**Cryogenic engine**

[](http://en.wikipedia.org/wiki/File:Moteur-Vulcain.jpg)

[*Vulcain*](http://en.wikipedia.org/wiki/Vulcain) engine of [Ariane 5](http://en.wikipedia.org/wiki/Ariane_5" \o "Ariane 5)rocket.

[](http://en.wikipedia.org/wiki/File:RL-10_rocket_engine.jpg)

[RL-10](http://en.wikipedia.org/wiki/RL-10) is an early example of cryogenic rocket engine.

A **cryogenic rocket engine** is a [rocket engine](http://en.wikipedia.org/wiki/Rocket_engine) that uses a [cryogenic fuel](http://en.wikipedia.org/wiki/Cryogenic_fuel) or [oxidizer](http://en.wikipedia.org/wiki/Oxidizer), that is, its fuel or oxidizer (or both) are gases liquefied and stored at very low temperatures.[[1]](http://en.wikipedia.org/wiki/Cryogenic_rocket_engine#cite_note-saturn-0) Notably, these engines were one of the main factors of the ultimate success in reaching the Moon by the [Saturn V](http://en.wikipedia.org/wiki/Saturn_V) rocket.[[1]](http://en.wikipedia.org/wiki/Cryogenic_rocket_engine#cite_note-saturn-0)

During [World War II](http://en.wikipedia.org/wiki/World_War_II), when powerful rocket engines were first considered by the German, American and Soviet engineers independently, all discovered that rocket engines need high [mass flow rate](http://en.wikipedia.org/wiki/Mass_flow_rate) of both oxidizer and fuel to generate a sufficient thrust. At that time oxygen and low molecular weight hydrocarbons were used as oxidizer and fuel pair. At room temperature and pressure, both are in gaseous state. Hypothetically, if propellants had been stored as pressurized gases, the size and mass of fuel tanks themselves would severely decrease rocket efficiency. Therefore, to get the required mass flow rate, the only option was to cool the propellants down to [cryogenic](http://en.wikipedia.org/wiki/Cryogenic) temperatures (below −150 °C, −238 °F), converting them to [liquid](http://en.wikipedia.org/wiki/Liquid) form. Hence, all cryogenic rocket engines are also, by definition, either [liquid-propellant rocket engines](http://en.wikipedia.org/wiki/Liquid-propellant_rocket) or [hybrid rocket engines](http://en.wikipedia.org/wiki/Hybrid_rocket_engine)[[2]](http://en.wikipedia.org/wiki/Cryogenic_rocket_engine#cite_note-isbn0-470-08024-8-1).

Various cryogenic fuel-oxidizer combinations have been tried, but the combination of liquid hydrogen ([LH2](http://en.wikipedia.org/wiki/LH2)) fuel and the liquid oxygen ([LOX](http://en.wikipedia.org/wiki/LOX)) oxidizer is one of the most widely used.[[1]](http://en.wikipedia.org/wiki/Cryogenic_rocket_engine#cite_note-saturn-0)[[3]](http://en.wikipedia.org/wiki/Cryogenic_rocket_engine#cite_note-2) Both components are easily and cheaply available, and when burned have one of the highest [entropy](http://en.wikipedia.org/wiki/Entropy) releases by combustion,[[4]](http://en.wikipedia.org/wiki/Cryogenic_rocket_engine#cite_note-isbn0-7923-5813-9-3) producing [specific impulse](http://en.wikipedia.org/wiki/Specific_impulse) up to 450 s ([effective exhaust velocity](http://en.wikipedia.org/wiki/Effective_exhaust_velocity) 4.4 km/s).

## Construction

The major components of a cryogenic rocket engine are the [combustion chamber](http://en.wikipedia.org/wiki/Combustion_chamber) (thrust chamber), [pyrotechnic igniter](http://en.wikipedia.org/wiki/Pyrotechnic_igniter), fuel injector, fuel [cryopumps](http://en.wikipedia.org/wiki/Cryopump" \o "Cryopump), oxidizer cryopumps, [gas turbine](http://en.wikipedia.org/wiki/Gas_turbine), cryo valves, regulators, the fuel tanks, and[rocket engine nozzle](http://en.wikipedia.org/wiki/Rocket_engine_nozzle). In terms of feeding propellants to combustion chamber, cryogenic rocket engines (or, generally, all liquid-propellant engines) work in either an [expander cycle](http://en.wikipedia.org/wiki/Expander_cycle), a [gas-generator cycle](http://en.wikipedia.org/wiki/Gas-generator_cycle_(rocket)), a [staged combustion cycle](http://en.wikipedia.org/wiki/Staged_combustion_cycle_(rocket)), or the simplest [pressure-fed cycle](http://en.wikipedia.org/wiki/Pressure-fed_cycle_(rocket)).

The cryopumps are always [turbopumps](http://en.wikipedia.org/wiki/Turbopump" \o "Turbopump) powered by a flow of fuel through gas turbines. Looking at this aspect, engines can be differentiated into a main flow or a bypass flow configuration. In the main flow design, all the pumped fuel is fed through the gas turbines, and in the end injected to the combustion chamber. In the bypass configuration, the fuel flow is split; the main part goes directly to the combustion chamber to generate thrust, while only a small amount of the fuel goes to the turbine

# 300 N Cryogenic Rocket Engine.

## A compact, re-ignitable, pressure fed cryogenic engine with an Isp of 415 sec.

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| 300 N cryogenic pressure fed rocket engine  **300 N Rocket Engine** |

This 300 N cryogenic propellant engine has a vacuum Isp of 415 seconds - the highestvalue ever achieved in Europe for an engine of such small size.

Being pressure-fed, the engine assembly is relatively simple and avoids the need for a turbo-pump. The thrust chamber and throat region of the engine are regeneratively cooled using hydrogen propellant. The nozzle extension is radiation cooled.

The engine incorporates a splash-plate injector having a star shaped configuration. Ignition and subsequent re-ignition is achieved using Triethylaluminium (TEA) - which is hypergolic with the oxygen propellant. The number of re-ignitions is a function of the volume of Triethylaluminium accommodated. The engine nominally provides for 1 ignition and 3 re-ignitions using just 1.5 cc of Triethylaluminium. The use of a chemical ignition system enables a very compact design.

The engine needs no pre-cooling prior to ignition. Only the propellant feed lines to the engine propellant valves need be pre-cooled.

Engine construction materials are mainly stainless steel, Nimonic 75 (Chromium-Nickel Alloy) and copper.

The engine has the status of a flight prototype and is available for flight qualification. Currently, 5 prototype engines have been manufactured.

**Applications**

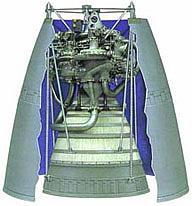
* The 300 N cryogenic engine enables the simplicity of a pressure fed propulsion system whilst offering the performance of a turbo-pump propulsion system.
* Being pressure fed, the engine does not require an additional turbo-pump, with its associated complexity.
* The 300 N cryogenic engine may be used as a main engine in dedicated stages for orbital insertion, orbital transfer, orbital, and interplanetary applications, including:

bullet Upper stages  
bullet Kick stages.  
bullet Vernier stages.  
bullet Transfer stages.

* The 300 N cryogenic engine may also be used as a thruster, or thruster cluster with existing cryogenic turbo-pump propulsion systems and stages for such applications as performance augmentation, upgrades, roll control.

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| **300 N Cryogenic Rocket Engine Characteristics** |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | |  |  | | --- | --- | | Propellants | LOX / LH2 | | Nominal thrust vac | 300 N | | Chamber pressure | 5 bar | | Mixture ratio | 5.5 | | Characteristic chamber length | 0.4 m | | Nozzle area ratio | 57 | | Specific Impulse vac. | 415 sec | | | | |  | |  |  | | --- | --- | | Overall efficiency | 91% | | Thrust range - chamber pressure - mixture ratio - propellant mass flow rate | 240 - 480 N 4 - 8 bar 3.5 - 6.5 0.06 - 0.12 kg/s | | Overall length | 390 mm | | Mass | 1.884 kg | | Number of ignitions | 4 | | | | | |

**RL-10B-2**

  
**Rl10B2**

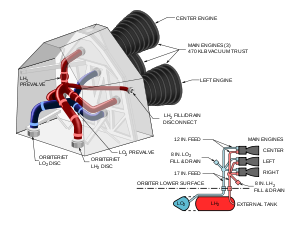
Pratt and Whitney lox/lh2 rocket engine. 110 kN. In production. Isp=462s. Used on Delta 3 , Delta IV launch vehicles. First flight 1998. Extendable exit cone for increased specific impulse; electromechanical actuators replace hydraulic systems.

The upgraded cryogenic second-stage Pratt & Whitney RL10B-2 engine is based on the 30-year heritage of the reliable RL10 engine. It incorporates an extendable exit cone for increased specific impulse (Isp) and payload capability. The basic engine and turbo pump are unchanged relative to the RL10. The engine gimbal system uses electromechanical actuators that increase reliability while reducing both cost and weight. The propulsion system and attitude control system (ACS) utilize flight-proven off-the-shelf components. The second-stage propulsion system produces a thrust of 24,750 lb with a total propellant load of 37,090 lb, providing a total burn time of approxi-mately 700 sec. Missions requiring more than one restart are accommodated by adding an extra helium bottle for the additional tank repressurization.

*Area Ratio:* 250.

*Status*: In production.   
*Diameter*: 2.13 m (6.98 ft).   
*Thrust*: 110.00 kN (24,720 lbf).   
*Specific impulse*: 462 s. 

## Hydrogen fuel system

[](http://en.wikipedia.org/wiki/File:Orbiter_main_propulsion_system.svg)

[http://bits.wikimedia.org/skins-1.5/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Orbiter_main_propulsion_system.svg)

Orbiter main propulsion system

[Fuel](http://en.wikipedia.org/wiki/Fuel) enters the orbiter at the liquid hydrogen feed line disconnect valve, then flows into the orbiter liquid hydrogen feed line manifold and branches out into three parallel paths to each engine. In each liquid hydrogen branch, a prevalve permits liquid hydrogen to flow to the low-pressure fuel turbopump when the prevalve is open.

The Low Pressure Fuel Turbopump (LPFTP) is an axial-flow pump driven by a two-stage turbine powered by gaseous hydrogen. It boosts the pressure of the liquid hydrogen from 30 to 276 psia (0.2 to 1.9 MPa) and supplies it to the High-Pressure Fuel Turbopump (HPFTP). During engine operation, the pressure boost provided by the LPFTP permits the HPFTP to operate at high speeds without cavitating. The LPFTP operates at approximately 16,185 rpm. The LPFTP is approximately 450 by 600 mm (18 by 24 inches). It is connected to the vehicle propellant ducting and is supported in a fixed position by the orbiter structure 180 degrees from the LPOTP.

The HPFTP is a three-stage centrifugal pump driven by a two-stage, hot-gas turbine. It boosts the pressure of the liquid hydrogen from 1.9 to 45 MPa (276 to 6,515 psia). The HPFTP operates at approximately 35,360 rpm. The discharge flow from the turbopump is routed to and through the main valve and then splits into three flow paths. One path is through the jacket of the main combustion chamber, where the hydrogen is used to cool the chamber walls. It is then routed from the main combustion chamber to the LPFTP, where it is used to drive the LPFTP turbine. A small portion of the flow from the LPFTP is then directed to a common manifold from all three engines to form a single path to the external tank to maintain liquid hydrogen tank pressurization. The remaining hydrogen passes between the inner and outer walls to cool the hot-gas manifold and is discharged into the main combustion chamber. The second hydrogen flow path from the main fuel valve is through the engine nozzle (to cool the nozzle). It then joins the third flow path from the chamber coolant valve. The combined flow is then directed to the fuel and oxidizer preburners. The HPFTP is approximately 550 by 1100 mm (22 by 44 inches). It is attached by flanges to the hot-gas manifold.

**India’s cryogenic engine comes of age**

India’s growing prowess in space technology is a nearly invisible, softly-softly adventure of notching up small, incremental successes on a continual basis. Yesterday the Prime Minister announced in the Parliament : “we have been able to successfully develop the cyrogenic engine on our own”. Behind that terse statement lies a trail thick with geo political intrigue, complex sciences and quiet Indians at their tasks.

India’s cryogenic engine initiative began in 1993 but when it carried out its nuclear tests in 1998, it also blew a big hole through its network of international relations in diplomacy and trade. Amidst world-wide condemnation India’s scientists were tarred with suspicion and most collaborations with them were severed.

The real reason for withholding cryogenic engine technology was however not ‘global security’ but commerce—big commerce. These engines are required to launch the geo-synchronous satellites that are used in communications. It’s a lucrative business. Russia, Europe and the US have carved out the launch market. Emergence of India as a low cost launcher would have threatened their shares.

Faced with the ostracisation, India chose to develop the engine on its own. It’s GSLV launch programme was kept on course with the essential cryogenic engines sourced from Russia. In all ten were contracted for. On April 18,2001 India bustled into the exclusive GSLV launchers’ club. It successfully launched a 1.5 tonne satellite and parked it at 36,000 km above, in lock-step with earth’s rotation. That was with a Russian engine.

At Mahendragiri in Tamil Nadu, is the Liquid Propulsion System Centre [LPSC]. Here work on developing India’s own cryo engines has been quietly moving. The system involves materials working at 250 deg below zero and pumps at speeds of 40,000 rpm. There are also complex metering, monitoring, integrating technologies involved. The engines are required to fire for about 700 seconds during the final stage of a launch providing 7 tonnes of thrust.

First signs of success came on Feb 10,2002 when India ‘test-fired’ it’s home-spun engine for the first time. It ran for a few seconds. Eight months later, on Sep 14,2002 the engine had been run for 1000 seconds on the test bed. This confirmed that the Indian design was sound . And yesterday --March 12,2003-- came the news that the engine is ready for manufacture.

Only the US, Russia, China, France and Japan have had this technology so far. The next piece of news you may expect to hear is that India has switched to its own engines to power its GSLV launches. The first of such a series is slated for next year. In ten years flat, India would have internalised and commercialised an advanced technology.

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