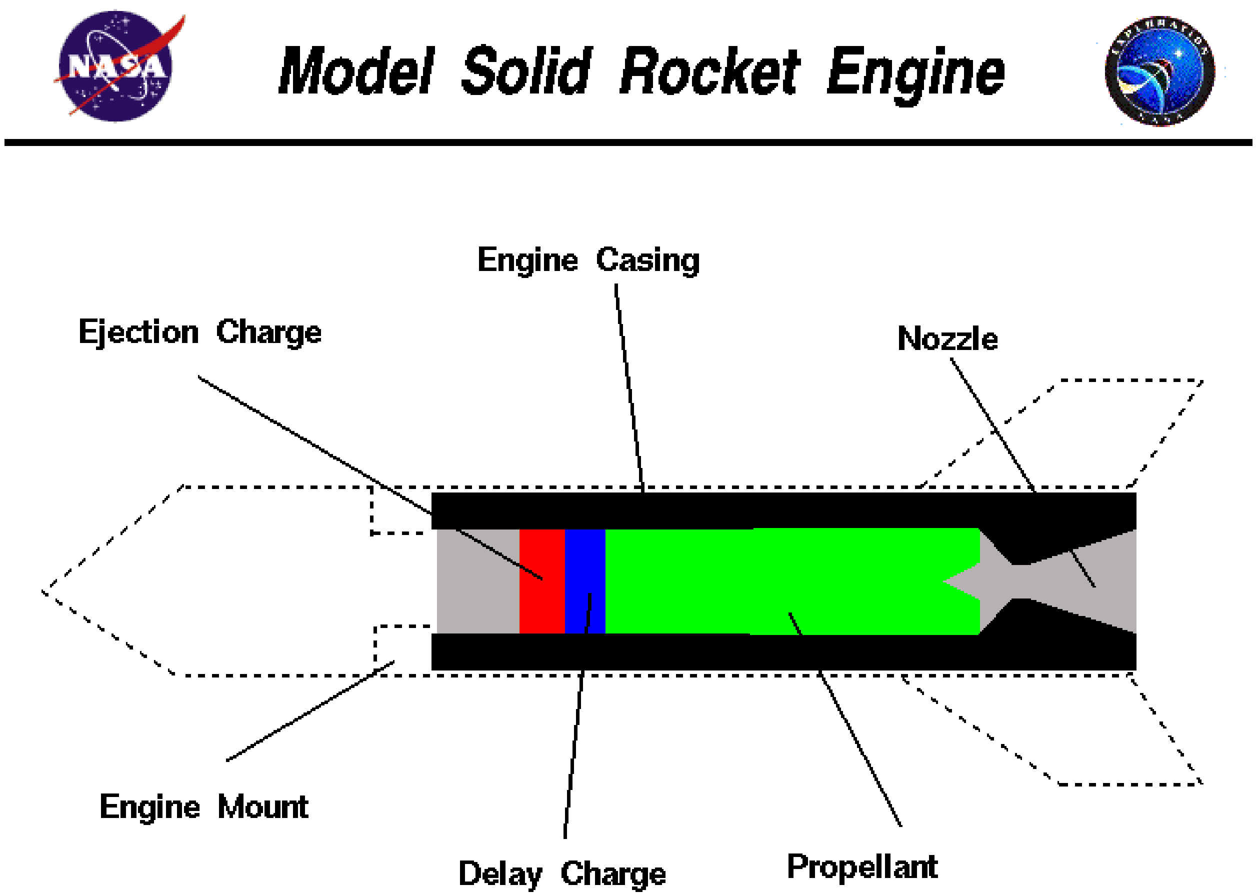
Rocketry – Level 2



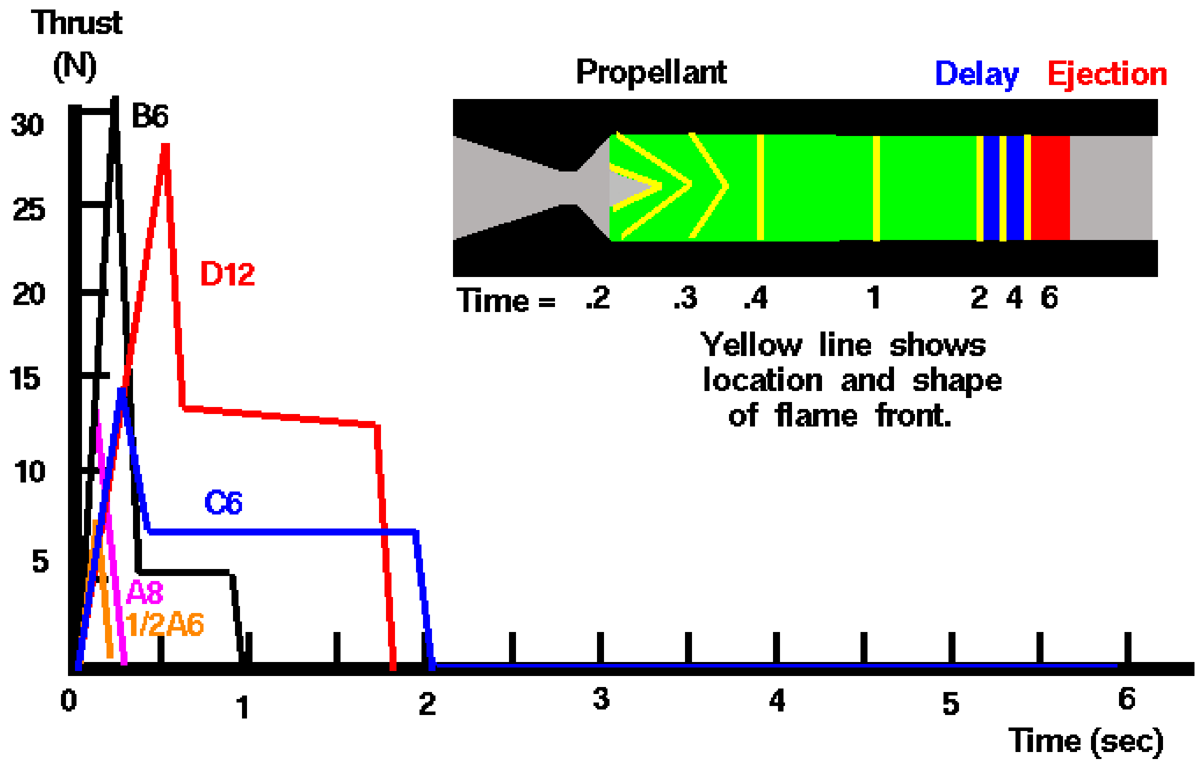
Flying model rockets is a relatively safe and inexpensive way for students to learn the basics of forces and the response of vehicles to external forces. Like an airplane, a model rocket is subjected to the forces of weight, thrust, and aerodynamics during its flight. The **thrust force** is supplied by a small solid rocket engine.

There are two main categories of rocket engines; liquid rockets and solid rockets. In a liquid rocket, the **fuel** and the source of oxygen (**oxidizer**) necessary for combustion are stored separately and pumped into the combustion chamber of the nozzle where burning occurs. In a solid rocket, the fuel and oxidizer are mixed together into a solid **propellant** which is packed into a solid cylinder. Under normal temperature conditions, the propellant does not burn; but the propellant will burn when exposed to an external source of heat. Some type of igniter is used to initiate the burning of a solid rocket motor at the end of the propellant facing the nozzle. As the propellant burns, hot exhaust gas is produced which is used to propel the rocket, and a "flame front" is produced which moves into the propellant. Once the burning starts, it will proceed until all the propellant is burned. With a liquid rocket, you can stop the thrust by turning off the flow of fuel or oxidizer; but with a solid rocket, you must destroy the casing to stop the engine. Liquid rockets tend to be heavier and more complex because of the pumps used to move the fuel and oxidizer, and you usually load the fuel and oxidizer into the rocket just before launch. A solid rocket is much easier to handle and can sit for years before firing.

The relative safety of building and flying model rockets is the result of the production and availability of pre-packaged solid model rocket engines. The engines are produced by several manufacturers and are available in a variety of sizes with a range of engine performance. The engines can be bought at most hobby stores and some toy stores for a modest price (average current price is 3 engines for $5). The engines are used once and discarded; a new engine is inserted into the rocket for the next flight. Before these engines became available, many young rocket builders lost limbs or life in the process of mixing rocket fuels. With these engines, you can still have the fun of building and flying rockets, learn the fundamentals, and then move on to the more dangerous and complex problems of propulsion.

On this slide we show a drawing of the parts of a model rocket engine so that you can learn how it works. We have laid the engine on its side, and "cut" the engine in half so that we can see what is inside. ***Never disturb, cut, or modify a real model rocket engine. The propellant can ignite at any time if there is a source of heat.*** The engine is installed in a rocket shown by the dashed lines on the figure. The **engine casing** is a cylinder made of heavy cardboard which contains the nozzle, propellants, and other explosive charges. At the right side of the engine is the nozzle, a relatively simple device used to accelerate hot gases and produce thrust. Model rocket nozzles are usually made of clays or ceramics because of the high temperature of the exhaust. The hot gases for a model rocket are produced by the solid **propellant**, shown in green. An electric igniter is used to launch a model rocket. As the flame burns through the propellant, the rocket experiences **powered flight**. When the flame front reaches the far left of the propellant, thrust goes to zero, and a **delay charge**, colored blue, begins to burn. During the delay, no thrust is produced and the rocket coasts up to its maximum altitude. The length of the delay varies between engines from 2 to 8 seconds and the amount of the delay is listed on the engine casing. When the delay charge is completely burned through, the **ejection charge**,shown in red, is ignited. This produces a small explosion which ejects hot gas out the front of the engine through the **engine mount**, ejects the nose cone, and deploys the parachute for a safe recovery.

Model Rocket Engine Performance

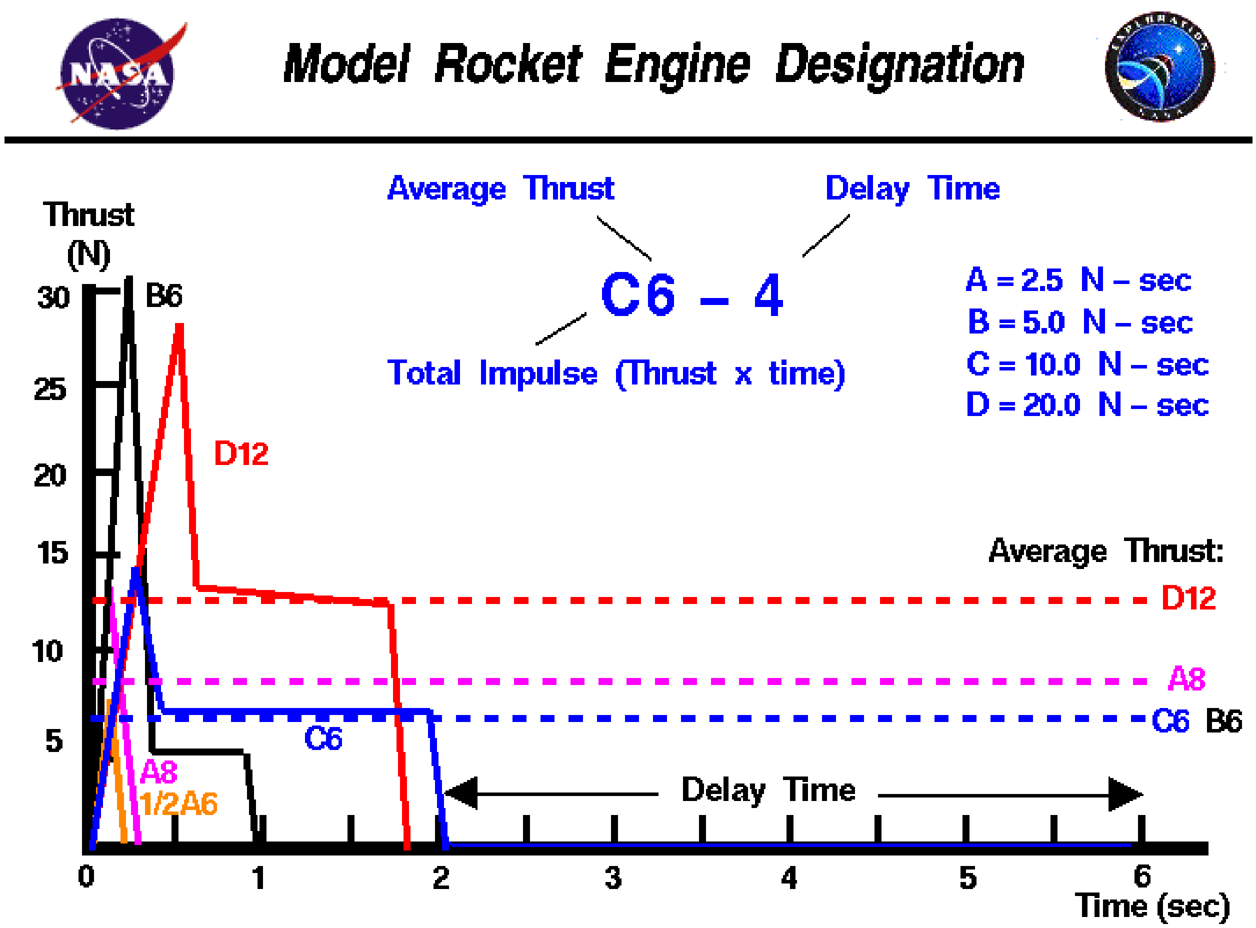


Flying model rockets is a relatively safe and inexpensive way for students to learn the basics of forces and the response of vehicles to external forces. Like an airplane, a model rocket is subjected to the forces of weight, thrust, and aerodynamics during its flight. The weight and aerodynamics are determined by the design of the model rocket components. The **thrust** is provided by a replaceable solid rocket engine which can be purchased at local hobby or toy stores.

Model rocket performance (how far, how high, how fast) depends a great deal on the rocket engine performance. There are several different ways to characterize rocket engine performance. Model rocket engines come in a variety of sizes and weights, with different amounts of propellant, with different burn patterns which effects the thrust profile, and with different values of the delay charge which sets the amount of time for the coasting phase of the flight. On this page, we discuss the factors that affect model rocket engine performance.

At the top of the page we show typical performance curves for several different rocket engines. We plot the thrust of the engine versus the time following ignition for each engine. You will notice that when comparing engines, there is a great difference between the levels and shapes of the plots. For any single engine, the thrust changes with time. To the right in the figure, we show a typical engine schematic which is used to explain why the thrust changes. The thrust of any rocket engine depends on how fast and how much hot exhaust gas passes through the nozzle.

Solid rocket propellant only burns at the surface of the propellant and the surface burns away as the propellant turns into a gas. You can then imagine a flaming surface that moves through the propellant. The flaming surface is called the **flame front**. At any time and at any location the amount of hot gas being produced depends on the area of the flame front. The greater the area, the greater the thrust. As the propellant burns, the shape and area of the flame front change and that causes the thrust to change.



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At the top of the page we show typical performance curves for several different rocket engines. We plot the **thrust versus the time** following ignition for each engine with solid lines. You will notice that when comparing engines, there is a great difference between the levels and shapes of the plots. For any single engine, the thrust changes with time. We can specify a **time-averaged thrust** of the engine by adding up the product of the thrust over some small time increment times the amount of the time increment and then dividing by the total time. The result of this averaging is shown by the dashed lines on the plot.

When purchasing model rocket engines, you will notice a label on each engine in the format; **letter number - number**. On the figure, we show a C6-4. The **first number** indicates the average thrust in Newtons. A C6-4 has an average thrust of 6 Newtons. The average thrust times the burn time of the engine is called the total impulse of the engine. The **letter** gives the maximum total impulse of that class of engine. An "A" engine has a maximum impulse of 2.5 Newton-seconds, a "1/2A" has 1.25 N-sec, a "B" has 5.0 N-sec, a "C" has 10.0 N-sec, and a "D" has 20.0 N-sec. If we compare the curves for B6 and the C6, we find that both engines have the same average thrust (6 Newtons), but the "C" engine burns almost twice as long for double the total impulse. The **second number** indicates the length of the delay time in seconds. A C6-4 has a delay time of 4 seconds between the engine cutoff and the firing of the ejection charge. The delay time determines the length of the coasting phase of the flight. If the delay time is too short relative to the optimum coast of the vehicle, the parachute deploys on the way up and stops the flight. If the delay time is too long, the vehicle might hit the ground before the parachute deploys.

The engine designer can affect the thrust and the total impulse of an engine by changing the diameter of the propellant (and casing). Typical "1/2A" engines are 13 mm in diameter, typical "A", "B" and "C" engines are 18 mm in diameter, and typical "D" engines are 24 mm in diameter. This is important to remember because a model rocket designed for a "B" engine will not accept a "1/2A" or a "D". The engines will not fit into the fixed engine mount of the rocket.