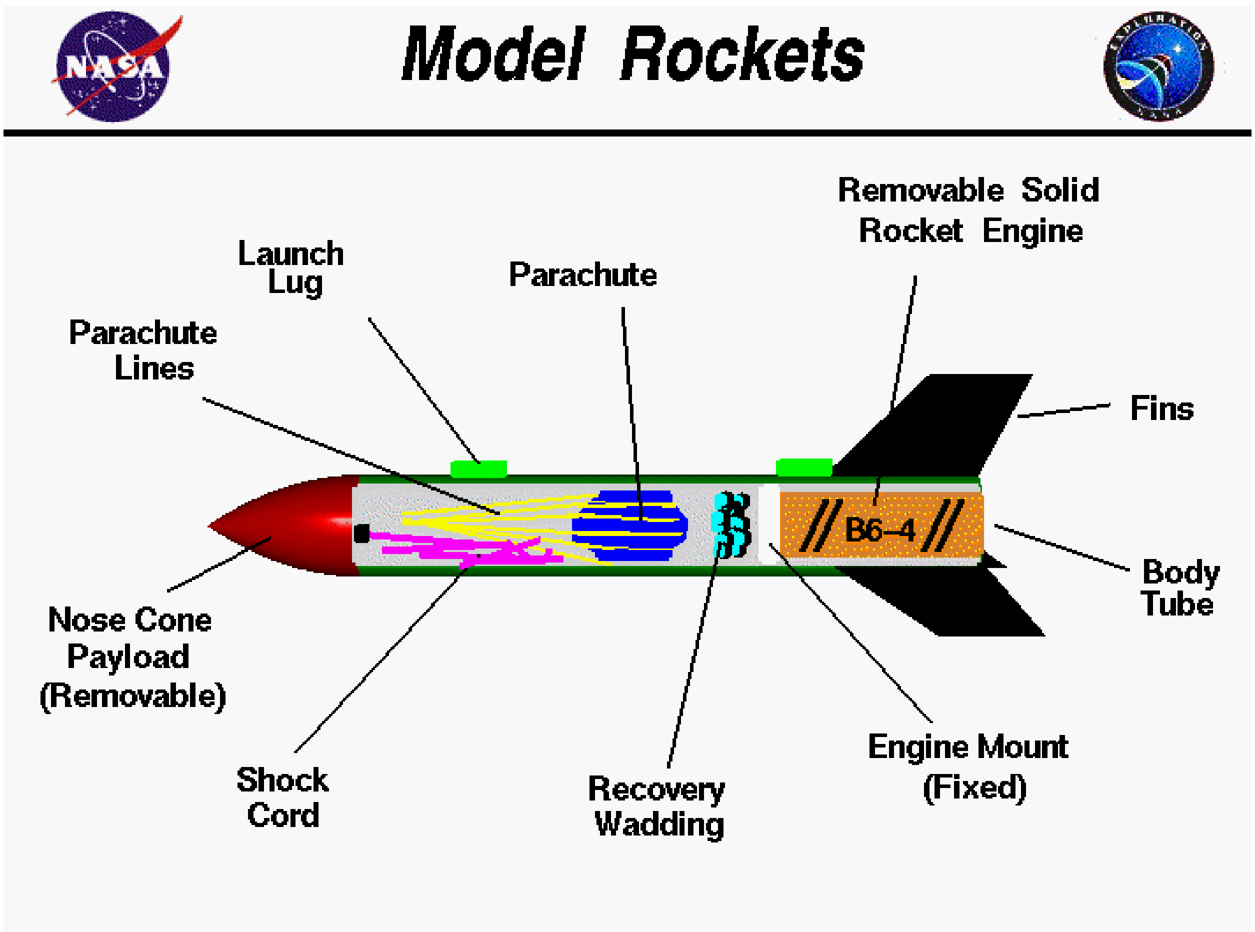
Rocketry – Level 1

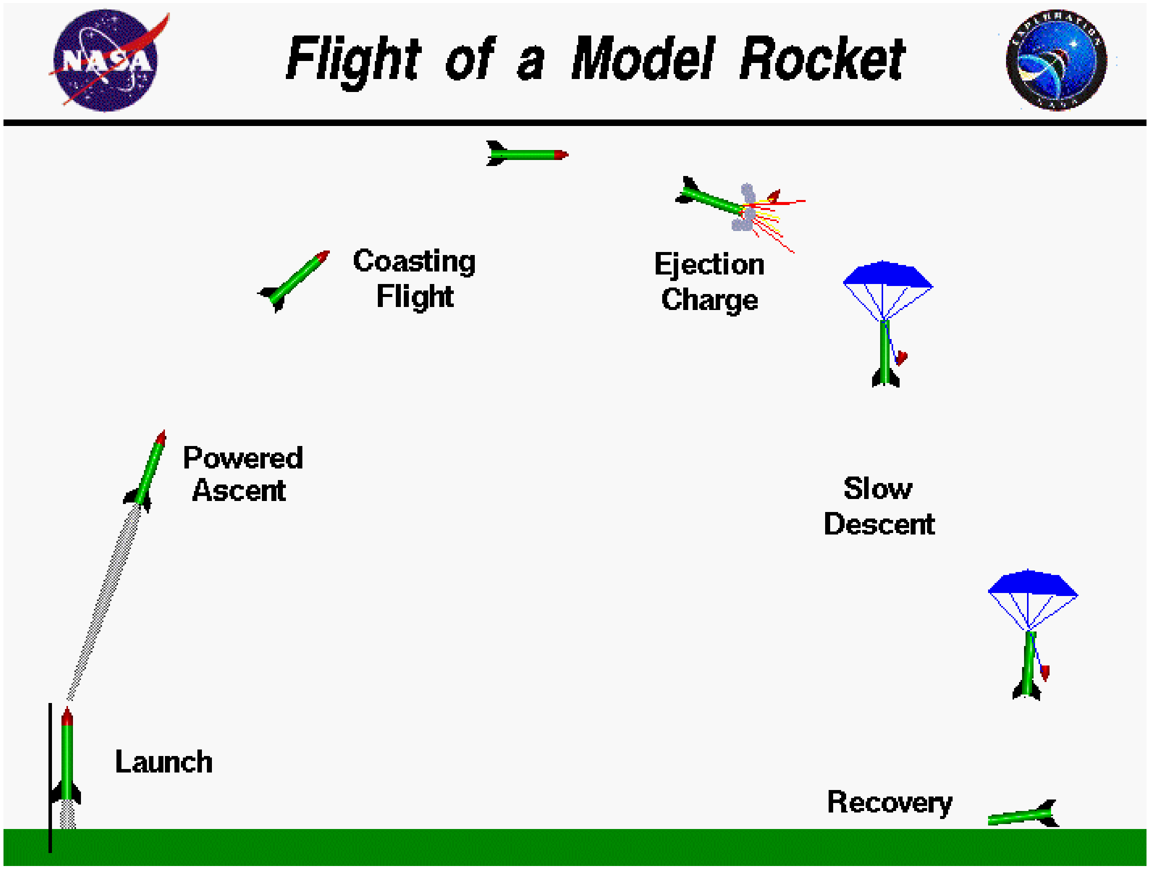
NASA has a lot of information on rockets, go figure. We need to understand the basic parts of a model rocket before we can move onto the concepts behind flight.



Flying model rockets is a relatively safe and inexpensive way for students to learn the basics of forces and the response of a vehicle to external forces. Like an airplane, a model rocket is subjected to the forces of weight, thrust, and aerodynamics during its flight.

In the picture above we show the parts of a single stage model rocket. We have laid the rocket on its side and cut a hole in the body tube so that we can see what is inside. Beginning at the far right, the **body** of the rocket is a green cardboard tube with black **fins** attached at the rear. The fins can be made of either plastic or balsa wood and are used to provide stability during flight. Model rockets use small, pre-packaged, solid fuel engines The engine is used only once, and then is replaced with a new engine for the next flight. Engines come in a variety of sizes and can be purchased at hobby stores and at some toy stores. The thrust of the engine is transmitted to the body of the rocket through the **engine mount**. This part is fixed to the rocket and can be made of heavy cardboard or wood. There is a hole through the engine mount to allow the **ejection charge** of the engine to pressurize the body tube at the end of the coasting phase and eject the nose cone and the recovery system. **Recovery wadding** is inserted between the engine mount and the recovery system to prevent the hot gas of the ejection charge from damaging the recovery system. The recovery wadding is sold with the engine. The recovery system consists of a **parachute** (or a **streamer**) and some **lines** to connect the parachute to the nose cone. Parachutes and streamers are made of thin sheets of plastic. The **nose cone** can be made of balsa wood, or plastic, and may be either solid or hollow. The nose cone is inserted into the body tube before flight. An elastic **shock cord** is connected to both the body tube and the nose cone and is used to keep all the parts of the rocket together during recovery. The **launch lugs** are small tubes (straws) which are attached to the body tube. The launch rail is inserted through these tubes to provide stability to the rocket during launch.

Flight of a Model Rocket:



In this picture we show the events in the flight of a single stage model rocket. Throughout the flight, the weight of a model rocket is fairly constant; only a small amount of solid propellant is burned relative to the weight of the rest of the rocket. This is very different from full scale rockets in which the propellant weight is a large portion of the vehicle weight. At **launch** , the thrust of the rocket engine is greater than the weight of the rocket and the net force accelerates the rocket away from the pad. Unlike full scale rockets, model rockets rely on aerodynamics for stability. During launch, the velocity is too small to provide sufficient stability, so a launch rail is used. Leaving the pad, the rocket begins a **powered ascent**. Thrust is still greater than weight, and the aerodynamic forces of lift and drag now act on the rocket. When the rocket runs out of fuel, it enters a coasting flight. The vehicle slows down under the action of the weight and drag since there is no longer any thrust present. The rocket eventually reaches some maximum altitude which you can measure using some simple length and angle measurements and trigonometry. The rocket then begins to fall back to earth under the power of gravity. While the rocket has been coasting, a delay "charge" has been slowly burning in the rocket engine. It produces no thrust, but may produce a small streamer of smoke which makes the rocket more easily visible from the ground. At the end of the delay charge, an ejection charge is ignited which pressurizes the body tube, blows the nose cap off, and deploys the parachute. The rocket then begins a slow descent under parachute to a recovery. The forces at work here are the weight of the vehicle and the drag of the parachute. After recovering the rocket, you can replace the engine and fly again.

On the graphic, we show the flight path as a large arc through the sky. Ideally, the flight path would be straight up and down; this provides the highest maximum altitude. But model rockets often turn into the wind during powered flight because of an effect called weather cocking. The effect is the result of aerodynamic forces on the rocket and cause the maximum altitude to be slightly less than the optimum.

How do Model Rockets Compare to Real Rockets:

Model Rockets and Real Rockets

Compare and Contrast

Model Rocket	Real Rocket
4 forces throughout flight	4 forces during atmospheric flight
all of flight in atmosphere aerodynamics very important	short time in atmosphere aerodynamics less important
very short powered flight	long powered flight
solid rocket engine small propellant mass fraction	liquid or solid rocket engine large propellant mass fraction
passive stability no control	passive stability active control
low speed heating not important	high speed heating important
inexpensive materials balsa, cardboard, plastic	expensive materials aluminum, titanium, nickel alloy

On this slide we compare and contrast real rockets and model rockets.

A model rocket is subjected to four forces during flight; weight, thrust, and lift and drag. The same forces operate on a full scale rocket as it moves through the atmosphere. The flight trajectory of a full scale rocket takes it out of the atmosphere as quickly as possible. Therefore, the aerodynamic lift and drag are less important for a full scale rocket relative to a model rocket. The magnitude of the aerodynamic forces depend on the air density and air density decreases to near zero at the edge of the atmosphere. For model rockets, the entire flight is conducted in the lower atmosphere and the aerodynamic effects are very important.

During powered flight both model rockets and full scale rockets use a rocket propulsion system. Model rockets employ a variety of small solid rocket engines. There are some larger "amateur" rockets which use liquid or hybrid engines, but these are intended for older, more experienced rocket builders and are not discussed at this site. Full scale rockets may employ either solid or liquid rocket engines. On full scale rockets, solid engines are often used as "strap-ons" during the first minutes of flight, with liquid engines used for sustainers and upper stages. For a model rocket, the propellant is a small fraction of the weight of the entire rocket, typically, 10 - 15%. For a full scale rocket the propellant represents a large **mass fraction** of the weight of the vehicle, typically,80 - 85%. Part of the reason for this difference is that model rocket engines burn very quickly, usually less than two seconds. A full scale rocket engine may fire for 10 minutes to get into orbit.

During flight both model rockets and full scale rockets must provide some system of stability and control. **Stability** indicates that if the flight path is slightly perturbed, the rocket will return to the previous path and not fly erratically. **Control** is the ability to maneuver the rocket during flight. Both models and full scale rockets are designed with passive stability within the atmosphere. The "passive" part means that the rocket will return to the flight path without moving any control surfaces. The conditions for stability are that the center of gravity must be located above the center of pressure. Model rockets have no provisions for control. After the rocket leaves the launch rail, it can go anywhere. You watch a model rocket fly; you can't control it. Model rockets often turn into the wind, in a maneuver called weather cocking, because of aerodynamic forces on the stability fins. Real rockets use very sophisticated instrumentation, computers, and high speed actuators for flight control. The early V2 had small vanes in the rocket nozzle which would deflect the thrust during flight. Most full scale rockets use a system called engine gimbals, in which the whole nozzle is rotated while the engine is firing.

Model rockets fly at relatively low speeds (<250 mph) so aerodynamic heating is not a concern. Model rockets are made of inexpensive materials like balsa wood, cardboard, or plastic. Full scale rockets fly very fast (> 10,000 mph) so aerodynamic heating is a big concern. Exotic, expensive materials are used in the construction of real rockets; materials like titanium, and nickel alloys. On some rockets, like the Space Shuttle external tank (ET), special insulating material is applied to the metal skin to prevent damage due to aerodynamic heating. That's why the ET is orange-colored.