

# Various rocket propellants and their characterstics



----- Rocket A rocket is

a missile, spacecraft, aircraft or other vehicle which obtains thrust from a rocket engine. In all rockets, the exhaust is formed entirely from propellants carried within the rocket before use. [1] Rocket engines work by action and reaction. Rocket engines push rockets forwards simply by throwing their exhaust backwards extremely fast. Rockets for military and recreational uses date back to at least 13th century China. 2] Significant scientific, interplanetary and industrial use did not occur until the 20th century, when rocketry was the enabling technology of the Space Age, including setting foot on the moon. Rockets are used for fireworks, weaponry, ejection seats, launch vehicles for artificial satellites, human spaceflight and space exploration. While comparatively inefficient for low speed use, they are very lightweight and powerful, capable of generating large accelerations and of attaining extremely high speeds with reasonable efficiency.

Chemical rockets are the most common type of rocket and they typically create their exhaust by the combustion of rocket propellant. Chemical rockets store a large amount of energy in an easily released form, and can be very dangerous. However, careful design, testing, construction and use minimizes risks. ----- HOW ROCKET WORKS

Rockets create thrust by expelling mass backwards in a high speed jet (see Newton's Third Law).

Chemical rockets, the subject of this article, create thrust by reacting propellants within a combustion chamber into a very hot gas at high pressure, which is then expanded and accelerated by passage through a

nozzle at the rear of the rocket. The amount of the resulting forward force, known as thrust, that is produced is the mass flow rate of the propellants multiplied by their exhaust velocity (relative to the rocket), as specified by Newton's third law of motion. Thrust is therefore the equal and opposite reaction that moves the rocket, and not by interaction of the exhaust stream with air around the rocket.

Equivalently, one can think of a rocket being accelerated upwards by the pressure of the combusting gases against the combustion chamber and nozzle. This operational principle stands in contrast to the commonly-held assumption that a rocket "pushes" against the air behind or below it. Rockets in fact perform better in outer space (where there is nothing behind or beneath them to push against), because there is a reduction in air pressure on the outside of the engine, and because it is possible to fit a longer nozzle without suffering from flow separation, in addition to the lack of air drag.

The maximum velocity that a rocket can attain in the absence of any external forces is primarily a function of its mass ratio and its exhaust velocity. The relationship is described by the rocket equation:  $V_f = V_e \ln(M_0 / M_f)$ . The mass ratio is just a way to express what proportion of the rocket is propellant (fuel/oxidizer combination) prior to engine ignition. Typically, a single-stage rocket might have a mass fraction of 90% propellant, 10% structure, and hence a mass ratio of 10: 1 .

The impulse delivered by the motor to the rocket vehicle per weight of fuel consumed is often reported as the rocket propellant's specific impulse. A

propellant with a higher specific impulse is said to be more efficient because more thrust is produced while consuming a given amount of propellant.

Lower stages will usually use high-density (low volume) propellants because of their lighter tankage to propellant weight ratios and because higher performance propellants require higher expansion ratios for maximum performance than can be attained in atmosphere.

Thus, the Apollo-Saturn V first stage used kerosene-liquid oxygen rather than the liquid hydrogen-liquid oxygen used on its upper stages. Similarly, the Space Shuttle uses high-thrust, high-density solid rocket boosters for its lift-off with the liquid hydrogen-liquid oxygen Space Shuttle Main Engines used partly for lift-off but primarily for orbital insertion.

----- Rocket propellant Rocket propellant is mass that is stored in some form of propellant tank, prior to being used as the propulsive mass that is ejected from a rocket engine in the form of a fluid jet to produce thrust.

A fuel propellant is often burned with an oxidizer propellant to produce large volumes of very hot gas. These gases expand and push on a nozzle, which accelerates them until they rush out of the back of the rocket at extremely high speed, making thrust. Sometimes the propellant is not burned, but can be externally heated for more performance. For smaller attitude control thrusters, a compressed gas escapes the spacecraft through a propelling nozzle. Chemical rocket propellants are most commonly used, which undergo exothermic chemical reactions to produce hot gas used by a rocket for propulsive purposes.

In ion propulsion, the propellant is made of electrically charged atoms (ions), which are electromagnetically pushed out of the back of the spacecraft.

Magnetically accelerated ion drives are not usually considered to be rockets however, but a similar class of thrusters use electrical heating and magnetic nozzles. —————

Chemical propellants There are three main types of propellants: solid, liquid, and hybrid. Solid propellants

### History

The earliest rockets were created hundreds of years ago by the Chinese, and were used primarily for fireworks displays and as weapons. They were fueled with black powder, a type of gunpowder consisting of a mixture of charcoal, sulfur and potassium nitrate (their version of black powder). This formulation is now used in Black Powder Rocket Motors. Rocket propellant technology did not advance until the end of the 19th century, by which time smokeless powder had been developed, originally for use in firearms and artillery pieces.

Smokeless powders and related compounds have seen use as double-base propellants. Description Solid propellants (and almost all rocket propellants) consist of an oxidizer and a fuel. In the case of gunpowder, the fuel is charcoal, the oxidizer is potassium nitrate, and sulphur serves as a catalyst. (Note: sulphur is not a true catalyst in gunpowder as it is consumed to a great extent into a variety of reaction products such as  $K_2S$ . The sulphur acts mainly as a sensitizer lowering threshold of ignition. During the 1950s and 60s researchers in the United States developed what is now the standard high-energy solid rocket fuel, Ammonium Perchlorate Composite

Propellant (APCP). This mixture is primarily ammonium perchlorate powder

<https://assignbuster.com/various-rocket-propellants-and-their-characterstics/>

(an oxidizer), combined with fine aluminium powder (a fuel), held together in a base of PBAN or HTPB (rubber-like fuels). The mixture is formed as a liquid, and then cast into the correct shape and cured into a rubbery solid.

#### ----- Propellant families

**Black Powder (BP) Propellants** Composed of charcoal (fuel), potassium nitrate (oxidizer), and sulfur (additive), black powder is one of the oldest pyrotechnic compositions with application to rocketry. In modern times, black powder finds use in low-power model rockets (such as Estes and Quest rockets), as it is cheap and fairly easy to produce. The fuel grain is typically a mixture of pressed fine powder (into a solid, hard slug), with a burn rate that is highly dependent upon exact composition and operating conditions.

Due to its sensitivity to fracture (and, therefore, catastrophic failure upon ignition) and poor performance (specific impulse around 80 s), BP does not typically find use in motors above 40 Ns. **Zinc-Sulfur (ZS) Propellants** Composed of powdered zinc metal and powdered sulfur (oxidizer), ZS or “micrograin” is another pressed propellant that does not find any practical application outside of specialized amateur rocketry circles due to its poor performance (as most ZS burns outside the combustion chamber) and incredibly fast linear burn rates on the order of 2 m/s.

ZS is most often employed as a novelty propellant as the rocket accelerates extremely quickly, leaving a spectacular large orange fireball behind it. “Candy” propellants In general, candy propellants are an oxidizer (typically potassium nitrate) and a sugar fuel (typically dextrose, sorbitol, or sucrose)

that are cast into shape by gently melting the propellant constituents together and pouring or packing the amorphous colloid into a mold. Candy propellants generate a low-medium specific impulse of roughly 130 s and, thus, are used primarily only by amateur and experimental rocketeers.

### Double-Base (DB) Propellants

DB propellants are composed of two monopropellant fuel components where one typically acts as a high-energy (yet unstable) monopropellant and the other acts as a lower-energy stabilizing (and gelling) monopropellant. In typical circumstances, nitroglycerin is dissolved in a nitrocellulose gel and solidified with additives. DB propellants are implemented in applications where minimal smoke is required yet medium-high performance (Isp of roughly 235 s) is required. The addition of metal fuels (such as aluminum) can increase the performance (around 250 s), though metal oxide nucleation in the exhaust can turn the smoke opaque.

Composite propellants A powdered oxidizer and powdered metal fuel are intimately mixed and immobilized with a rubbery binder (that also acts as a fuel). Composite propellants are often either ammonium nitrate-based (ANCP) or ammonium perchlorate-based (APCP). Ammonium nitrate composite propellant often uses magnesium and/or aluminum as fuel and delivers medium performance (Isp of about 210 s) whereas Ammonium Perchlorate Composite Propellant often uses aluminum fuel and delivers high performance (vacuum Isp up to 296 s with a single piece nozzle or 304 s with a high area ratio telescoping nozzle). 8] Composite propellants are cast, and retain their shape after the rubber binder, such as Hydroxyl-terminated polybutadiene (HTPB), cross-links (solidifies) with the aid of a curative

<https://assignbuster.com/various-rocket-propellants-and-their-characterstics/>

additive. Because of its high performance, moderate ease of manufacturing, and moderate cost, APCP finds widespread use in space rockets, military rockets, hobby and amateur rockets, whereas cheaper and less efficient ANCP finds use in amateur rocketry and gas generators. Ammonium dinitramide,  $\text{NH}_4\text{N}(\text{NO}_2)_2$ , is being considered as a 1-to-1 chlorine-free substitute for ammonium perchlorate in composite propellants.

Unlike ammonium nitrate, ADN can be substituted for AP without a loss in motor performance. In 2009, a group succeeded in creating a propellant of water and nanoaluminum (ALICE). The Constellation program uses a mix of aluminum, ammonium perchlorate, a polymer of polybutadiene and acrylonitrile, epoxy and iron oxide. [15] High-Energy Composite (HEC) propellants Typical HEC propellants start with a standard composite propellant mixture (such as APCP) and add a high-energy explosive to the mix. This extra component usually is in the form of small crystals of RDX or HMX, both of which have higher energy than ammonium perchlorate.

Despite a modest increase in specific impulse, implementation is limited due to the increased hazards of the high-explosive additives. Composite Modified Double Base propellants Composite modified double base propellants start with a nitrocellulose/nitroglycerin double base propellant as a binder and add solids (typically ammonium perchlorate and powdered aluminum) normally used in composite propellants. The ammonium perchlorate makes up the oxygen deficit introduced by using nitrocellulose, improving the overall specific impulse. The aluminum also improves specific impulse as well as combustion stability.

<https://assignbuster.com/various-rocket-propellants-and-their-characterstics/>



High performing propellants such as NEPE-75 used in Trident II D-5, replace most of the AP with HMX, further increasing specific impulse. The mixing of composite and double base propellant ingredients has become so common as to blur the functional definition of double base propellants. Minimum-signature (smokeless) propellants One of the most active areas of solid propellant research is the development of high-energy, minimum-signature propellant using CL-20 (China Lake compound #20),  $C_6H_6N_6(NO_2)_6$ , which has 14% higher energy per mass and 20% higher energy density than HMX.

The new propellant has been successfully developed and tested in tactical rocket motors. The propellant is non-polluting: acid free, solid particulates free, and lead free. It is also smoke free and has only a faint shock diamond pattern that is visible in the otherwise transparent exhaust. Without the bright flame and dense smoke trail produced by the burning of aluminized propellants, these smokeless propellants all but eliminate the risk of giving away the positions from which the missiles are fired. The new CL-20 propellant is shock-insensitive (hazard class 1. ) as opposed to current HMX smokeless propellants which are highly detonable (hazard class 1. 1). CL-20 is considered a major breakthrough in solid rocket propellant technology but has yet to see widespread use because costs remain high. [14] Advantages Solid-fueled rockets are much easier to store and handle than liquid-fueled rockets, which makes them ideal for military applications. In the 1970s and 1980s the U. S. switched entirely to solid-fueled ICBMs: the LGM-30 Minuteman and LG-118A Peacekeeper (MX).

In the 1980s and 1990s, the USSR/Russia also deployed solid-fueled ICBMs (RT-23, RT-2PM, and RT-2UTTH), but retains two liquid-fueled ICBMs (R-

<https://assignbuster.com/various-rocket-propellants-and-their-characterstics/>

36 and UR-100N). All solid-fueled ICBMs on both sides have three initial solid stages and a precision maneuverable liquid-fueled bus used to fine tune the trajectory of the reentry vehicle. Their simplicity also makes solid rockets a good choice whenever large amounts of thrust are needed and cost is an issue. The Space Shuttle and many other orbital launch vehicles use solid-fueled rockets in their first stages (solid rocket boosters) for this reason.

Disadvantages Relative to liquid fuel rockets, solid rockets have a number of disadvantages. Solid rockets have a lower specific impulse than liquid-fueled rockets. It is also difficult to build a large mass ratio solid rocket because almost the entire rocket is the combustion chamber, and must be built to withstand the high combustion pressures. If a solid rocket is used to go all the way to orbit, the payload fraction is very small. (For example, the Orbital Sciences Pegasus rocket is an air-launched three-stage solid rocket orbital booster.

Launch mass is 23, 130 kg, low earth orbit payload is 443 kg, for a payload fraction of 1. 9%. Compare to a Delta IV Medium, 249, 500 kg, payload 8600 kg, payload fraction 3. 4% without air-launch assistance. ) A drawback to solid rockets is that they cannot be throttled in real time, although a predesigned thrust schedule can be created by altering the interior propellant geometry. Solid rockets can often be shut down before they run out of fuel. Essentially, the rocket is vented or an extinguishant injected so as to terminate the combustion process.

In some cases termination destroys the rocket, and then this is typically only done by a Range Safety Officer if the rocket goes awry. The third stages of

the Minuteman and MX rockets have precision shutdown ports which, when opened, reduce the chamber pressure so abruptly that the interior flame is blown out. [citation needed] This allows a more precise trajectory which improves targeting accuracy. Finally, casting very large single-grain rocket motors has proved to be a very tricky business. Defects in the grain can cause explosions during the burn, and these explosions can increase the burning propellant surface enough to cause a runaway pressure increase, until the case fails. Liquid propellants History Though early rocket theorists, such as Konstantin Tsiolkovsky, proposed liquid hydrogen and liquid oxygen as propellants,[1] the first liquid-fueled rocket, launched by Robert Goddard on March 16, 1926, used gasoline and liquid oxygen. Liquid hydrogen was first used by the engines designed by Pratt and Whitney for the Lockheed CL-400 Suntan reconnaissance aircraft in the mid-1950s.

In the mid-1960s, the Centaur and Saturn upper stages were both using liquid hydrogen and liquid oxygen. The highest specific impulse chemistry ever test-fired in a rocket engine was lithium and fluorine, with hydrogen added to improve the exhaust thermodynamics (making this a tripropellant). [2] The combination delivered 542 seconds (5.32 kN·s/kg, 5320 m/s) specific impulse in a vacuum. The impracticality of this chemistry highlights why exotic propellants are not actually used: to make all three components liquids, the hydrogen must be kept below -252 °C (just 21 K) and the lithium must be kept above 180 °C (453 K).

Lithium and fluorine are both extremely corrosive, liquid lithium ignites on contact with air, fluorine ignites on contact with most fuels, and hydrogen, while not hypergolic, is an explosive hazard. Fluorine and the hydrogen

<https://assignbuster.com/various-rocket-propellants-and-their-characteristics/>

fluoride (HF) in the exhaust are very toxic, which damages the environment, makes work around the launch pad difficult, and makes getting a launch license that much more difficult. The rocket exhaust is also ionized, which would interfere with radio communication with the rocket. How a Liquid Propellant Functions

As with conventional solid fuels rockets, liquid fueled rockets burn a fuel and an oxidizer, however, both in a liquid state. Two metal tanks hold the fuel and oxidizer respectively. Due to properties of these two liquids, they are typically loaded into their tanks just prior to launch. The separate tanks are necessary, for many liquid fuels burn upon contact. Upon a set launching sequence two valves open, allowing the liquid to flow down the pipe-work. If these valves simply opened allowing the liquid propellants to flow into the combustion chamber, a weak and unstable thrust rate would occur, so either a pressurized gas feed or a turbopump feed is used. The simpler of the two, the pressurized gas feed, adds a tank of high pressure gas to the propulsion system. The gas, an unreactive, inert, and light gas (such as helium), is held and regulated, under intense pressure, by a valve/regulator. The second, and often preferred, solution to the fuel transfer problem is a turbopump. A turbopump is the same as regular pump in function and bypasses a gas-pressurized system by sucking out the propellants and accelerating them into the combustion chamber.

The oxidizer and fuel are mixed and ignited inside the combustion chamber and thrust is created. Current Types The most common liquid propellants in use today: \* LOX and kerosene (RP-1). Used for the lower stages of most Russian and Chinese boosters, the first stages of the Saturn V and Atlas V, <https://assignbuster.com/various-rocket-propellants-and-their-characterstics/>

and all stages of the developmental Falcon 1 and Falcon 9. Very similar to Robert Goddard's first rocket. This combination is widely regarded as the most practical for boosters that lift off at ground level and therefore must operate at full atmospheric pressure. LOX and liquid hydrogen, used in the Space Shuttle orbiter, the Centaur upper stage of the Atlas V, Saturn V upper stages, the newer Delta IV rocket, the H-IIA rocket, and most stages of the European Ariane rockets. \* Nitrogen tetroxide ( $N_2O_4$ ) and hydrazine ( $N_2H_4$ ), MMH, or UDMH. Used in military, orbital, and deep space rockets because both liquids are storable for long periods at reasonable temperatures and pressures.  $N_2O_4$ /UDMH is the main fuel for the Proton rocket. This combination is hypergolic, making for attractively simple ignition sequences.

The major inconvenience is that these propellants are highly toxic, hence they require careful handling. \* Monopropellants such as hydrogen peroxide, hydrazine, and nitrous oxide are primarily used for attitude control and spacecraft station-keeping where their long-term storability, simplicity of use, and ability to provide the tiny impulses needed, outweighs their lower specific impulse as compared to bipropellants. Hydrogen peroxide is also used to drive the turbopumps on the first stage of the Soyuz launch vehicle. Advantages/Disadvantages

Liquid propellant rockets are the most powerful (in terms gross thrust) propulsion systems available. They are also among the most variable, that is to say, adjustable given a large array of valves and regulators to control and augment rocket performance. Unfortunately the last point makes liquid propellant rockets intricate and complex. A real modern liquid bipropellant

<https://assignbuster.com/various-rocket-propellants-and-their-characterstics/>

engine has thousands of piping connections carrying various cooling, fueling, or lubricating fluids. Also the various sub-parts such as the turbopump or regulator consist of a separate vertigo of pipes, wires, control valves, temperature gauges and support struts.

Given the many parts, the chance of one integral function failing is large. As noted before, liquid oxygen is the most commonly used oxidizer, but it too has its drawbacks. To achieve the liquid state of this element, a temperature of -183 degrees Celsius must be obtained—conditions under which oxygen readily evaporates, losing a large sum of oxidizer just while loading. Nitric acid, another powerful oxidizer, contains 76% oxygen, is in its liquid state at STP, and has a high specific gravity—all great advantages. The latter point is a measurement similar to density and as it rises higher so to does the propellant's performance.

But, nitric acid is hazardous in handling (mixture with water produces a strong acid) and produces harmful by-products in combustion with a fuel, thus its use is limited. SOLID PROPELLANT vs. LIQUID PROPELLANT

Advantages Liquid fueled rockets have higher specific impulse than solid rockets and are capable of being throttled, shut down, and restarted. Only the combustion chamber of a liquid fueled rocket needs to withstand combustion pressures and temperatures and they can be regeneratively cooled by the liquid propellant.

On vehicles employing turbo pumps, the propellant tanks are at very much less pressure than the combustion chamber, and thus can be built far more lightly than a solid propellant rocket case, permitting a higher mass ratio. For

these reasons, most orbital launch vehicles use liquid propellants. The primary performance advantage of liquid propellants is due to the oxidizer. Several practical liquid oxidizers (liquid oxygen, nitrogen tetroxide, and hydrogen peroxide) are available which have much better specific impulse than the ammonium perchlorate used in most solid rockets, when paired with comparable fuels.

These facts have led to the use of hybrid propellants: a storable oxidizer used with a solid fuel, which retain most virtues of both liquids (high ISP) and solids (simplicity). [citation needed] While liquid propellants are cheaper than solid propellants, for orbital launchers, the cost savings do not, and historically have not mattered; the cost of propellant is a very small portion of the overall cost of the rocket. [citation needed] Some propellants, notably Oxygen and Nitrogen, may be able to be collected from the upper atmosphere, and transferred up to low-Earth orbit for use in propellant depots at substantially reduced cost. 3] Disadvantages The main difficulties with liquid propellants are also with the oxidizers. These are generally at least moderately difficult to store and handle due to their high reactivity with common materials, may have extreme toxicity (nitric acids), moderately cryogenic (liquid oxygen), or both (liquid fluorine, FLOX- a fluorine/LOX mix). Several exotic oxidizers have been proposed: liquid ozone (O<sub>3</sub>), ClF<sub>3</sub>, and ClF<sub>5</sub>, all of which are unstable, energetic, and toxic. Liquid fueled rockets also require potentially troublesome valves and seals and thermally stressed combustion chambers, which increase the cost of the rocket.

Many employ specially designed turbo pumps which raise the cost enormously due to difficult fluid flow patterns that exist within the casings.

<https://assignbuster.com/various-rocket-propellants-and-their-characterstics/>

Historical propellants These include propellants such as Syntin, which is an expensive high energy hydrocarbon fuel which was used on Soyuz U2 until 1995. ————— Syntin Syntin is a hydrocarbon with the molecular formula  $C_{10}H_{16}$  used as a rocket fuel. It is a mixture of cis and trans isomers. It has a density of 0.851 g/mL, and a boiling point of 158 °C.

Due to the presence of three strained cyclopropane rings, the molecule has high positive enthalpy of formation:  $\Delta_f H^\circ(l) = 133 \text{ kJ/mol}$  (980 kJ/kg, the average value for the isomeric mixture), bringing additional energy during the combustion process. Thus, it has advantages over the traditional hydrocarbon fuels, such as RP-1, due to higher density, lower viscosity and higher specific heat of oxidation. Syntin was used in the Soviet Union and later Russia in 1980s-1990s as fuel for the Soyuz-U2 rocket. It was first synthesized in USSR in the 1960 and brought to mass production in the 1970s.

It was prepared in a multi-step synthetic process from common hydrocarbon sources. After dissolution of the USSR, the production of this fuel became too expensive and was halted. Gas propellants A gas propellant usually involves some sort of compressed gas. However, due to the low density and high weight of the pressure vessel, gases see little current use, but are sometimes used for vernier engines, particularly with inert propellants. GOX (gaseous oxygen) was used as one of the propellants for the Buran program for the orbital maneuvering system. Hybrid propellants A hybrid rocket usually has a solid fuel and a liquid or gas oxidizer.



The fluid oxidizer can make it possible to throttle and restart the motor just like a liquid fueled rocket. Hybrid rockets are also cleaner than solid rockets because practical high-performance solid-phase oxidizers all contain chlorine, versus the more benign liquid oxygen or nitrous oxide used in hybrids. Because just one propellant is a fluid, hybrids are simpler than liquid rockets. Hybrid motors suffer two major drawbacks. The first, shared with solid rocket motors, is that the casing around the fuel grain must be built to withstand full combustion pressure and often extreme temperatures as well. However, modern composite structures handle this problem well, and when used with nitrous oxide and a solid rubber propellant (HTPB), relatively small percentage of fuel is needed anyway, so the combustion chamber is not especially large. The primary remaining difficulty with hybrids is with mixing the propellants during the combustion process. In solid propellants, the oxidizer and fuel are mixed in a factory in carefully controlled conditions. Liquid propellants are generally mixed by the injector at the top of the combustion chamber, which directs many small swift-moving streams of fuel and oxidizer into one another.

Liquid fueled rocket injector design has been studied at great length and still resists reliable performance prediction. In a hybrid motor, the mixing happens at the melting or evaporating surface of the fuel. The mixing is not a well-controlled process and generally quite a lot of propellant is left unburned,[4] which limits the efficiency and thus the exhaust velocity of the motor. Additionally, as the burn continues, the hole down the center of the grain (the 'port') widens and the mixture ratio tends to become more

oxidiser rich. There has been much less development of hybrid motors than solid and liquid motors.

For military use, ease of handling and maintenance have driven the use of solid rockets. For orbital work, liquid fuels are more efficient than hybrids and most development has concentrated there. There has recently been an increase in hybrid motor development for nonmilitary suborbital work: \*

The Reaction Research Society, although known primarily for their work with liquid rocket propulsion, has a long history of research and development with hybrid rocket propulsion. [citation needed] \* Several universities have recently experimented with hybrid rockets.

Brigham Young University, the University of Utah and Utah State University launched a student-designed rocket called Unity IV in 1995 which burned the solid fuel hydroxy-terminated polybutadiene (HTPB) with an oxidizer of gaseous oxygen, and in 2003 launched a larger version which burned HTPB with nitrous oxide. [citation needed] Stanford

University researches nitrous-oxide/paraffin hybrid motors. [citation needed]

\* The Rochester Institute of Technology was building a HTPB hybrid rocket to launch small payloads into space and to several near Earth objects.

Its first launch was scheduled for Summer 2007. [dated info] [5][Full citation needed] \* Scaled Composites SpaceShipOne, the first private manned spacecraft, is powered by a hybrid rocket burning HTPB with nitrous oxide.

The hybrid rocket engine was manufactured bySpaceDev. [citation needed] SpaceDev partially based its motors on experimental data collected from the testing of AMROC's (American Rocket Company) motors at NASA's

Stennis Space Center's E1 test stand. Motors ranging from as small as 1000 lbf (4.4 kN) to as large as 250,000 lbf (1.1 MN) thrust were successfully tested. SpaceDev purchased AMROCs assets after the company was shut down for lack of funding. [citation needed] \* The Delchev Motor utilises a binary fuel system consisting of Sucrose (or other fuel) dissolved in a 30% aqueous solution of Hydrogen Peroxide. The fuel is atomized by injection into an expansion chamber above a catalyst bed of Manganese Dioxide, and on contacting the catalyst, rapid decomposition of the Hydrogen Peroxide occurs, supporting the combustion of the Sucrose.

A distinct attraction of the Delchev Motor is that spilled fuel is rendered inert by flushing with a relatively small amount of water, and no toxic residue results. [6] Gel Propellants \* The demand for high-performance and improved safety propellants for various rocket motor applications has been constantly increasing during the last decades and gels seem to be a promising answer to these requirements. In this particular solid-liquid state, these propellants combine the advantages of the solids with those of liquids.

Gels are liquids whose rheological properties have been altered by the addition of certain gelling agents (gellants) and as a result their behavior resembles that of solids. According to Brinker and Scherer, a gel is defined as a substance that contains a continuous solid skeleton enclosing a continuous liquid phase. The continuity of the solid structure gives elasticity to the gel. ————— Inert propellants See also: ion drive

Some rocket designs have their propellants obtain their energy from non chemical or even external sources. For example water rockets use the compressed gas, typically air, to force the water out of the rocket. Solar thermal rockets and Nuclear thermal rockets typically propose to use liquid hydrogen for an Isp (Specific Impulse) of around 600-900 seconds, or in some cases water that is exhausted as steam for an Isp of about 190 seconds. Additionally for low performance requirements such as attitude jets, inert gases such as nitrogen have been employed.