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THIS IS MODEL ROCKETRY

Model rocketry has been called miniature astronautics, a technology in miniature, a hobby, a sport, a technological recreation, and an educational tool—and it is *all* of these things. It is a safe, enjoyable, and highly respected pastime that now boasts the enthusiastic participation of millions of people, young and old, in countries such as Australia, Bulgaria, Canada, China, the Czech and Slovak Republics, France, Germany, Japan, Latvia, the Netherlands, Poland, Romania, Russia, Slovenia, Spain, Switzerland, the Ukraine, the United Kingdom, and the United States.

Model rocketry started in the United States in 1957. Its beginnings were carefully and thoroughly documented. Models, correspondence, drawings, publications, and other artifacts and documents concerning the precise details of the early years have been donated to the National Air and Space Museum of the Smithsonian Institution in Washington, D.C., where this extensive collection can be properly preserved for posterity. The sense of history, of doing something new and unique in the world, ran high among those of us who participated in those early years. As a result, an enormous collection of significant things was saved.

Model rocketry resulted from a timely combination of model aviation, the ancient art of pyrotechnics, and modern rocket technology. Although all of these elements had existed separately for over a decade before 1957, it fell to two people to combine them successfully into a Space Age hobby.

The first model rockets were built and flown by the late Orville H. Carlisle, the owner of a shoe store in Norfolk, Nebraska. Carlisle was an outstanding amateur pyrotechnician. His brother, Robert, was a model airplane enthusiast. With Robert's help, Orville designed the first model rockets in 1954. Early in 1957, he wrote to me, and I added the elements of professional rocket technology. Thus, today's model rocketry was born.

What is model rocketry? What makes model rockets so safe, so inexpensive, so easy to build, and so much fun to fly that millions of people have

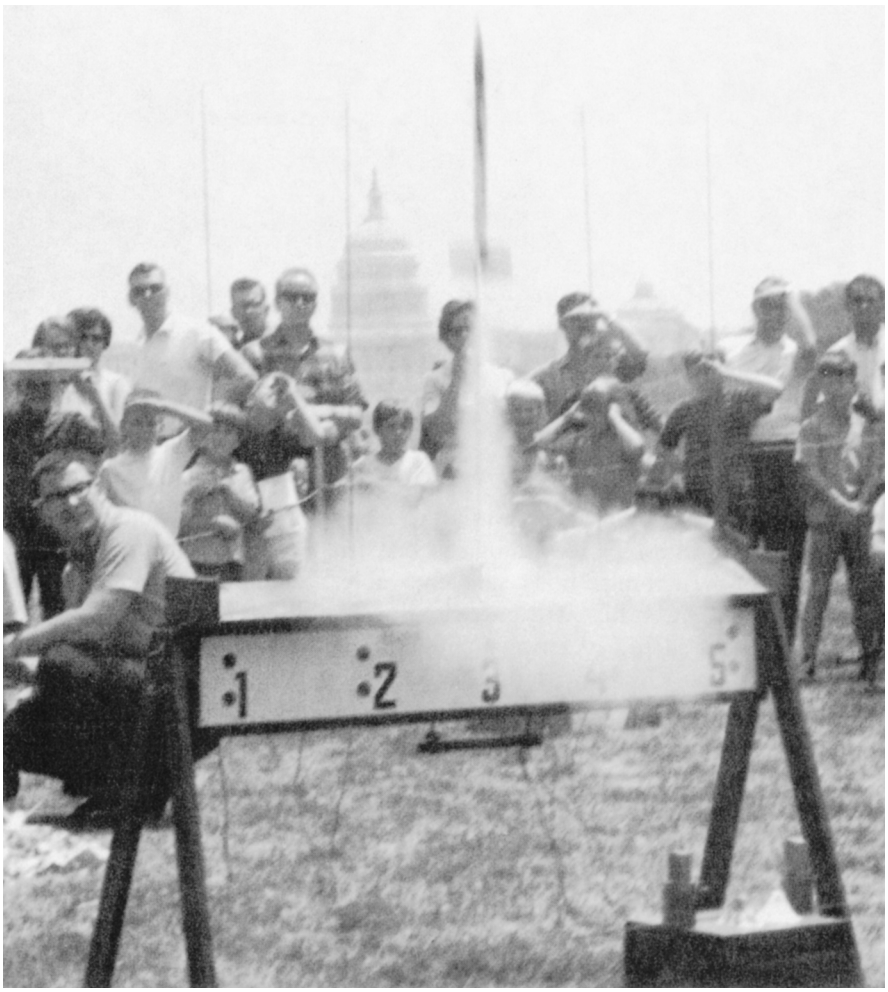

FIGURE 1-1 Model rocketry has been a national and international sport and hobby since 1957. Here a model rocket lifts off from the Mall in Washington, D.C., with the nation's Capitol in the background. The occasion was the annual Mall demonstration of the National Association of Rocketry (NAR) sponsored by the National Air and Space Museum of the Smithsonian Institution.

successfully launched them since the first kits and motors appeared in April 1958? Why has model rocketry brought the Space Age to Main Street, directly involving more people in rocket technology than have ever watched a real space rocket launch from Cape Canaveral?

A model rocket is an aerospace model, a miniature version of a real space vehicle, with *all* of the following characteristics:

1. It is made of paper, balsa wood, plastic, cardboard, and other non-metallic materials used as structural parts.

FIGURE 1-2 Model rocketry was started by the late G. Harry Stine (left) and the late Orville H. Carlisle (right), founders of the National Association of Rocketry, shown here comparing model rockets at the Ninth Annual National Model Rocket Championships in 1967.

2. It weighs less than 3.3 pounds (1,500 grams) and uses less than 4.4 ounces (125 grams) of rocket propellant.
3. It uses professionally designed, factory-made solid-propellant rocket motors produced to strict national and international standards for reliability. In model rocketry, we don't make our own rocket motors.
4. Its solid-propellant rocket motor is ignited electrically from a distance of 15 feet or more using a battery and an electric launch controller with built-in safety features that allow the motor to be ignited on a countdown only when conditions are safe for flight.
5. It contains a recovery device (or devices) to lower it gently and safely back to the ground; thus, it can be flown again and again by installing a new solid-propellant rocket motor and repacking the recovery device.

A model rocket is that simple, yet it changed the nature of nonprofessional rocketry. Before 1958, nonprofessional rocketry was so dangerous that it was banned by law in most states. The American Rocket Society (now the American Institute of Aeronautics and Astronautics) estimated that one out of seven nonprofessional rocketeers would be injured or killed in their avocation. Today, model rocketry is so ubiquitous, so available, and so safe that you can launch almost anywhere with safety, provided you follow the simple rules of

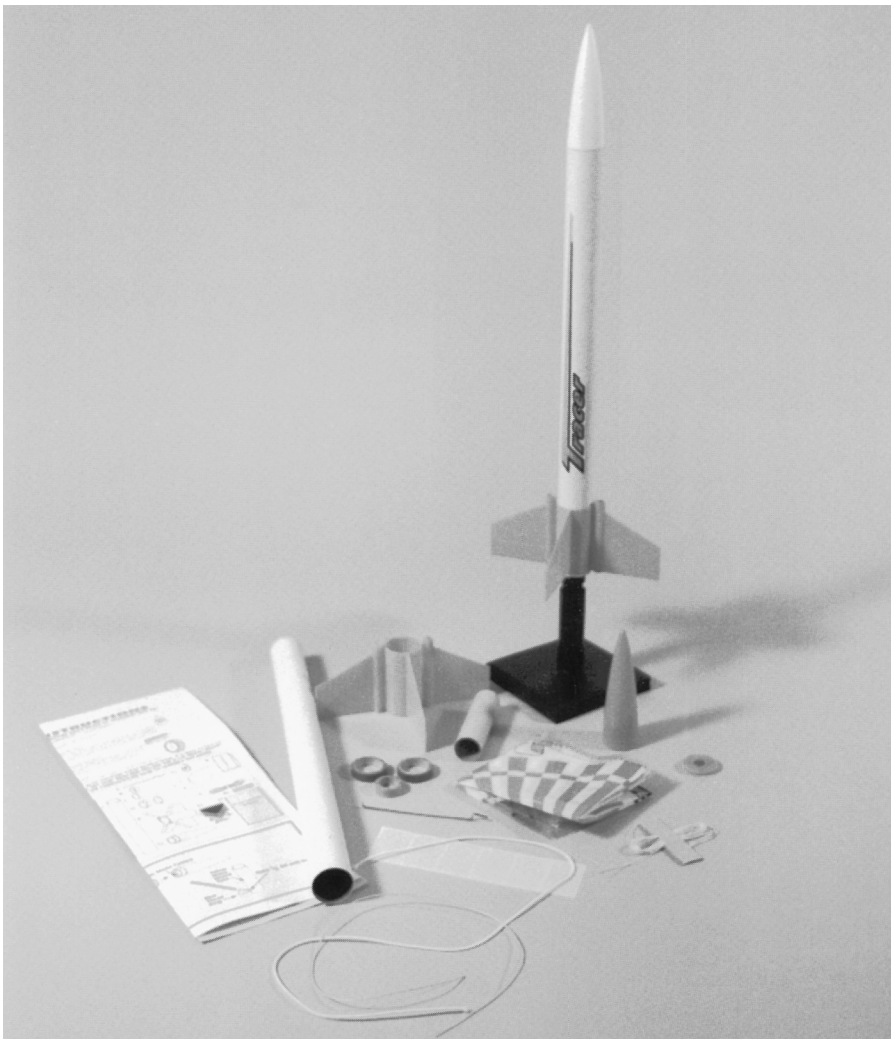

FIGURE 1-3 This typical model rocket, the Quest Tracer, is shown here in kit and assembled forms. It uses a plastic nose and tail fin unit, paper body, and parachute recovery.

the National Association of Rocketry (NAR) Model Rocket Safety Code. Because of its outstanding safety record, model rocketry enjoys the support of such government agencies as the Federal Aviation Administration (FAA), the Consumer Product Safety Commission, the National Aeronautics and Space Administration (NASA), and the armed services. It has won the support of the prestigious and safety conscious National Fire Protection Association (NFPA). Model rocketry is used by the Boy Scouts of America, the 4-H Clubs of America, the YMCA, the Civil Air Patrol, the Young Astronauts, and the various

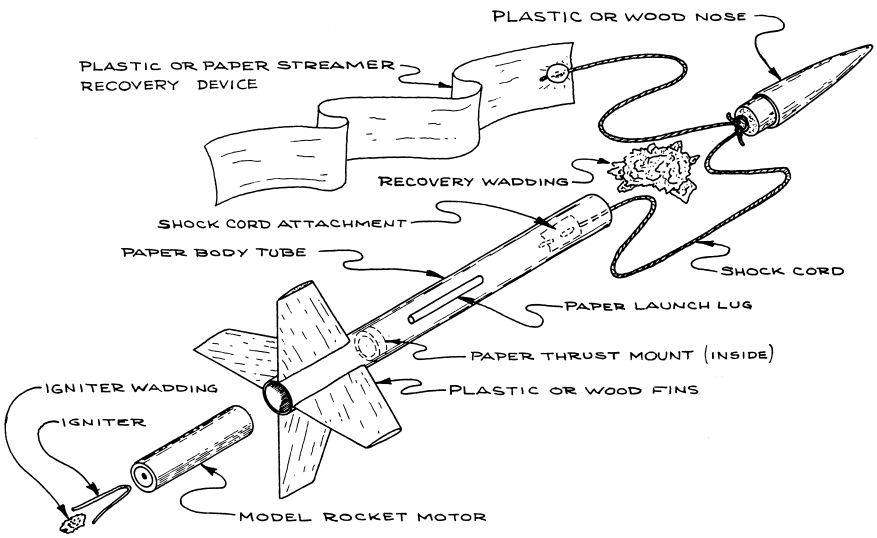

FIGURE 1-4 A sketch of a typical model rocket showing its various parts. There are many variations in the size and shape of the parts, but all model rockets are basically similar.

space camps. Model rocketry is used as a learning tool in more than 20,000 elementary and secondary schools. Even the American Institute of Aeronautics and Astronautics reversed its early stand against nonprofessional rocketry to endorse model rocketry.

This confidence is deserved. As of 2003, nearly 600 million model rockets have been flown safely and successfully in the United States alone. The hobby is far safer than swimming, boating, baseball, football, and cycling. Since 1964, members of the National Association of Rocketry (NAR) have been covered by a major liability insurance policy underwritten by a large domestic insurance firm.

As of this updated writing in 2003, all fifty states have adopted permissive state laws based on the National Fire Protection Association's NFPA 1122 "Code for Model Rocketry." This permissive national standard requires extensive product testing and quality control of model rocket motors by the manufacturers; certification by the NAR; and no permits for sale, purchase, possession, or use by merchants or the public. The only exceptions are that you must be 14 to purchase ¼A–D motors in California or ¼A–C motors in New Jersey. You must be 18 to purchase larger motors in California and New Jersey. It is always a good idea to check with your local fire authority before launching a model rocket within your city's limits.

Naturally, it's possible to get hurt in model rocketry if you're stupid, don't follow the NAR Model Rocket Safety Code, and don't read and follow instructions. It's possible to get hurt with *any* sort of technology, new or old. Some people even manage to get hurt while collecting stamps.

Model rocketry's excellent safety record is due primarily to the premanufactured model rocket motor, the lightweight construction of the model rocket airframe, and the voluntary limitations that model rocketeers have placed on their hobby.

It's not obvious at first that you can learn anything about rockets if you can't experiment with the rocket motor itself. But the science and technology of astronautics are more than a matter of rocket motors and propulsion. The business of making rocket propellants as well as designing and making a rocket motor of *any* type or size is a very complicated, expensive, dangerous, and delicate affair that must *not* be attempted by anyone with less than many thousands of dollars for the proper equipment, an advanced college degree in chemistry, several years' experience in handling explosive materials, several acres of land providing a safe place to work, and a very large life insurance policy. (Very few professional model rocket motor technicians have been killed while making model rocket motors under the most carefully controlled conditions with all of the safety equipment available. The model rocket motor manufacturing companies therefore take grave risks and assume the awful hazards of rocket motor manufacture so that model rocketeers can enjoy the hobby safely.)

Model rocketry is very similar to model aviation. If you want to build a flying model airplane, it would be very expensive and time-consuming if you had to build the *entire* model, including the little gasoline engine. You have more fun and more flying time if you build only the model airplane's airframe and purchase the motor ready-to-run. Then you know you have a motor that will work and—if you're a careful modeler and flyer—an airplane that will usually get high enough to crash.

The same holds true for model rocketry. By properly using a factory-made model rocket motor and building a model rocket airframe around it, you can have an excellent chance of flying it successfully and safely. Furthermore, you will eventually learn about rocket thrust, duration, total impulse, specific impulse, grain configuration, thrust-time performance, and other rocket motor technology. Since a model rocket is a free body in space even when it's in the air, its actions in flight are quite different from those on the ground on wheels or skids. Subtract the known effects of the surrounding air and you will be able to understand how a rocket behaves in the vacuum of space. Flight performance can tell you a great deal about how things move in the universe. And even the fact that your model rocket always flies within the earth's atmosphere will introduce you to the fascinating mysteries of aerodynamics, weight and balance, stability, and drag. In finding out more about why your model rockets fly as they do (and sometimes why they don't fly as predicted), you can begin to delve into optics, structures, dynamics, electronics, meteorology, materials science, and many other modern technologies including the mathematical tools that make them useful to humankind. Model rocket design and flight performance are also excellent areas where computer analysis can be brought into play. Many good computer programs now exist that permit a model rocketeer to use a personal computer or personal digital assistant to

determine model rocket design and flight factors. You'll learn more about these in chapters 8 and 9.

A model rocket is wonderfully simple to build. You can use common hobby tools of the sort used to build model airplanes, model cars, and model boats. Even the materials employed in these other modeling hobbies are used in model rocketry. Many people believe that a rocket has to be made out of steel or other metals, but this isn't so. Why make a rocket out of metal when you can make one cheaply out of paper, plastic, and wood? Why spend a lot of money to buy a metal-welding outfit when a tube of white glue or epoxy will do the same job?

Besides ease of construction, there are other reasons for using nonmetallic materials. High strength and light weight have always been prime design goals for flying devices of any type. Paper, plastic, and balsa wood meet these requirements well. Even the new composite materials are now being used in model rocketry (paper, of course, being an ancient composite material). All of these materials are surprisingly strong. In fact, balsa wood has a higher ratio of strength to weight than carbon steel.

In addition, nonmetallic materials used as structural parts—nose, body, or fins—are much safer should something go wrong during the flight of a model rocket. A model rocket literally disintegrates when it hits something because its airframe absorbs the energy of impact by destroying itself. This is the same principle used in modern automobiles where "crush zones" absorb the energy of a crash by deforming and collapsing. Model rockets have been deliberately launched directly into sheets of window glass; these experiments completely destroyed the models but didn't even scratch the glass. (The tests were done by professionals to find out what would happen; please don't try this in your living room!)

All model rockets have recovery devices. You might ask, "Why bother about a recovery device?" Answer: because you want your model rocket to come down and land as gently as possible in a condition to fly again, just like the NASA space shuttle *Orbiter.* After you've spent a lot of money and taken hours of time to build a model rocket, you'll want to get more than a single flight out of it. Recovery devices are easy to install. And they work with exceedingly high reliability. Furthermore, the requirement for a recovery device helps make model rocketry a safe activity. Even a 2-ounce model rocket plummeting back to the ground from an altitude of 500 feet can hurt if it hits you. A recovery device to retard the speed of its descent eliminates this potential hazard. The mandatory use of recovery devices is one of the reasons model rocketry has been and continues to be such a safe activity.

But why build model rockets so small? Why not build them big so that they're impressive, go several miles high, or carry lots of payload like the big ones at Cape Canaveral? There are several reasons. Model rockets are small for the sake of cost, simplicity, and safety. The price of a model rocket goes up even faster than the rocket itself as the size increases. You can look at any model rocket catalog for proof of this. Big models get to be very expensive. And, as size increases, they become more difficult and demanding to build. Large model

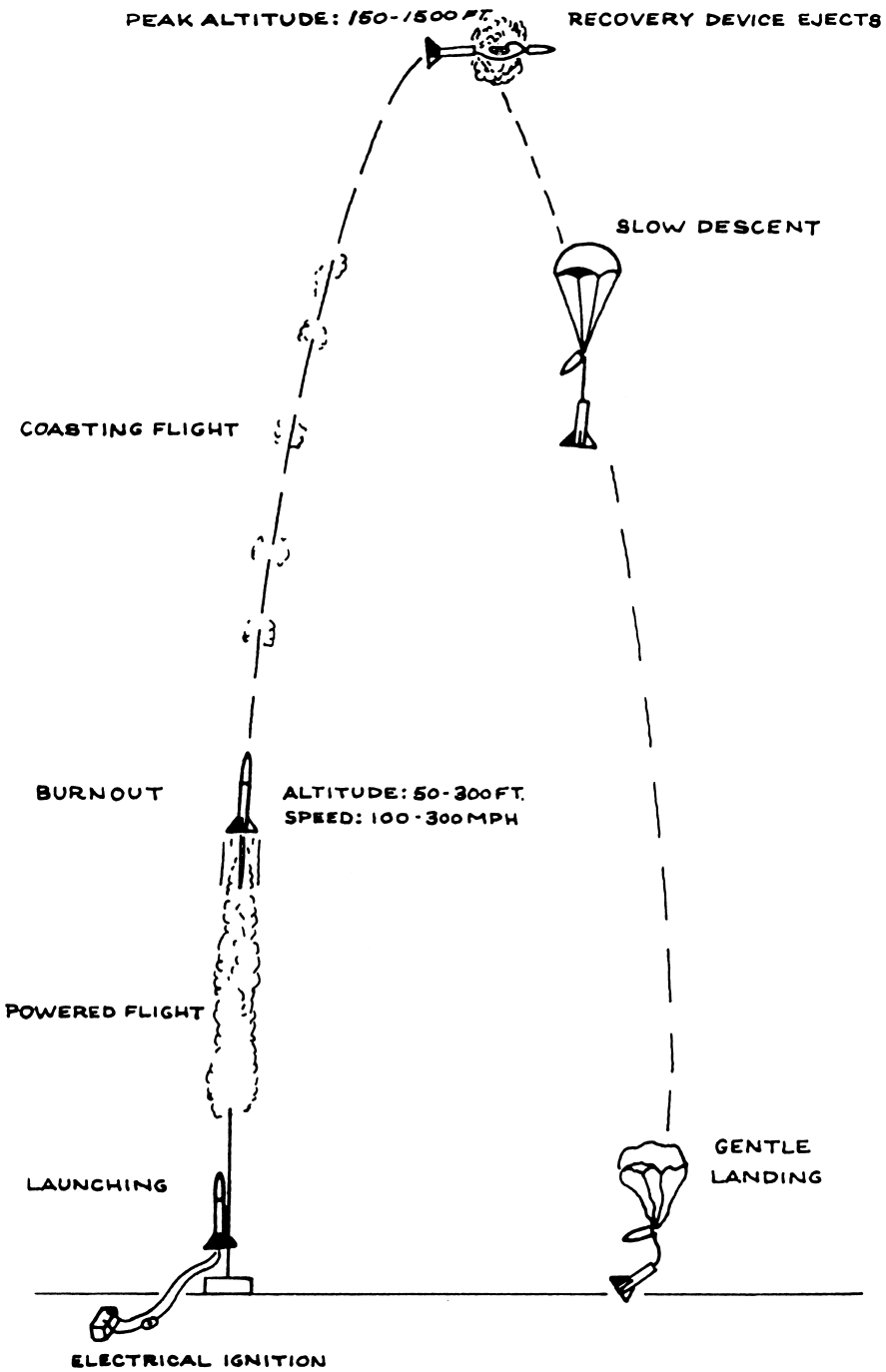

FIGURE 1-5 The typical flight of a single-staged model rocket with parachute recovery.

rocket motors are required for large model rockets, and large model rocket motors are expensive. Some adults have become active in high-power rocketry—building very large rockets powered by very large and very expensive rocket motors. These require open land areas several square miles in extent, plus a waiver from the FAA for flight. I recall watching one large high-power rocket fail in flight on a dry lake bed in the desert of the American West; the rocketeer moaned, "There goes six months of work and $1,200!" (For that amount of money and in that time period, I can fly a *lot* of model rockets that will actually go higher!) That rocketeer might just as well go to work for NASA, the armed forces, or an aerospace company and get paid for it.

To begin, you'll work hard getting your first model rocket together and off the ground for its first successful flight. You can do it—*if you read and follow all instructions carefully!*

If at first you don't succeed, try reading the instructions.

After your first launch or two, you'll be striving for reliable flight, reliable ignition, straight flight paths, full recovery deployment, recovery in the same county, getting the model out of trees, and getting it ready for another flight. You'll progress to more difficult models, motors of higher power, multistage models, glide-recovery models, and payload-carrying models. You'll be able to try your hand at scale model rockets. Or perhaps you'll design your own model and experience the thrill of seeing it work exactly as you predicted. Maybe you'll enter contests, and, after learning all the ins and outs of model rocket competition, start to win ribbons, trophies, and prizes. And you'll make lots of new friends who share your interest in model rocketry. Some of these people will turn out to become friends for life.

As you grow more deeply involved in model rocketry, you'll find yourself studying a wide variety of subjects in order to understand what your model rockets are doing and how to improve them. You'll *never* have to worry about a science fair project if you're a student rocketeer.

When a model rocketeer talks with a professional rocketeer, they speak the same language. They can talk about specific impulse, ballistics, data reduction, static testing, spin stability, recovery parachute deployment, lift-to-drag ratios, and hundreds of other topics. And, surprisingly, they have a great deal of mutual respect for one another. Many professional rocket engineers are also model rocketeers. And now, after half a century, many young people who started as model rocketeers have become professionals in the aerospace sciences and engineering fields. I can hardly go to a NASA center or an aerospace company without meeting somebody whom I last saw years before on a model rocket range, as a teenage student taking the first steps toward the stars.

This is because model rocketry is indeed a technology in miniature and was deliberately designed that way. It recognizes that there are many interesting aspects to aerospace technology other than the propulsion system. To model rocketeers, a model rocket motor is nothing more than a prime mover, a realistic device that produces the thrust force to lift their models into the sky.

Model rocketry has become many things to many people. It can be a means to learn something about the universe. It can be a way to satisfy the

FIGURE 1-6 Model rocketry is international, having spread from the United States to around the world. Here Juliuz Jaronzyk of Poland puts his scale model of the French Diamant satellite launch vehicle on the pad with the help of his fellow rocketeers.

TABLE 1
NAR Model Rocket Safety Code (Approved February 10, 2001)

1. *Materials*. I will use only lightweight, nonmetal parts for the nose, body, and fins of my rocket.

2. *Motors*. I will use only certified, commercially made model rocket motors and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer.

3. *Ignition System*. I will launch my rockets with an electrical launch system and electrical motor igniters. My launch system will have a safety interlock in series with the launch switch, and I will use a launch switch that returns to the "off" position when released.

4. *Misfires*. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

5. *Launch Safety*. I will use a countdown before launch and will ensure that everyone is paying attention and is a safe distance of at least 15 feet away when I launch rockets with D motors or smaller and 30 feet away when I launch larger rockets. If I am uncertain about the safety or stability of an untested rocket, I will check the stability before flight and will fly it only after warning spectators and clearing them away to a safe distance.

6. *Launcher*. I will launch my rocket from a launch rod, tower, or rail that is pointed to within 30 degrees of the vertical to ensure that the rocket flies nearly straight up, and I will use a blast deflector to prevent the motor's exhaust from hitting the ground. To prevent accidental eye injury, I will place launchers so that the end of the launch rod is above eye level or will cap the end of the rod when it is not in use.

7. *Size*. My model rocket will not weigh more than 1,500 grams (53 ounces) at liftoff and will not contain more than 125 grams (4.4 ounces) of propellant or 320 newton-seconds (71.9 pound-seconds) of total impulse. If my model rocket weighs more than 1 pound (453 grams) at liftoff or has more than 113 grams (4 ounces) of propellant, I will check and comply with Federal Aviation Administration regulations before flying.

8. *Flight Safety*. I will not launch my rocket at targets, into clouds, or near airplanes, and I will not put any flammable or explosive payload in my rocket.

9. *Launch Site*. I will launch my rocket outdoors, in an open area at least as large as shown in the accompanying table, and in safe weather conditions with wind speeds no greater than 20 miles per hour. I will ensure that there is no dry grass close to the launch pad and that the launch site does not present the risk of grass fires.

Launch Site Dimensions

Installed Total Impulse (N-sec)	Equivalent Motor Type	Minimum Site Dimensions (ft.)
0.00–1.25	¼A, ½A	50
1.26–2.50	A	100
2.51–5.00	B	200
5.01–10.00	C	400
10.01–20.00	D	500
20.01–40.00	E	1,000
40.01–80.00	F	1,000
80.01–160.00	G	1,000
160.01–320.00	2Gs	1,500

(continues)

TABLE 1
(continued)

10. *Recovery System.* I will use a recovery system such as a streamer or parachute in my rocket so that it returns safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

11. *Recovery Safety.* I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places.

competitive spirit that says, "My model is better than your model!" It can be a way to learn and a way to teach others. For many people, it's an enjoyable recreation that combines the individualistic craftsmanship of the home workshop and the happy socializing with others on the flying field in the sunshine and fresh air. It can be a way for young and old to get together in an activity that interests both.

Model rocketry combines modern science and technology, craftsmanship and shop practice, individual creativity and group cooperation, and the pursuit of excellence in a healthy outdoor activity. Sportsmanship, craftsmanship, self-reliance, discipline, application of creativity, and pragmatic thinking are only a few of the things that can be learned in model rocketry.

But, mostly, model rocketry is fun—as long as you follow the NAR Model Rocket Safety Code.

You'll never run out of things to do in model rocketry; it's an endless countdown, a hobby that you can grow up with and stay with for years because it offers a never-ending challenge to build better model rockets. It's the hobby of the final frontier.

Congratulations on getting hooked on the best aerospace hobby this side of Alpha Centauri!