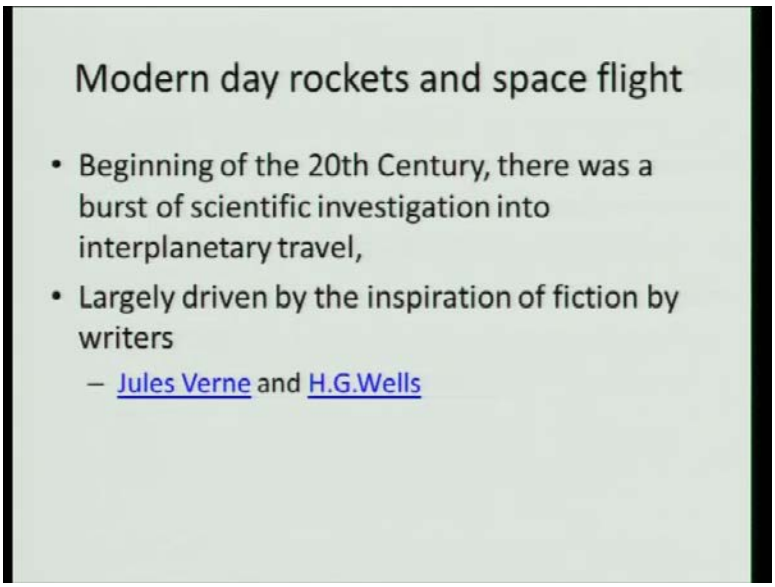

So, that was the golden era of rocket science starting from the beginning of 20th century till about 10, 15 years. So, beginning of 20th century there was a burst of scientific investigation, particularly into interplanetary travel and this interest was a largely due to the science fiction books written by Jules Verne or H. G. Wells, where they talked about going to moon or people coming for mars etcetera, etcetera. So, travelling long distances

or interplanetary travels become a passion for that generation, and that's started the actual scientific development.

So, for when we talk about rocket science, essentially is well all practical application that if you put this, this is going to happened like that. But, they are no theoretical foundation for rocket science, now the beginning of 20th century, the rocket science started to emerge with the strong theoretical basis. So, the pioneer of mathematical rocket science set to be Konstantin Tsiolkovsky.

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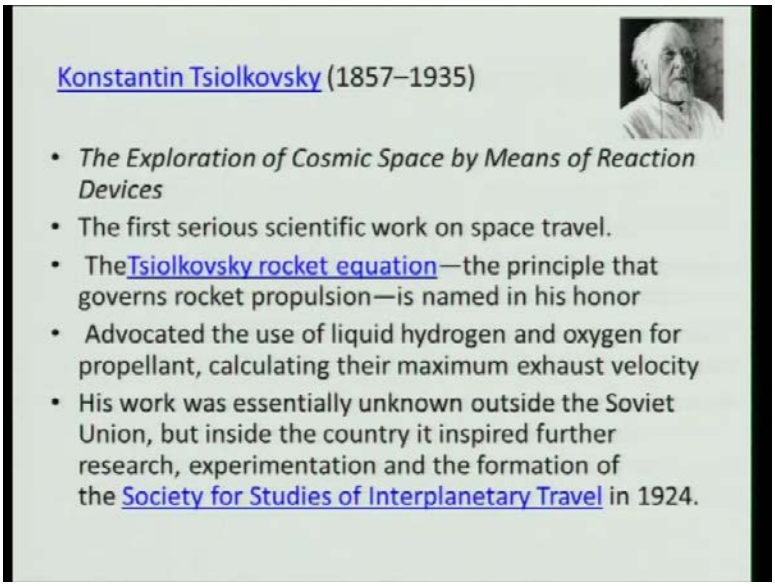

He was a math's teacher in Russia and he essentially first wrote a book title the exploration of cosmic space by means of reaction devices. And there if formulated the full principle of rocket propulsion, so therefore, this can be considered to be the first Sevier scientific work on space travel. He propose the Tsiolkovsky rocket equation; which essentially are the principle that govern rocket propulsion and named in his honor.

But, actually it was not proposed by him or developed by him, but it was named in his honor because, this was a I would say the development of this rocket equation was an ongoing war. So, many, many researchers were actually involved in that, but the final equations for then honored named after him in is honor because, he had profound impact on the development of rocket science, not only that we are looking at 1903 or 1905. So, more than 100 years back, he advocated the use of liquid hydrogen and liquid oxygen.

That means, cryogenic rocket; which actually came into being some time in 1960 s, so about 60 years before they actually were used he propose the use of liquid hydrogen and liquid oxygen. And this proposal was not out of the year, he actually did calculations and showed how efficient this type of fuels will be in rocket propulsions. So, therefore, he first propose the cryogenic propellant, and he calculated their maximum exhaust velocity.

So, essentially he calculated the specific impulse produce by cragenic fuels; however, his work was essentially unknown outside the soviet union. And, but inside soviet union he was inspired, he had inspired a generation of rocket scientists, and if I look history of development of rocket science, substantial development at happened in soviet union and the present day Russia. And most of that work was inspired and following circular his work, and they inspired the research in rockets, experimentation and also it inspired the formation of society of studies of interplanetary travel in 1924 as back as in 1924.

So, but the point is that although he has formulated many things, it was quite unknown of outside soviet union. Because of that, there were parallel developments outside because, the physical principle remains same, so many people at particularly we are talking about the golden age of science, where they were all stall work present everywhere. So, many people started to think alike and that is what happened in rocket science also, he proposed something there were people outside soviet union working independently propose the same.

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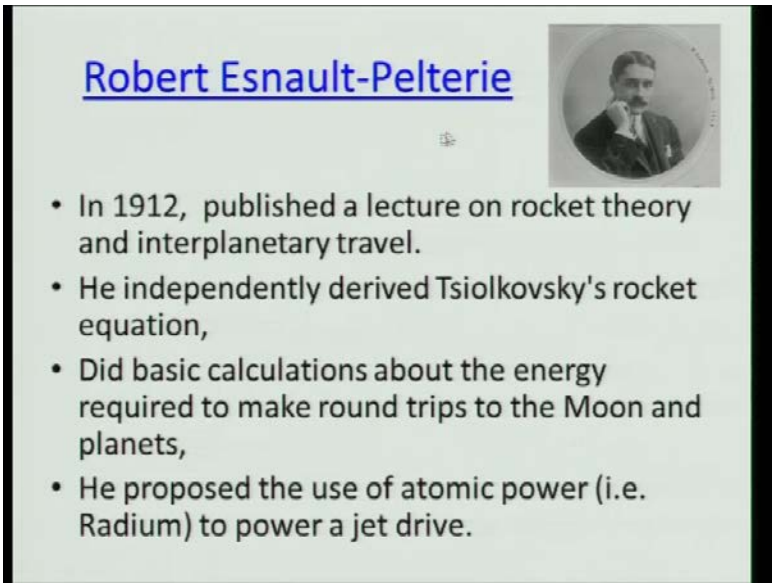

So, one such person was Robert Esnault Pelterie in 1912, published a lecture on rocket theory and interplanetary travel; which looks very similar towards Tsiolkovsky he has proposed, he independently derived Tsiolkovsky's rocket equation again. So, as we can see here, the development was happening in both places independent of each other, nobody knows about other persons contribution and at the time the communications were also not that fast. So, it used take long time for the information to calculate from one place to another.

He did basic calculation about the energy required to make a round trips to moon and planets, and again till date these are the equations we are following for interplanetary travel. He also propose the use of atomic power that is radium to power a jet drive, but that has still not come in to quotation, because of some geo political issues. But, technically it is a very feasible thing because of the fact that nuclear reactors have very high energy density. So, they can produce huge amount of energy and if they can be controlled in a manner that you can exhausts that jet effectively we can produce huge amount of thrust, so can go to extreme velocities.

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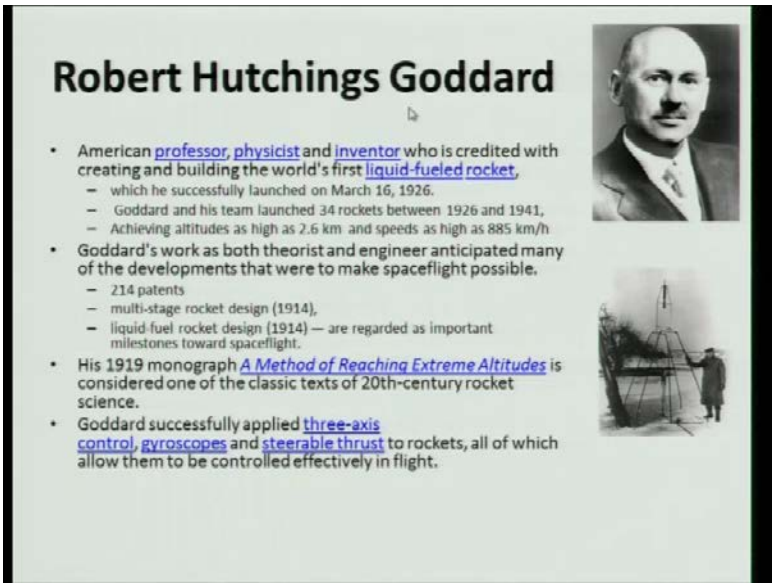

Now, next we come to the person called Robert hutching Goddard, he is named as the father of modern rocket science, he is an American professor. He was a physicists and also acknowlefic inventor, he is credited with creating an building the world's first liquid fuel rocket. And he successfully launch this rocket as you can see there is a picture here at the bottom, he successfully launch this liquid fuel rocket in march 16, 1926 between 1926, 1941 his team has launched up to 34 rockets.

These rockets achieved altitude as high as 2.6 kilo meter and speeds high as 885 kilo meter per hour, and again we are talking about early part of 20th century. And at that time this were massive achievements by any standards, and Goddard work has both theorists as well as an engineer anticipated many of the developments and this developments actually led to the first successful space flight possible. So, many technology which he propose and patented, were actually found application in the real space flight.

He had about 214 patterns to his credit, as I said that he was a terrific inventor, the two most important patterns that he had related to rocket science, which kind of changed the way rocket science developed was multi stage rocket design, which he pet tended in 1914. And liquid fuel rocket design also in 1914, this two are regarded as the important mile stone towards specified, so as again I am saying that not only if you look at the

liquid fuel rocket design it involve the many, many subsystems; which he also needed to design, the fuel feeding system, the pumping system, the combustor, the nozzle.

One of the greatest I would say proposal that he put forward, which met possible again successful flight of rockets was using deal of all nozzles with rockets, the converging diverging deal of all nozzles, he was the one first want to propose it and use it. And that allowed the hot gasses to be expanded at very high supersonic speed producing large amount of thrust. So, in 1919 he wrote a monograph called a method of reaching extreme altitude, and this is considered one of the classic text of 20th century rocket science, it has all the calculations and description of how to achieve extreme speeds and altitude.

Not only this he successfully applied three access control, gyroscopes and steerable thrusts to rockets to improve their stability and range all of which allow them to be controlled effectively in flight. So, his inventions were also used in flight control, so actually he was complete rocket scientist starting from the combustion system to fuel system to the stability and control system, he worked on everything and develop full rockets, which is a very real feed.

Because, these are different specialties, but he had expert is in all of them that is way he is considered to be the father of rocket science. Now, so this three I have talked about as father they were other people also next let me talk about some very important mile stones or programs in rocket development the first one I can think of is the V 2 rocket.

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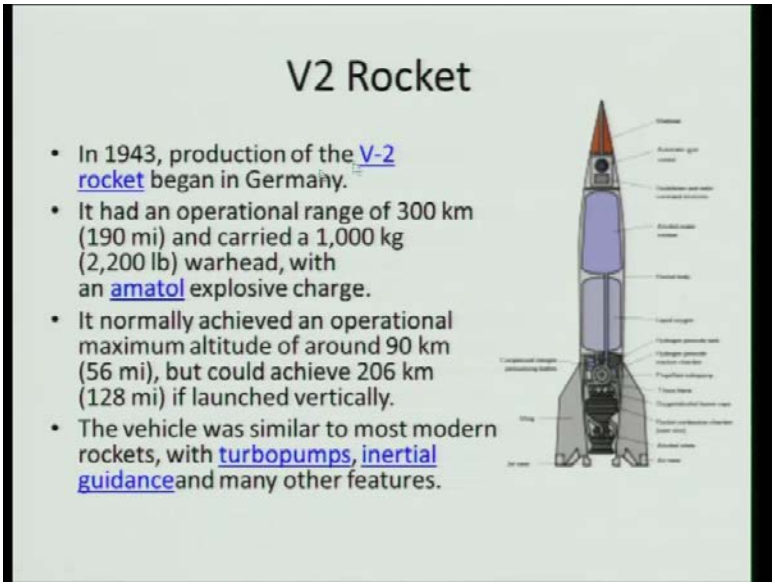

V 2 rockets were developed by germens during the second world war in 1943, the production of V 2 rocket begin in Germany. This rocket was designed in a germen labin pinaminday and ((Refer Time: 22:28)) and they were the pioneers of this, they design they are team was involved in the design and development of this rocket, started somewhere in about 1935 also. And there was able to successfully developed this rocket, it had an operational range of about 300 kilometer, so they were fired for main land Europe and they were able to reach in England.

So, this rockets were actually used in the second world war ((Refer Time: 23:03)) of war head with an amount all explosive charge. This rocket altitude of about 90 kilo meter, but if vertically launched it could have achieve up to 206 kilo meter thus quite a bit of range or altitude. This vehicle was essentially I would say the first proto type of modern rockets, this was the solid propellant rocket, the first of modern rockets and it was similar to most modern rockets with turbo pumps, initial guidance and many other features.

It was successfully used, but it was introduced, so late in the war as we can see 1943 the production began. Let it did not have much of impact on the outcome of the war, just like that turbojet engine was introduced, so late in the war that by that time the war was almost over, but did not have much of impact. But, first successful military use of rockets in modern era has opened a flood gate, what happened after the war all the scientist germen scientist who were working in the germen rocket development machines, were essentially taken either through USSR or through USA.

Wernher von Braun and his team were taken to USA there were re habituated in marshal space centered in Huntsville Alabama. And they started working on the development of American rocket program, later on I will come to one of the most successful rocket program satin five, who was prior headed by owner one round, who was the chief architect of V 2 and that was the rocket, which put man into moon. So, they started with V2 rocket, so that is why V 2 is a very important mile stone in the history of rocket science.

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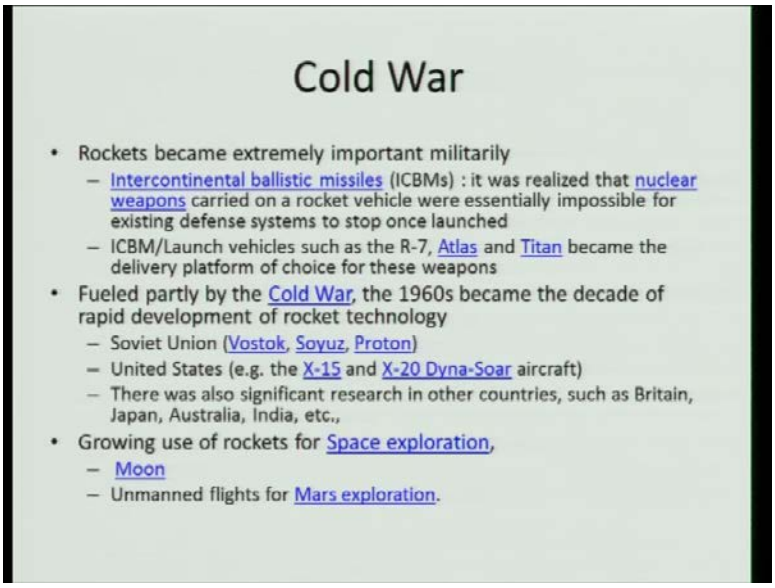

Now, after the second world war we come to the era of cold war, and although that was a very tense period for the world, but because of the cold war the competition between the two super powers putting on the military competition. So, rapid development particularly in the rocket science and space science, so where ever we are today started from that era; weather was massive funding available they were lot of resources put in the what in rocket science and the space science, and because of that they were massive development in every sphere of rocket science.

So, very early in this thing you are cold war in 1950 and 1960 end of 1950's we already had ICBM's Intercontinental Ballistic Missiles developed, it and this missiles it was realize that they can carry nuclear weapons to very large distances up to about 10,000 kilometer. So, no part of the world was not in the reach of this missiles, so entire world came under the nuclear crowd because, all this missiles were capable of carrying nuclear wars heads.

So, America and Russia developed arsenals to destroy world many, many, many times, and because of that since both of them had it, it worked as a deterrent that is why we never had a third world war. So, but that was the ugly part of it, but the other part of it this ICBM's later on we will see, where the precursors of the space flight, initially they came as ICBM's we shall military use. But, very soon they were converted to civiler news and then at different program started for space flight.

So, the ICBM launch vehicles such as such as R 7 atlas entire, became the delivery platform of choice of this weapons the nuclear war heads, but they also were later converted for space machine and it is continues till today. So, the development was partly fill by cold war and 1960's became the decade of rapid development of rocket technology, were soviet union and we was savvier in the fore front. So, Viet union had the Vostok program, the Soyuz program, the proton rocket program all of them were actually of shore from the ICBM's.

So, we will see that the impact the ICBM's had in the rocket science or at the space flight science per say. United states has many experimental program like X 15, X 20 Dyna soar aircraft etcetera, etcetera plus they started working on the Saturn project also, so that I will just come to later. There was also significant research in other countries such as Russia, Japan, Australia and India, about that time India also entered the club I S Arova was started some time in 1960.

And they we started our own indigenous rocket program, starting from very small sounding rockets and we have come a long away in Chandrayaan. So, that 1960's was the era when the rapid development in rocket science started, and that essentially then drew to be in space exploration. And we had successfully by the end of the 60's successfully man landed in moon, and also now we have already achieved the unmanned, mars exploration there is a plant to put man in mars also in near feature by 20 20, but are the genesis of all are this lies in the cold war development of ICBM's.

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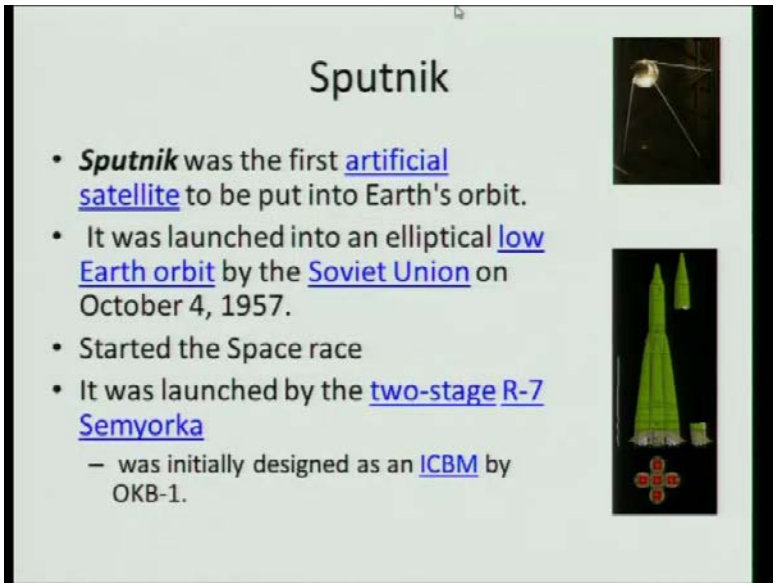

So, now let us look at again some other mile stone program, sputnik program by Russians. Sputnik was the first artificial satellite to be put into earth's orbit, this is the sputnik satellite, it was launched into an elliptical low earth orbit by soviet union on October 4'th 1957. Some say that the launch of sputnik because, the Americans were taken by surprise when sputnik was launched and they were very, very panic, so during that time they also started massive investment in their space program.

And then that lead to because, at that time Americans vote to put man in moon maintains and their successfully achieved it. Now, coming to the launch vehicle because, that the focus of this course, this is the launch vehicle, which is a two stage R 7 Semyorka this as I just said was initially designed as an ICBM by OKB 1 that was the organization the designed it. So, again you see that I C B M converted to a launch vehicle, so first satellite launch was done by an ICBM.

So, and repeatedly Russians have done that many, many of they have launches very important launches, where on converted ICBM's. Because, they did not have a separated a civilian military rocket program on like that Americans, American had separated program, NASA was completely on space and department of defense was complete on defense production. But, Russians did not have separate program, so they use the military vehicles for launch.

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Now, another mile stone Yuri Gagarin, Yuri Alekseyevich Gagarin was first was a soviet pilot and cosmonaut, and he was the first human to journey into out of space. So, here is a picture of Yuri Gagarin, this is the module in which, he went to outer space, when his Vostok spacecraft completed an orbit of the earth on 12'th April 1961. So, the first man flight to space was in 1961, and once again the space craft Vostok let me just go back to the list of ICBM's.

Vostok was also an ICBM's as you can see here, so Vostok was also an ICBM converted for space flight. So, once again we see that the military use in converted to civilian use and with profound effect and the development of science and technology, so one of the space mile stone was Gagarin going to outer space.

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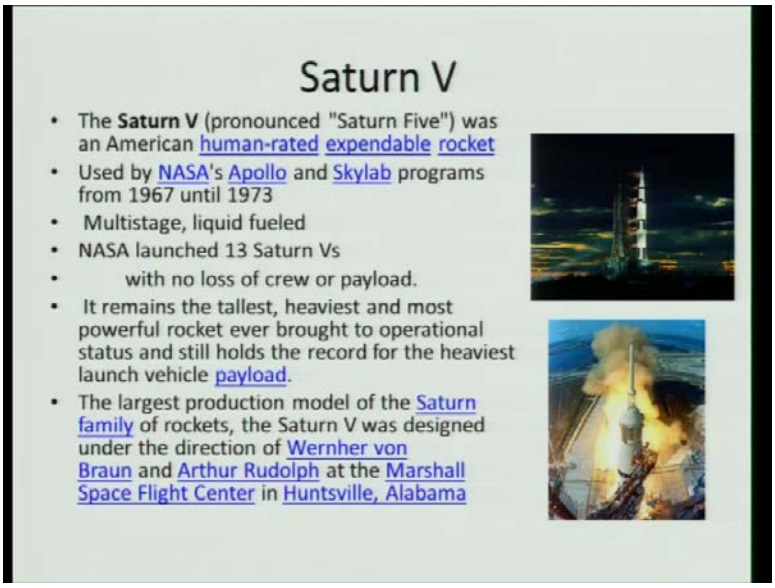

Then it come to another very important program, this program was by NASA Saturn 5, now Saturn 5 was an American human rated expendable rocket. It was used by NASA for all their Apollo machines, as well as in the Skylab program started something about in 1967, until 1973. It was a multi stage liquid fuel rocket NASA launched as many as 13 Saturn's and with no loss of crew or payload with Saturn's there are very successful rocket, it still remains the tallest, heaviest and most powerful rocket ever brought to operational status.

And still holds the records for the heaviest launch vehicle payload, it is the huge rocket still the models are there in the Canady space center, as well as the Marshall mars space center in Huntsville. This rocket was again the chief architect of the that is Wernher von Braun, the scientist would developed the V 2 rocket, so far is the biggest rocket ever built.

The largest production model of the Saturn family of rockets, the Saturn 5 was designed under the direction of Wernher Von Braun and Arthur Rudolph, at the Marshall space flight center in Huntsville and Alabama and it has a very successful stint as a launched vehicle, repeatedly it was used without any heritage.

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Now, one of the most important machines taken by Saturn rocket program was Apollo machine. Apollo program was the spaceflight effort carried out by NASA, that landed the first humans on earth's moon, it was conceived during as an how was as the president. But, after the sputnik launched by Russians it got the steam, particularly under president J. F. Kennedy because, J. F. Kennedy propose the national goal of landing a man on the moon and returning him safely to the earth, this was proposed in 1916's and in 1961 in his address to the congress.

And he promised that it will be done within 10 years and it was a achieved by 1969, so within 10 years NASA was successful in fulfilling that promise and putting a man on moon. So, the Kennedy goal was accomplished with the Apollo 11 mission, so Apollo started from Apollo 1 there was various missions going to outer space not to moon, but in Apollo 11 the astronauts Neil Armstrong and Buzz Aldrin landed their lunar module, here is the picture of the lunar module on the moon on 20 th of July 1969.

And they walked on the surface, while Michael Collins remained in the lunar orbit in the command spacecraft is the lunar orbit. This is the assembly of lunar orbit, this is the Saturn 5 rocket launching the lunar module and this is the full assembly full picture of the system and various sub systems of the entire mission. So, they landed on the surface of moon and then successfully came back, the three safely landed back on earth on July

24 th. So, that as Neil Armstrong is famously quoted small stay for man and joint stay for mankind putting some body in the surface of moon.

After that they were few five subsequent Apollo mission, which also landed astronauts on moon, the last one in December 1972. And in this says spaceflights 12 men walked on the moon, after 1972 the Apollo mission was scraped and after that, so till date nobody has ever landed on moon. Now, the interesting part of history is that during the Apollo developed the Apollo mission, Russians were also in the risk, they were also trying to put man on moon, but since Americans have done before them they stopped the program.

So, they were tried to put man on moon yes, so far after 1972 nobody has landed on moon, I think India has planned some time in 1920, 1915 or something to have a man mission to moon that is in Chandra an 2, but that is collaborative mission between India and Russians.

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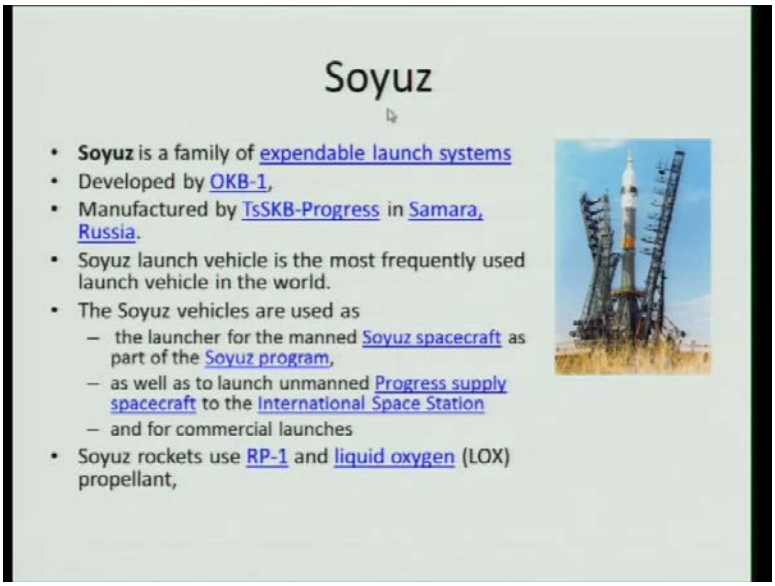

Now, another very important rocket program was Soyuz program, this was the main war horse of Russians space program, the Soyuz rocket. Soyuz is a family of expandable launch system this was developed by OKB 1, it was manufactured by TSSKB progress in samara Russia. This launched vehicle is the most frequently used launch in the world, still date it has the maximum number of missions, the Soyuz vehicle are used as the launcher for the manned Soyuz spacecraft as part of the Soyuz program of course.

As well as for launch of unmanned progress supply spacecraft to the international space station and for commercial launches, that is commercial launches are satellites from different countries. Soyuz rocket uses RP 1 and liquid oxygen as the propellant, so far this is considered to be the most widely used rocket in the world, so it is still in operational, still it sense supply to the international space station is in Soyuz rockets.

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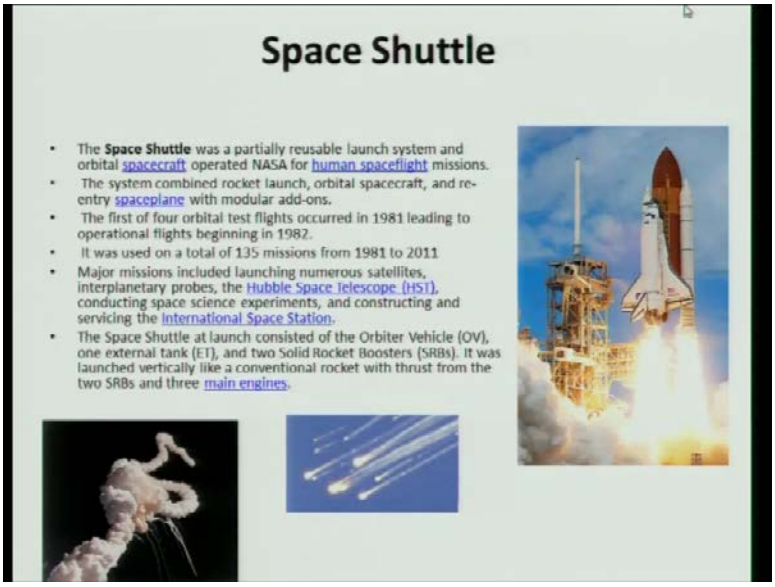

Now, another very important space program is the American space shuttle program, the space shuttle was a partially reusable launch system and also an orbital spacecraft operated by NASA for human spaceflight missions. So, this essentially it was a vehicle mounted on a space rocket and then it worked as an rocket vehicle, it was used extensively of course, now it has stopped at the end of 2011 the program was stopped.

This system had a combined rocket launch or vital space that is a rocket launch as you can see the picture of the rocket, this is the space shadow sitting on this and re entry space plane with modular add-ons. So, it is a very I would say versatile program they it was, so much flexibility in this program that many, many things can be done in space shuttle. And the basic structure was same and it was large extended reusable, particularly this module was reusable the reentry space plane.

Now, it was used for total of 135 missions spanning almost 30 years started in 1981, till 2011, 30 years it was operate this program was operational participating 135 missions. The major missions taken by space shuttle, includes the launching of numerous satellites,

interplanetary probes Seciny Galileo these all launched by space shuttle program which are now gone beyond the solar system. The Hubble's space telescope was launched by space shuttle, then they were very extensively used in space and experiments.

Because, they suite a scientist on board who is to conduct experiments in space and also they were extensively involve in the construction of the international space station, I will come to next and also servicing of international space station. The space shuttle at launch consisted of the orbital vehicle, the external tank, two solid rocket booster as you can see here. It was launch vertically like a conventional rocket with thrust from the two side boosters and three main engines, and then at the edge of the outer space the actual space vehicle shuttle vehicle will take off.

However, this program has space two of the most talked about space tragedies, first one we can see here the picture of challengers, challengers disasters. Challenger was a space shuttle operation and it was challenger first one was challenger or second one was challenger, this is the challenger disaster, this is Colombia, this is challenger disaster. Where the entire system, particularly started from the solid rocket boosters, the SRBS nothing to do with the space shuttle as this for say, the solid rocket boosters exploded in 73 seconds into the flight, it just took off and it exploded in flight.

So, we can see a picture of the entire the explosion happening and all the astronauts on both are killed. And another equally as a black spot in the space exploration is the Colombia disasters is shown here, whether the Colombia space shuttle is broken into pieces, this was during the reentry it fulfilled it mission when it was coming back there was some problem with the heat shields and the entire vehicle was broken into pieces and all astronauts on board were killed, including Kalpana Chawla. So, but even after the Colombia disasters the space shuttle program continued for few years, but now in 2011 they have stopped the space shuttle program. But, again this was a major program and major mile stone in space program.

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Now, the next international space station, this is a collaborative efforts between various countries like the, Americans, Russians, Japanese, Europeans and Canadians. This is a habitable artificial satellite in low earth orbit, it follows the Salyut, Almaz, Skylab and Mir stations and this is the nine space station to be inhabited by human beings, it has a modules structures. Whose first components they have been launched by American space shuttles, as well as Russian proton and Soyuz rocket.

Once again proton was ICBM, as you can see that Russians very successfully use the ICBM for various space applications. So, is a joint project between 5 participating space agencies, international space station was intended to be a laboratory, observatory and factory in space. It is also plan to provide transportation, maintenance and act as a staging base for possible future missions far or into far up places like moon and mars and also asteroids, so this will be the launching pad for further space missions.

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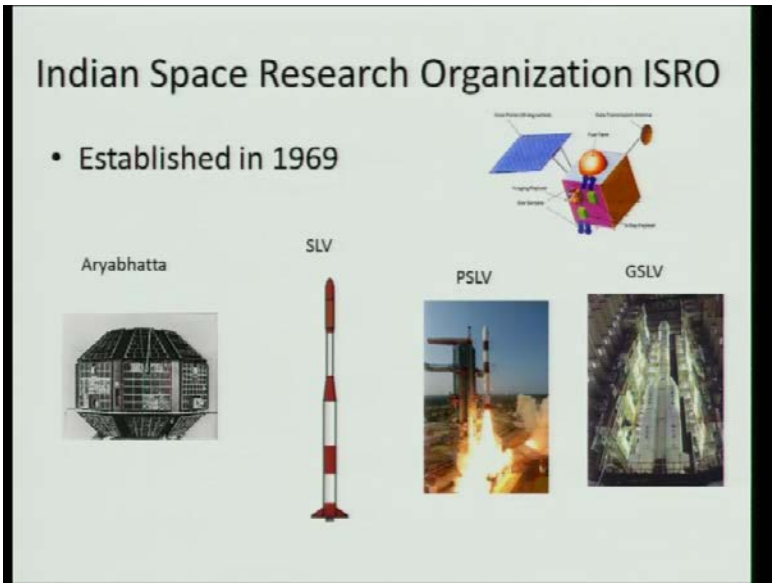

Now, coming to the Indian perspectives ISRO, this was establish in 1969, proposed by the visuals airlines (Refer Time: 43:48) led. So, starting from the early days of the first successful endower taken up by ISRO was Aryabhatta first Indian satellite, which was launched by Russians because, at that time did a launch the vehicles. Then the successful launch program started with first of sounding of rocket, which is go to pity low altitude, then SLV Satellite Launch Vehicle program, which is to send Rohini class satellites to low at orbits.

Then can the PSLV program Polar Satellite Launch Vehicle, very successful program till date had many, many successful missions and this is the power horse for Chandrayaan. This is the picture of Chandra Yaan, Indian lunar vision and it has successfully send the rover to moon and now they are planning as Chandrayaan to just suppose to be man mission. So, PSLV is now the war horse for ISRO most of the successful mission are with PSLV.

And the next is GSLV, GSLV could not launch vehicle, which is suppose to be capable of putting head light into 36,000 kilo meter orbit; geo synergize orbit, which uses a Cragenic stage. PSLV is primary initial stage of solid and then liquid, GSLV has a Cragenic stage as well. So, this is the Indian space program as under ISRO, ISRO and like in America the civilian and military applications of space is under two different entities in India.

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So, ISRO for the civilian side, primary goal is to develop launch vehicles and put in satellites. Where the military side we have DRDO Different Research and Development Organization, which has a Integrated Guided Missile Development Program IGMDP, started long time back sometime in late 70's early 80's under the leadership of Dr. A. P. J. Abdul Kalam. And they have successfully developed many, many missile systems there are some pictures, first one is Agni.

Agni is, so for an (Refer Time: 46:11) next step in to go beyond 5000 kilo meter will be ICBM. So, Agni is the had the longest range missile developed by India, successfully test by many times or another way successful missiles is Pridvi, which is shown here, Pridvi is a small range ballistic missile and Pridvi has been put for multiple users, including as a missile intercepted, this is a Pridvi missile interceptor. So, it is part of Indian development of Indian missile shield Pridvi missile is being used as the interceptor.

Apart from that there are other missiles, which are developed by DRDO, one such missile is akaash at just shown here this is surface to air missile, typically an anti air craft missile. Then NAC is shown here, this a anti tank missile wherever high energy explosive at the tip of it and this one is trishul, again a surface to air missile show as shown some of them this also piyaka has also somebody launch missiles etcetera, which I have not shown here.

But, India is now in the top leak of space exploration as well as in the missile programs because, we have achieved almost 90 percent of what are thus I have already done. So, we are very close there, so one of the Indian success story is it in rocket program, either we talk about missiles or in space the success story is in the rocket program, unlike most other program, which are failed or still continuing this is a successful end over taken of the India. So, we stop here we talked about the history of rockets today, the next then we come to now the actual theoretical formulation stock about rocket preparation next.

Thank you.