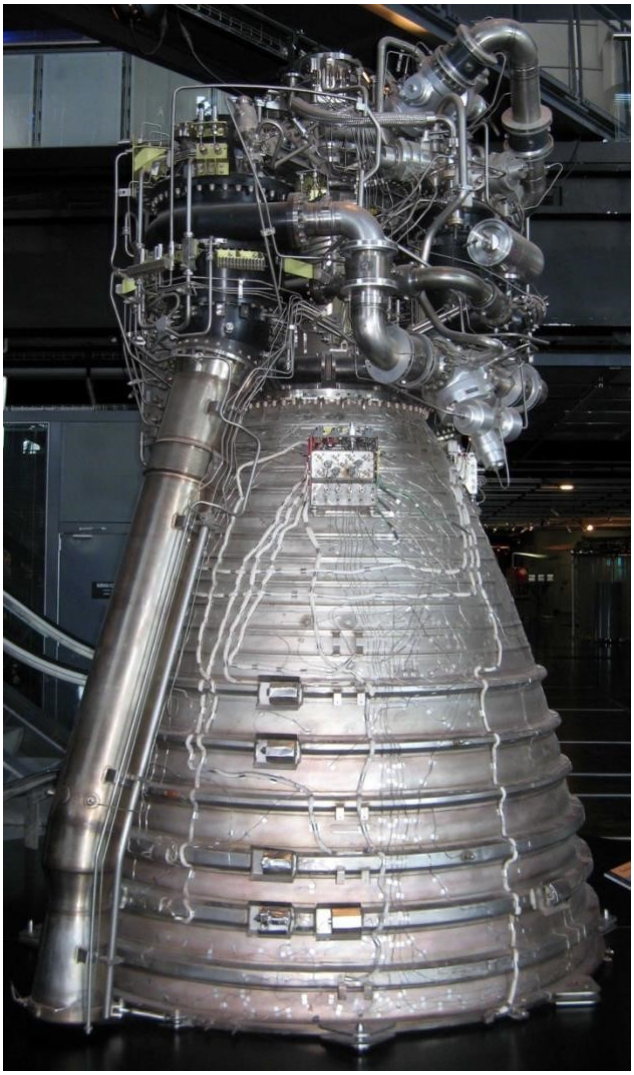
# CRYOGENIC TECHNOLOGY

# FOR

# ROCKET ENGINES

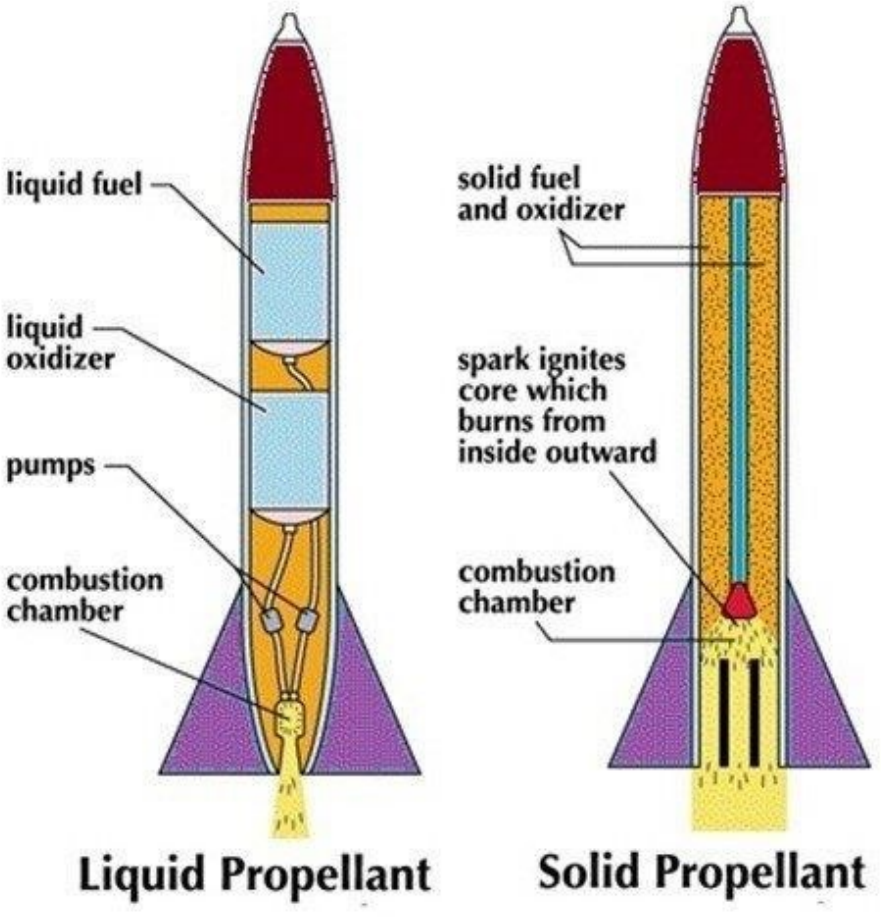
# AN ABSTRACT ABOUT THE PROJECT IDEA

Cryogenic engines are ordinarily utilized in rockets for launching fixed category satellites This paper is all concerning refrigerant Technology utilized in rocket's engine for all its area missions & its applications. This technology consists of use of 2 basic parts of universe Liq. Hydrogen(-253°C) &Liq. nitrogen (-183°C). This engine follows Newton's basic third law of motion. this is often the sole engine that offers 100% potency with none greenhouse emissions or pollution up to the date on earth. Key Words: refrigerant Engine, jet engine, refrigerant Temperature, Liquid hydrogen and chemical element, Newton third law of Mechanics.



# 1.INTRODUCTION

Cryogenic originated from 2 Greek word “Kyros” which suggests cold or phase change “gene” which suggests burn or produced. refrigerant is that the study of production of terribly vasoconstrictive nearly concerning ‘123 k’ within which the fabric behavior and properties ar estudied at that temperature. refrigerant engine could be a variety of rocket designed to use the fuel or oxidizing agent that should be cold to stay in liquid state. Liquid propellant Rocket engine(LPRE) ar usually utilized in area technology. Thrust chamber is one in all the foremost necessary scheme of a rocket. The liquid propellant (i.e.…liquid H and liquid oxygen) ar metered, injected, atomized, vaporized, mixed and burned to create hot reaction gas product, that in turned ar accelerated and ejected at supersonic speed. Payload capability of the craft is exaggerated with the system having higher specific impulse, generally liquid propellant engines end in longer burning time than typical solid rocket that end in higher specific impulse.



## 2. HISTORY OF TECHNOLOGY

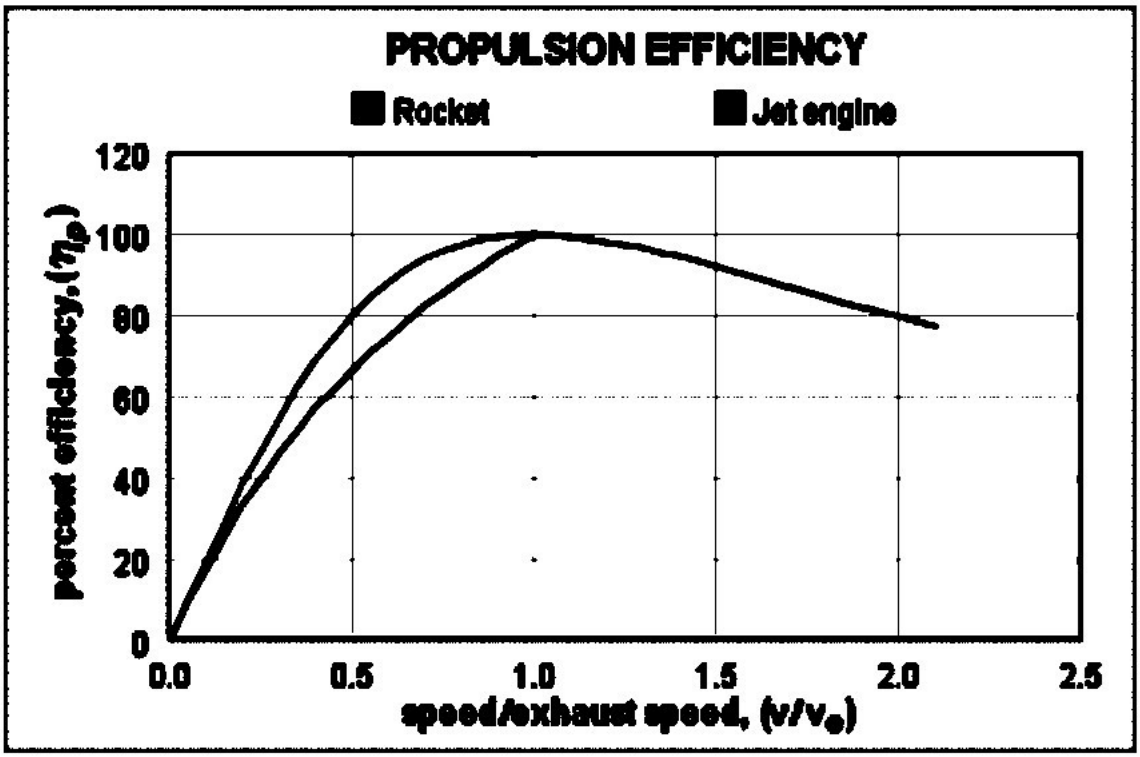
This Rocket Technology contains a great History involving many big nations as well as USA, Russia, Japan, France etc. an in depth competition was lead in later half twentieth Century for this technology since it's invention by USA. once USA with success launched its first Atlas V rocket in 1963 boosted up the conflict between Russia & USA that contend a big role in fast advancement during this technology in such a brief amount of your time. when USA Russia started its tests of launch vehicles. Firstly, Russia carried a dog named 'Linus' in house in 1983. Russia was 1st to require human in house exploitation satellite. throughout this era heap of European countries were attempting their rockets with same technologies &succeeded later, however no creature until 1985.

| ROCKET ENGINE | NATION | YEAR |
|---|---|---|
| RL- 10 | USA | 1963 |
| LE5 | JAPAN | 1977 |
| HM7 | FRANCE | 1979 |
| N1 | RUSSIA | 1983 |
| GSLV-D5 | INDIA | 2013 |

History of countries in Cryogenic engines

# CRYOGENIC TECHNOLOGY

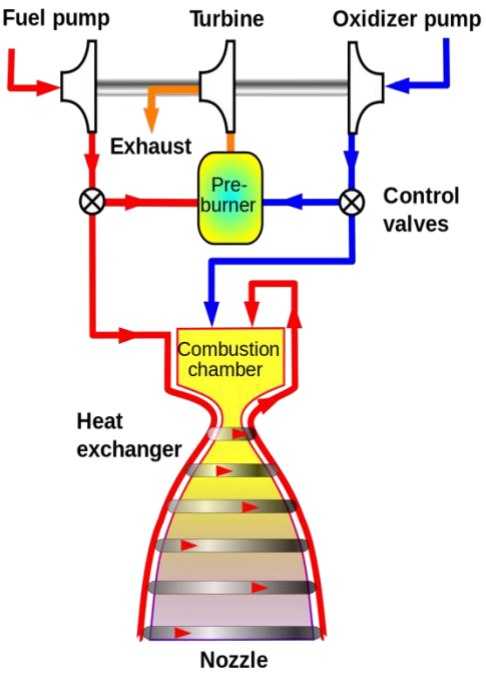
A refrigerant technology is that the method of involvement or as well as of usage of rocket propellants at a refrigerant temperature. It may be the mixture of liquid fuels such as: liquid oxygen (LOX), And liquid hydrogen (LH2) as an chemical agent and fuel within the totally different mixtures or proportions. The mixture of fuels offers terribly best the best} energy potency for the rocket engines that produces very high quantity of thrust. Here, the gas remains liquid solely at the temperature below (–183 C) and element at below (–253 C). this can be a kind of rocket that's functionally designed to use the chemical agent that should be cold within the liquid state. Sometimes, the liquid {nitrogen|nitrogen|N|atomic number 7|cryogen} (LN2) is typically used as a fuel as a result of the exhaust is additionally nitrogen. liquid oxygen is injected below essential temperature however higher than essential pressure. In our atmosphere gas is almost regarding seventy eight. gas could be a non-pollutant gas and through exhaust no alternative harmful gases are created. thence its potency is incredibly high than the other Jet engines. in line with Newtonian third law of mechanics: 'Action and Reaction are equal and opposite in direction'. rocket operates through force of its exhaust pushing it backwards. Thrust is in other way and a lot of economical in lower atmosphere or vacuum (sometimes). It makes the employment of atomic number 8 as AN chemical agent and liquid element as fuel. Pure liquid oxygen as chemical agent operates considerably at hotter combustion chambers because of that extraordinarily high heat fluxes are created that isn't obtainable in any jet engines. In jet engines hydrocarbon, diesel, kerosene, gasoline, LPG, CNG and PNG, etc., are used having the properties of hydrocarbons.



# 4. COMPONENTS

4.1 Gas Generator: The gas generator is employed to drive the turbo by a gas flow. The gas generated produces this energy by pre-burning some quantity of liq. Fuel. Use of Gas generator aligned with Turbo pump will increase the potency of this engine.

4.2 Turbo Pumps :The operating of this engine is incredibly straightforward to grasp because it doesn't involve any difficult cycles or any mutual mechanism. The fuel from tanks is first of all had the turbo pumps that rotates at a speed of regarding 14000 rate by that the mass flow rate of fuel will increase to regarding two.4 tons before reaching the combustion chamber.




4.3 Injector: Injector plays the foremost key role within the rocket engine it's like heart of the engine that generates the acceptable quantity of fuel from the turbo pump to the combustion chamber as per demand. contrivance ensures the soundness of the combustion chamber.
The frequency of the combustion chamber is to be maintained between 100-500 cycles per second. however if contrivance is therefore designed to extend the particular impulse quite 700 house crafts will travel a lot of long distances within the universe. contrivance is that the solely element of this engine that continues to be below construction nevertheless.

4.4 Combustion Chamber: Finally, once this finely distributed fuel droplets enter the thrust chamber at such high velocities & at their refrigerant temperatures they mixture to every different within the trust chamber, this reaction at such specific conditions will increase the pressure of chamber to regarding 250 bars with a unharness of giant quantity of thrust that is quite 15000 avoirdupois unit. This high quantity of trust is then manipulated bay slim gap towards the nozzle. The gap is unbroken slim to follow law of rate of discharge that states that 'velocity is reciprocally proportional to area'. By this method we tend to get the fascinating quantity of thrust that helps an area craft to realize its speed. Due this reaction in continues amount the temperature of Combustion Chamber furthermore as nozzle raises up to 3000-4000°C. to face up to such Associate in Nursing elevated temperature for extended amount of your time with none deformation a cooling Jacket is needed.

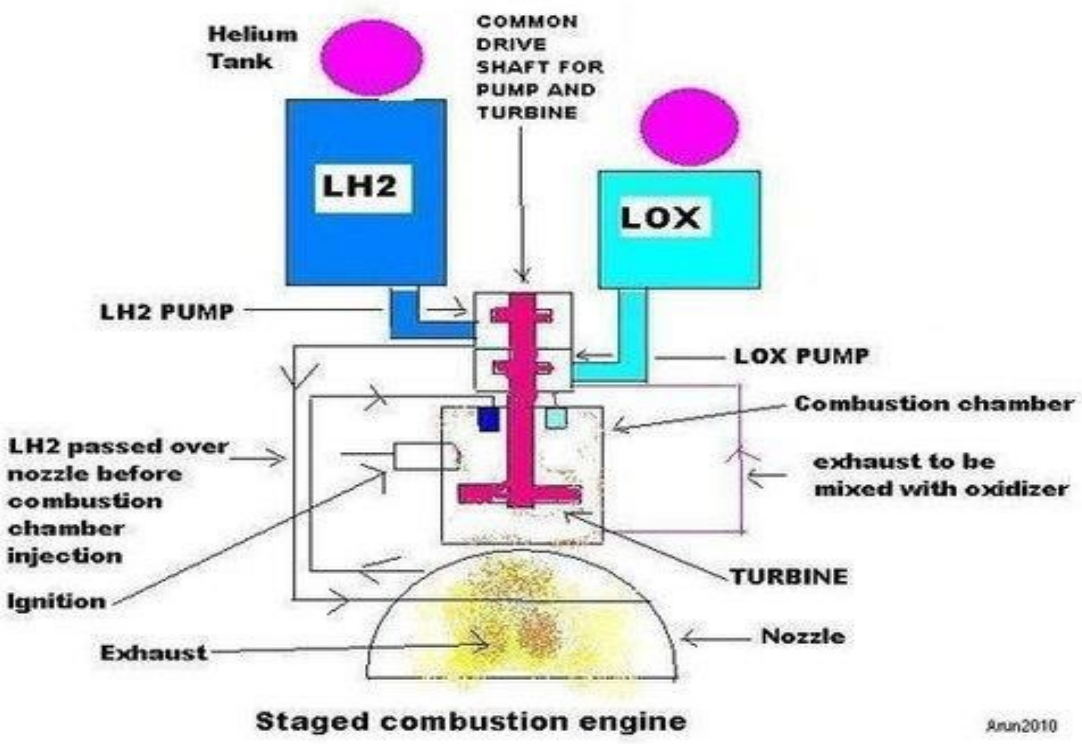
4.5. Cooling Jacket: Cooling Jacket is that the necessity of this engine however this facility is provided by the fuel of the engine itself therefore no external energy is to be used. The mechanism typically utilized in cooling jackets is active cooling. during this Technique, the cooling jacket is formed specified a flow if liq. Proponents is had the tubes provided from between the jackets. The liq. propellant passed area unit already at their refrigerant temperature therefore offer a awfully effective cooling. this easy mechanism permits the. Use of this technology throughout its journey with none deformation in Combustion chamber or Nozzle. once of these elements add their excellent formula, solely then we will reach our goal a booming launch of {a sapcelan area} vehicle for its space mission.

4.6. NOZZLE: The pressure generated in combustion chamber can be used increased thrust by acceleration of combustion gas to high supersonic velocity. Nozzle generally passes parabolic enters. Because when high velocity gases entrance and at exit of the nozzle, pressure of exhaust gas increases with high value and hence velocity and hence velocity reduces.

## 5. WORKING

Cryogenic Engines are rocket motors designed for liquid fuels that has got to be command at terribly low "cryogenic" temperatures to be liquid - they'd preferably be gas at normal temperatures. Typically, H and element are used which require to be command below 20°K (-423°F) and 90°K (- 297°F) to stay liquid. The engine elements also are cooled therefore the fuel does not boil to a gas within the lines that feed the engine. The thrust comes from the fast enlargement from liquid to gas with the gas rising from the motor at terribly high speed. The energy required to heat the fuels comes from burning them, once they're gases. refrigerant engines ar the very best performing rocket motors. One disadvantage is that the fuel tanks tend to be large and need serious insulation to store the propellant. Their high fuel potency, however, outweighs this disadvantage. The house Shuttle's main engines used for lift-off are refrigerant engines. The Shuttle's smaller thrusters for orbital manoeuvring use non-cryogenic hypergolic fuels, that are compact and are hold on at heat temperatures. Currently, solely the u. s., Russia, China, France, Japan and Republic of India have down refrigerant rocket technology. The refrigerant engine gets its name from the extraordinarily cold temperature at that liquid nitrogen is hold on. Air touring the vehicle is employed to heat liquid nitrogen to a boil. Once it boils, it turns to gas within the same manner that heated water forms steam in a very external-combustion engine. A rocket just like the Ariane five uses oxygen and hydrogen, each hold on as a refrigerant liquid, to provide its power. The liquid

nitrogen, hold on at -320 degrees Fahrenheit, is vaporized by the warmth money handler. N gas shaped within the device expands to regarding 700 times the amount of its liquid kind. This extremely pressurised gas is then fed to the expander, wherever the force of the nitrogen gas is converted into mechanical power.



## 6. CRYOGENIC FUELS/PROPELLANT

Latent heat of vaporization is that the most significant characteristic of any refrigerant (cryogenic fluid) due to its terribly straightforward thanks to cool instrumentality. Therefore, the helpful temperature vary of refrigerant fluids is that within which there exists heat of transformation of vaporization, i.e., between the triple purpose and therefore the juncture, with a specific interest within the traditional boiling purpose, i.e., the saturation temperature at air pressure. This information is given in Table one. within the following, we have a tendency to shall think about two cryogens: helium that is that the solely liquid at terribly cold, and nitrogen for its wide handiness and easy use for precooling instrumentality and for thermal shielding. Liquid element could be a clear, colourless liquid with boiling purpose at twenty seven.1 K and normally employed in element advertising boards. It's additionally used as refrigerant refrigerant and this refrigerant is compact, inert and fewer pricy as compared to liquid helium. liquid nitrogen boils at seventy seven.3 K and freezes at sixty three.2 K. It exists in 2 stable isotopes N14 & N15 in quantitative relation of 10000:38. Heat of vaporization of this fluid is 199.3 KJ and it's made by distillation of cryogen. nitrogen is primarily accustomed give associate

degree inert atmosphere in chemical and scientific discipline industries. it's additionally used as a liquid to supply refrigeration. For food preservation, blood, cells preservation liquid nitrogen is employed and it's has property of warmth electrical conduction. oxygen (LOX) is in blue color thanks to long chains of O4. Density of LOX is 1141 kg/m3. O2 is slightly magnetic and exists in three stable isotopes- O16, O17, and O18 in quantitative relation of 10000:4:20. due to the distinctive properties of atomic number 8, there's no substitute for atomic number 8 in any of its uses- wide employed in industries and for medical purpose. it's mostly employed in iron and steel producing trade. It applies in chemical agent propellant for satellite rocket.

## 7. ADVANTAGES

Storable liquid stages of PSLV and GSLV engines used presently unleash harmful product to the setting. The trend worldwide is to alter over to ecofriendly propellants. Liquid engines operating with refrigerant propellants (liquid oxygen and liquid hydrogen) and semi refrigerant engines using liquid oxygen and fuel are thought-about comparatively setting friendly, non-toxic and noncorrosive. additionally, the propellants for semi refrigerant engine are safer to handle & store. it will additionally reduce it will of launch operations. This advanced propulsion technology is currently obtainable solely with Russia and USA. India capability to fulfill existing mission needs. The semi refrigerant engine can facilitate applications for future area missions like the Reusable Launch Vehicle, Unified Launch Vehicle and vehicle for heavenly body missions.

(1)High Specific Impulse.
(2)Non-toxic and non-corrosive propellants.
(3)Non-hypergolic, improved ground safety.

## 8. DISADVANTAGES

(1) Low density of liquid Hydrogen-More structural mass.
(2)Low temperature of propellants -Complex storage.
(3)Transfer systems and operations.
(4)Hazards related to cryogens.
(5)Overall cost of propellants relatively high.
(6) Need for ignition system.

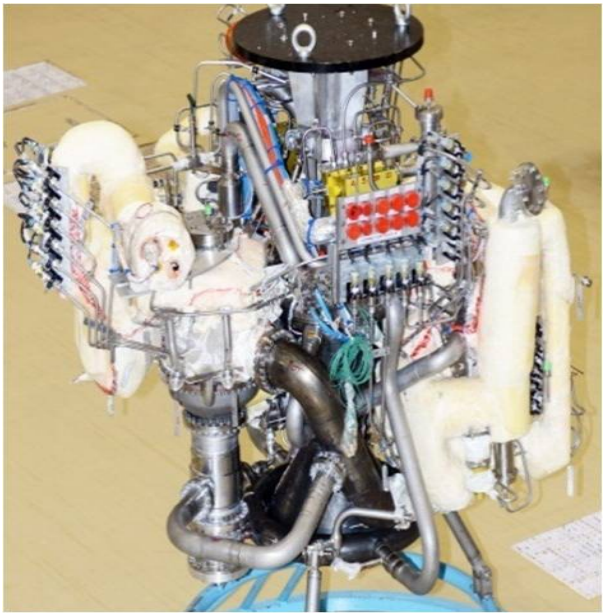
# ISRO’s Cryogenics In GSLV Mk-III D-5

GSLV-D5 flight of India’s Geosynchronous Satellite Launch Vehicle (GSLV). It is also the fourth developmental flight of GSLV. During this flight, the indigenously developed Cryogenic Upper Stage (CUS) will be flight tested for the second time. GSLV-D5 will launch 1982 Kg GSAT-14, a communication satellite, into Geosynchronous Transfer Orbit (GTO). After reaching GTO, GSAT-14will use its own propulsion system to reach its geostationary orbital home and will be stationed at 74º East longitude. GSAT-14 will help provide many satellite based communication services to the country including tele-education and telemedicine. GSLV-D5/GSAT-14 mission will be launched from the
Second Launch Pad at Satish Dhawan Space Centre SHAR (SDSC SHAR),Sriharikota. The flight duration of GSLV-D5 is 17 min 8 sec.

| GSLV-D5 Mission | |
|---|---|
| Overall Height | : 49.13 metre |
| Lift-off Mass | : 414.75 Ton |
| Lift-off Thrust | : 6773 kilo Newton |
| No. of Stages | : 3 |

# High Thrust Cryogenic Engine (CE20) Development

ISRO is developing a high thrust cryogenic engine to be used for the upper stage of its heavy lift launch vehicle GSLV Mk-III. This high thrust cryogenic engine produces a nominal thrust of 196.5 kN in vacuum with a specific impulse of 434 seconds. The engine works on “Gas Generator Cycle” which has flexibility for independent development of each sub-system before the integrated engine test, thus minimising uncertainty in the final developmental phase and reducing development time. This engine generates nearly 2 MW power as compared to 1 MW generated by the engine of Cryogenic Upper Stage (CUS) engine of GSLV. The high thrust cryogenic engine is one of the most powerful cryogenic engines of upper stages in the world. ISRO has achieved a major milestone by successfully conducting the ground test of Indigenous High Thrust Cryogenic Engine at ISRO Propulsion Complex at Mahendragiri on April 28, 2015 at 1657 Hrs for a duration of 635 seconds. All the propulsion parameters during the tests were found satisfactory and closely matched with predictions. This ground test was preceded in the last few weeks, by four short duration tests of 5.5, 7.5, 20 and 30 seconds.



The high thrust cryogenic engine is designed and realised by Liquid Propulsion Systems Centre
(LPSC) at Valiamala with the support of Vikram Sarabhai Space Centre (VSSC) at Thiruvananthapuram. The engine assembly, integration and testing is carried out by ISRO Propulsion Complex (IPRC) at Mahendragiri. Indian Industries have significantly contributed in the realization of the cryogenic engine.

While ground tests conducted so far validate this the design adequacy and performance of the integrated engine, further demonstration tests are planned at engine and stage level to characterise the different performance parameters under various operating conditions. After completion of the tests, the indigenous high thrust cryogenic engine and stage are planned to be flight tested in GSLV Mk- III-D1 mission.

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