

FORTY YEARS OF MODEL ROCKETRY

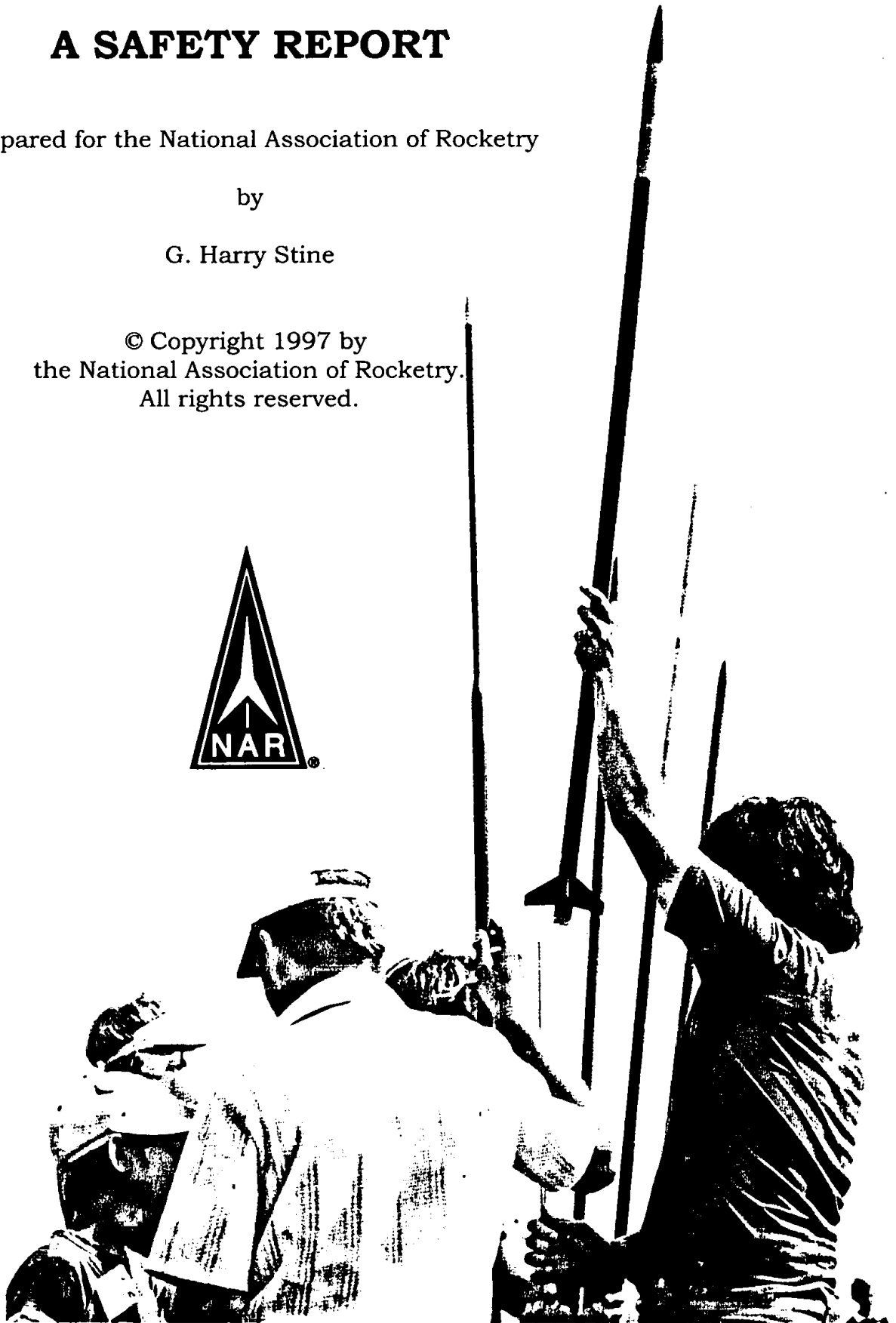
A SAFETY REPORT

Prepared for the National Association of Rocketry

by

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FOREWORD

This report was prepared specifically for those persons interested in the safety of model rocketry and model rocket motors. It describes the technology of the hobby. It summarizes the safety history of the hobby over a 40-year period. It summarizes the current rules and regulations governing the hobby including the endorsements of national, governmental, and civic organizations who have recognized the safe, educational, and recreational aspects of the hobby.

The hobby of model rocketry began in 1957 in response to the launching of the Soviet Sputnik satellites and the beginning of the Space Age. Many young people were hurt trying to build rockets and rocket motors without adequate knowledge, equipment, or safety precautions. Model rocketry was developed as a synthesis of model aviation, pyrotechnics, and professional rocket engineering. From model aviation came materials such as balsa wood, paper, and plastic as well as construction techniques, bonding agents, and paints. From the ancient art of pyrotechnics came the inexpensive factory-made solid-propellant rocket motor. From professional rocket engineering came the quality control standards and procedures that elevated the model rocket motor to a professional level of safety and reliability, the aerodynamic principles that ensure safe and predictable flights with full recovery of the entire model, the safety precautions and operating codes that have made model rocketry the safest of all hobbies (except perhaps stamp collecting), and, finally, advanced model rocket motor technology that has continued to allow the manufacture of progressively safer and more reliable motors.

Basically, the safety success of model rocketry has resulted from:

- (1) a factory-made, mass-produced solid propellant rocket motor of tested and proven design and predictable performance;
- (2) positive control of the launch conditions using electrical ignition;
- (3) airframes made from non-metallic materials such as paper, wood, and plastic that are light and strong but will absorb any impact energy by self-destructing;
- (4) a recovery system that returns the model rocket safely to the ground in a condition to be flown again by repacking the recovery system and installing a new, factory-made model rocket motor.

An on-going program of quality control testing and retesting is carried out by the National Association of Rocketry (NAR) and the model rocket manufacturers to assure that products — especially model rocket motors — are produced that meet the strict national standards for safety, performance, and reliability of the National Fire Protection Association's NFPA 1122 "Code for Model Rocketry," the National Association of Rocketry's own NFPA-compatible standards, and federal regulatory requirements. In addition, model rocket components and systems have been tested and re-tested for 40 years to determine potential hazards and to reaffirm previous test results. Since 1957, people involved in the hobby and public safety officials have been constantly amazed and pleased by test results that have continued to indicate a higher level of safety than suspected. NAR and the model rocket manufacturers have continually worked to devise and conduct more difficult safety tests that would reflect the environments encountered in manufacture, shipment, storage, and use,

probing the "edge of the envelope" of model rocket safety. The tests results often seem incredible, but they are repeatable.

The NAR and the model rocket manufacturers do not recommend that model rocket products be handled or misused in the manner required to perform the tests summarized in this report. If done at all by others than the NAR and model rocket manufacturers, such testing should always be carried out only by public safety officials who may be interested in checking these results. These tests are NOT intended for public demonstration or academic instruction.

Forty years after the hobby began, model rocketeers can proudly boast of about 500 million safe flights. There have been a few burned fingers but only one accident that could be classed as "serious" — a young spectator lost an eye as a result of improper construction and flight operations of a model rocket conducted by a science teacher before a class. ALL of the accidents in model rocketry have been caused by product misuse or failure to read and follow explicit instructions and safety rules. Considering the enormous number of model rocket flights — more than 20 million per year at the present rate — this safety record is better than that of Little League Football or even bicycle riding.

This is in direct contrast to an estimate made in 1957 by a professional rocket society that predicted more than one major injury in each *seven attempts to launch* a non-professional rocket.

Model rocketry's outstanding safety record is a result of a unique long-term co-operative effort between manufacturers, public safety officials, and users to develop, implement, and abide by workable controls and regulations at the manufacturing and distribution levels and simple yet explicit common sense safety rules at the user

level. In these litigious times, manufacturers do not wish to produce unsafe products. Public safety officials don't want to be burdened by over-regulating something that has proved to be safe. Users want success, not accidents and injuries. Model rocketry's safety record has thus depended upon informed self-interest at all levels...and it has worked!

This report will show how and why this unique system has evolved and will strive to answer the most commonly-asked questions and allay the most commonly-held fears.

After 40 years, safety is still the top priority in model rocketry. But safety is no longer something that should be of critical concern to public safety officials, school officials, and other public servants. Indeed, many of them built and flew model rockets when they were young — many still do — and the contents of this report will hopefully be useful to them in convincing those who weren't model rocketeers when they were young.



PART ONE

WHAT IS MODEL ROCKETRY?

Model rocketry is:

- (a) an educational tool;
- (b) a "technical recreation" or hobby.
- (c) an international aerospace sport;

Who says so?

The National Fire Protection Association (NFPA)
The National Aeronautics and Space Administration (NASA)

The United States Air Force (USAF)

The United States Navy (USN)

The United States Army (AUS)

The Federation Aeronautique Internationale (FAI)

The International Astronautics Federation (IAF)

The American Institute of Aeronautics and Astronautics (AIAA)

The National Aeronautics Association (NAA)

The National Science Teachers Association (NSTA)

The Civil Air Patrol (CAP)

The 4-H Clubs of America

The YMCA/YWCA/YMHA/YWHA

The Boy Scouts of America

What is a model rocket?

A model rocket is an aerospace model having the following characteristics:

1. It is made of paper, plastic, wood, and other non-metallic materials without any metal as a structural part.

2. It weighs less than 3.3 pounds (1500 grams) and uses less than 4.4 ounces (125 grams) of rocket propellant in accordance with the standards of the NAR and the NFPA.

3. It uses a factory-made solid propellant rocket reaction motor. This motor may either be expendable or reloadable. This eliminates any hazard of compounding and mixing rocket chemicals by the user.

4. Its model rocket motor is ignited electrically from a distance of at least 15 feet using a low-voltage electrical source and a launch controller with safety features established by the standards of the NAR and NFPA.

5. It contains a recovery system to lower it safely and gently back to the ground so that it can be flown again.

Who so-defines a model rocket?

A. The National Fire Protection Association NFPA 1122 Code for Model Rocketry.

B. The Federation Aeronautique Internationale Sporting Code, Section 4b.

C. The American National Standards Institute.

D. Federal law: Section 307, 72 Statute 749, 49 U.S. Code 1348, "Airspace Control and Facilities."

Is a model rocket a toy?

No. A flying model rocket is a scientifically-designed educational aero model, not a toy. It is capable of attaining speeds of more than 200 miles per hour. It should be used only as instructed in accordance with all safety codes.

How long does it take to build a model rocket?

Some model rockets are available as carefully-designed almost-ready-to-fly models requiring little or no skill on the part of the user; they can be launched within minutes by preparing the recovery

device and installing a model rocket motor. Simple model rocket kits can be assembled with ordinary hobby tools and glue in thirty minutes while others require more time. Complex scale models and advanced high-performance model rockets often take weeks or months to assemble.

What is required to fly a model rocket?

A flying model rocket is but one part of a system consisting of the model itself, a model rocket motor, a launch pad, an electrical launch control device, an electrical igniter for the model rocket motor, and a source of 6-volt or 12-volt electricity such as a battery.

How does a model rocket operate?

Ignition of the model rocket's motor is accomplished electrically by the user at a distance of 15 feet or more from the launch pad.

The launch pad provides support for the model rocket during pre-flight operations and provides the initial guidance for the model rocket as it begins its flight when its airspeed is too low for the fins to stabilize the model rocket.

At the end of powered flight after a rocket motor thrust period varying from 0.2 seconds to as long as 10 seconds (depending upon the type of model rocket motor chosen by the user), the model rocket may be 50 to 500 feet in the air and moving straight up at a speed of 100 miles per hour or more. Some advanced model rockets have reached the speed of sound.

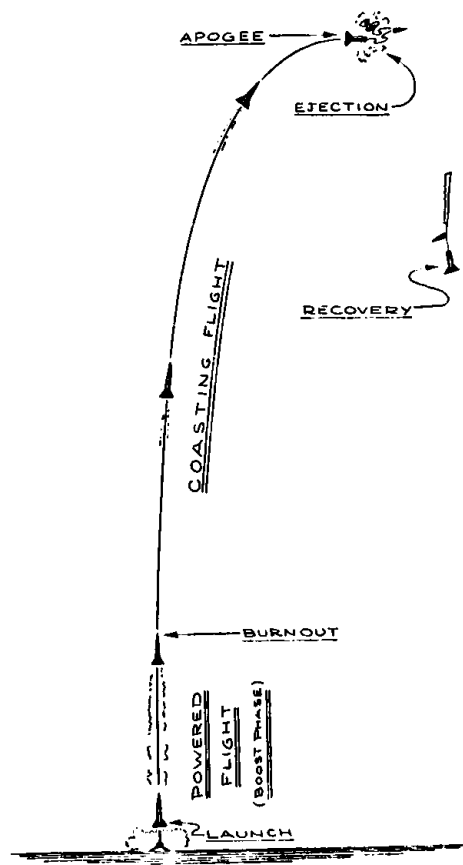
Following the thrust phase of the flight, a time-delay element in the model rocket motor is automatically activated, permitting the model rocket to coast upward for several seconds to its peak altitude (apogee).

At or near apogee and at a pre-determined time after ignition — pre-selected by the user in choosing the type of model rocket motor to be used for the flight — the recovery ejection charge in the model rocket motor activates. This produces a retro-fire puff of gas that pressurizes the inside of the hollow body

tube, forcing the recovery device forward to dislodge the nose. (For further technical details on the operation of a model rocket motor, see Part Two of this report.) Some models use more complex mechanisms activated by the ejection charge. The recovery device — a parachute, streamer, helicopter rotor, or gliding wing — then deploys. Parachutes and streamers are the most commonly-used recovery devices. The entire model rocket with all its parts tied together then returns to the ground in a gentle manner so that it's undamaged and can be prepared for another flight.

Another flight can be made almost at once. The user re-packs the recovery device and installs a fresh model rocket motor and electrical igniter in the model rocket.

Some model rockets have flown more than 100 times.



What are the parts of a simple model rocket?

Most model rockets, regardless of their size, construction, and performance capabilities, usually have the following components:

a. A hollow plastic or balsawood aerodynamically-shaped nose that can come off the model.

b. A light-weight, hollow plastic or paper body tube that is also the main structural airframe part.

c. One or more launch lugs affixed to the side of the body tube that in turn slip over the guide rod of the launch pad.

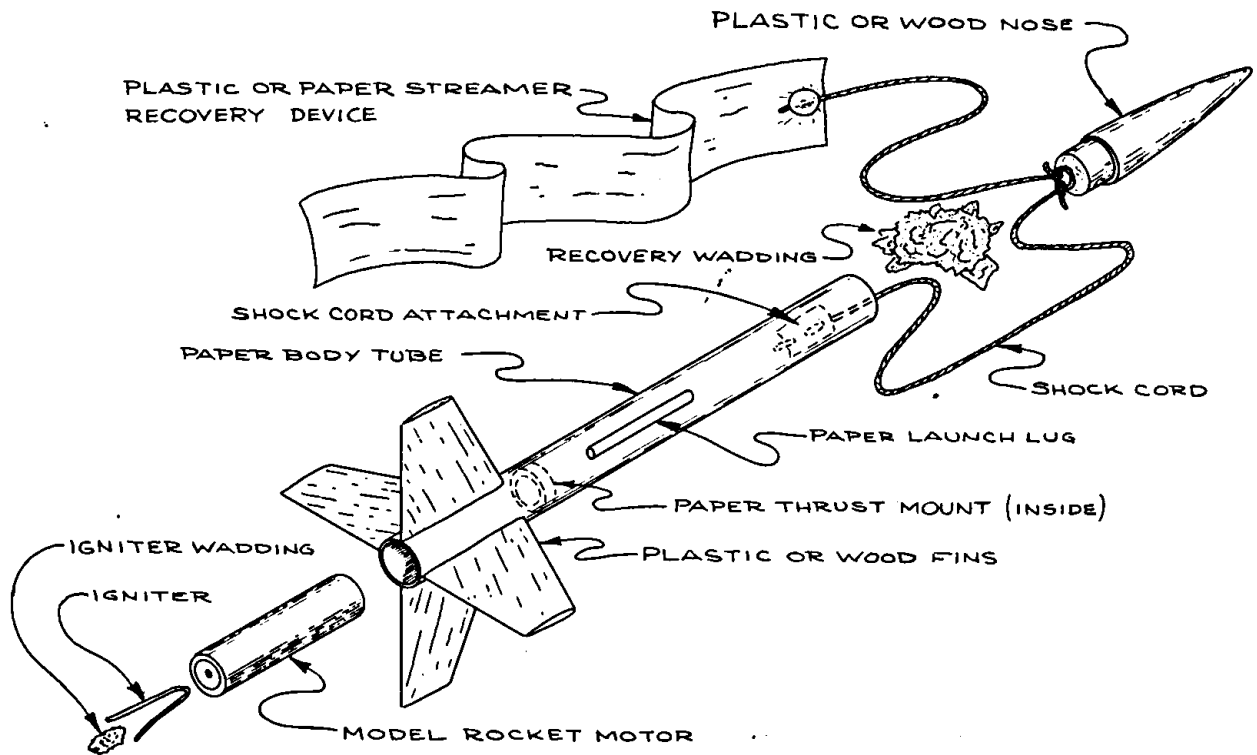
d. A recovery device such as a plastic or nylon parachute or a simple plastic streamer that is packed inside the body tube and ejected forward by a "retro-fire" action of the model rocket motor at a predetermined time in the flight at or near maximum altitude or apogee.

e. A replaceable factory-made, mass-produced solid propellant model rocket motor of tested performance quality along with the thrust mount and retainer that hold it properly in the model rocket airframe. Model rocket motors are usually one-use expendable units, but advanced model rocket motors may be reloaded using materials manufactured and intended for this purpose.

f. Fins made of plastic, balsawood, paper, or plywood which keep the model rocket travelling in a predictable flight path like fletching feathers on an arrow.

g. Expendable, non-flammable, bio-degradable wadding or an internal baffle system to protect the recovery device from the retro-fire action of the model rocket motor.

h. An electrical igniter to start the model rocket motor.



How is a model rocket recovered?

The means used to recover a model rocket depend upon the design, construction, and weight of the model. Plastic parachutes or streamers are the most commonly-used recovery devices. However, airframe tumbling, deployment of helicopter rotors, and gliding are also used in advanced model rockets. If the model is designed to separate into two or more parts for recovery, each part must be lowered by a recovery device. The basic concept is to allow all parts of the model rocket to return to the ground safely and gently so the model rocket can be flown again by re-packing the recovery system and installing a fresh model rocket motor.

Who are the model rocketeers?

Model rocketeers range in age from 8 to 80 and include men and women as well as boys and girls. Most young people involved in the hobby are about 13 years old. More than 50% of the model rocketeers are adults, some of whom started building and flying model rockets when they were teen-agers. For 40 years, model rocketry has shown itself to be an outstanding parent-child activity, and many old-time model rocketeers are now guiding their children into the hobby because model rocketry appeals to such a broad spectrum of age groups. A parent can use model rocketry to teach children many things beyond the simple activity of putting together a model rocket kit and flying it. Most of the people involved are interested in science and technology and are highly intelligent. A study conducted among students in Pennsylvania indicated that a model rocketeer has an average I.Q. of 141.

Is there a minimum age for a model rocketeer?

Experience indicates that children less than 10 years old may have the enthusiasm but not the necessary manual skills to build a model rocket without adult supervision and assistance although they are certainly capable of operating the simpler "ready-to-fly" model rockets. The instructions and safety rules that accompany every model rocket kit are simple, visual, and easy to understand. Decades of experience have showed that people, young and old, will

follow good instructions and observe reasonable and understandable safety rules because they want success. All model rocket manufacturers, however, recommend adult assistance and supervision in building and flying model rockets for those children under 12 years of age. (This is no longer considered mandatory as it was 30 years ago by the NFPA and other organizations.) Adult supervision is recommended because a young rocketeer's enthusiasm and excitement could cause him to overlook some important point in the pre-flight sequence; the "double-check" feature of adult supervision can often prevent mistakes made in haste and excitement. However, it's fair to point out that model rocketry's safety record has NOT depended upon adult supervision and that all mistakes made in haste and excitement were non-hazardous in nature and result. The adult presence merely helps assure the important element of success.

Is model rocketry a learning tool?

Yes, it's a learning tool in disguise. Science and industrial arts teachers have discovered that model rocketry is a useful and motivating adjunct to academic studies. Since model rocketry combines modern science and technology, craftsmanship and shop practice, individual creativity, and group co-operation in the pursuit of a goal with a healthy outdoor activity, model rocketry isn't confined to young students; many universities have model rocket clubs. Sportsmanship, craftsmanship, self-reliance, discipline, and pragmatic approaches to problems are areas in which model rocketry excels. The hobby has been used with both high-achievement students and disadvantaged or handicapped youngsters because, if the simple rules and instructions are followed, a successful flight is a certainty — and for many of these young people, it may be the first successful thing they've ever done.

Among adults, printers, insurance salesmen, photographers, artists, business executives, rocket engineers, museum directors, recreation directors, and school teachers are included among the five million-plus model rocketeers in the United States.

What does it cost?

A complete model rocket "starter set" consisting of a model rocket, a launch pad, an electrical launch controller, model rocket motors, and electrical igniters is available in various levels of complexity and cost ranging from \$25.00 up. Components may be purchased separately. The price of a model rocket motor ranges from \$1.00 up. The larger the model rocket and the more powerful the model rocket motor, the higher the price. This economic factor acts to concentrate the majority of youth model rocket flying in the "low performance area of the flight envelope" while more affluent adults are the ones able to purchase the more complex and costly high-performance model rocket equipment. This cost factor also tends to mitigate the purchase of model rocket equipment for deliberate misuse; it costs too much as well as requiring some intelligence to use.

Is model rocketry dangerous?

On the basis of 40 years of public experience and about 500 million model rocket flights, it is possible to state categorically that model rocketry is not dangerous if done in accordance with established and tested safety rules *just like every other human activity*. The majority of accidents thus far have involved such injuries as minor burns. *All incidents have been caused by failure to read and follow the simple instructions and safety rules.* On the basis of an established record, model rocketry is safer than swimming, boating, bicycling, baseball, football, and nearly every other hobby and sport. There is no question that model rocket equipment can be misused just like every other hobby and sport item. After all, a baseball bat can be turned into a lethal club. Because of the early perceived potential for misuse of model rocket equipment leading to injuries, it is truly surprising that the record shows surprisingly little of this.

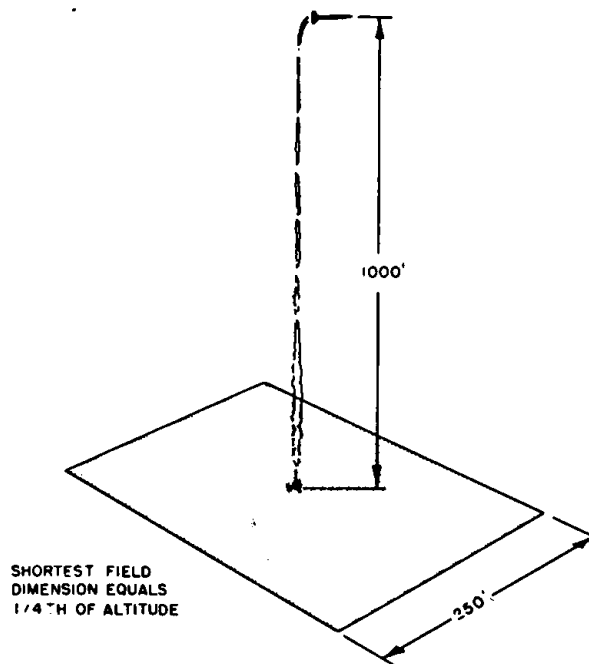
Model rocketry is the safest of all hobbies except perhaps stamp collecting.

How much room is needed to fly model rockets?

Model rocketeers like to fly in the largest available open area so they can get their models back. The biggest problem faced by a model rocketeer involves trees in which descending parachutes and streamers can become snagged.

To determine the shortest dimension of an open area to be used for flying model rockets on a relatively calm day, divide the expected altitude of the model rocket by 4. The flying field should have no horizontal dimension shorter than this number expressed in feet.

For most model rockets propelled by NAR Type A through Type C model rocket motors, a ground area the size of a football field is usually adequate. Model rocket flight demonstrations have been successfully and safely conducted thousands of times on airport ramps, outdoor civic plazas and parks, and even in such places as the Houston Astro-Dome during half-time of a Blue Bonnet Bowl before tens of thousands of people.



Are model rockets a hazard to aircraft?

No. The NAR has conducted comprehensive tests to confirm this. Aircraft face a far greater hazard from bird strikes, foreign objects on a runway, and hail. All jet engines are designed to ingest 4-pound birds and continue to operate. At a national competition, a Cessna-152 flew into a model rocket which disintegrated into a cloud of balsa and paper pieces.

The NAR Model Rocket Safety Code requires that model rockets not be flown into clouds or when aircraft are present over the flying site. This effectively eliminates any potential aircraft hazard. It should also be noted that neither the NAR or the Federal Aviation Administration have any restrictions against flying model rockets within 5 miles of an airport.

The chances of a model rocket actually hitting an aircraft in flight are so vanishingly small as to be insignificant. The U.S. Department of Defense has had to develop very expensive and highly complex multi-million-dollar guided missiles in order to deliberately hit airplanes.

However, it is not recommended that model rocketeers set up flying sites in the approach and landing zones of airport runways. The pilot of an airplane taking off or landing has plenty to do without worrying about model rockets. Several national championships and two international World Championships have been held in the middle of active airports where aircraft operations were not affected. As long ago as 1959, model rockets were part of airshows with no hazard to aircraft and no complaints from some of the world's finest civil and military pilots.

Model rockets may be operated without clearances or waivers from the Federal Aviation Administration (FAA).

What are model rocket manufacturers doing about safety?

In addition to following the national standards established by the National Fire Protection Association in NFPA 1122 "Code for Model Rocketry" and

NFPA 1125 "Manufacture of Model and High Power Rocket Motors," the general policy of model rocket manufacturers is this: If it isn't safe, it won't be produced and sold. This is because (a) a tradition of 40 years must be maintained, (b) the hobby was originally created to solve the safety problem of young people trying to make their own rocket motors, not to create a new safety problem, and (c) in this litigious culture, any manufacturer who doesn't produce a reasonably safe product will not long remain in business.

Model rocketry was founded upon the principle of self-policing by manufacturers and users alike. All are well aware that if they don't police themselves, public safety officials and government regulators will step in to do it...and the results may not be palatable to either manufacturers or users.

In pursuit of these goals, all model rocket manufacturers do the following:

1. A copy of the NAR Model Rocket Safety Code is enclosed in each model rocket kit and with every sealed package of model rocket motors.
2. Complete instructions for assembly and use are included in every model rocket kit and package of model rocket motors.
3. All products meet or exceed the standards established by the NAR and set forth in NFPA 1122 Code for Model Rocketry.
4. All model rocket motor types are tested and certified as meeting NFPA standards by the NAR's Standards & Testing Committee.
5. All publications, catalogs, and other printed material from model rocket manufacturers stress safety and the scientific approach to model rocketry.
6. All model rocket manufacturers establish and maintain close co-operative liaison with safety officials at all levels of government, cooperate with the NAR, and participate in the activities of the NFPA's Technical Committee on Pyrotechnics.

What is the National Association of Rocketry?

The National Association of Rocketry (NAR) is a not-for-profit organization of unpaid volunteers who are model rocketeers. NAR is the primary U.S. consumer organization for model rocketry. NAR has thousands of members of all ages, most of them organized into local clubs. NAR membership is reasonable in cost and includes a subscription to *Sport Rocketry* magazine published every two months by the NAR and *The Model Rocketeer* newsletter published in alternate months. Liability insurance coverage for members, clubs, and third parties is available from the NAR at a reasonable cost.

Under the provisions of NFPA 1122 Code for Model Rocketry, the NAR tests all model rocket motor types produced for sale in the U.S. to ascertain they meet NFPA standards. Model rocket motor types bearing the triangular NAR logo have been certified by NAR as meeting or exceeding these standards. The NAR also conducts random sampling tests of production model rocket motors purchased from retail stores around the country. Model rocket motor types are re-tested and recertified on a regular schedule.



The NAR maintains close liaison and co-operates with various government agencies such as the Consumer Product Safety Commission and public safety organizations such as the Fire Marshal's Association of North America. Since 1967, NAR has played an active role on the Technical Committee on Pyrotechnics of the National Fire Protection Association.

Further information about the NAR may be obtained by writing to NAR Headquarters, 1311 Edgewood Drive, Altoona WI 54720, calling 800-262-4872, or visiting the NAR's Internet web site at:

<http://www.nar.org>.

or the e-mail address:

narhq@eau.net

PART TWO

THE HOW AND WHY OF A MODEL ROCKET MOTOR

What is a model rocket motor?

A model rocket motor is a small reaction propulsion motor designed and manufactured to stringent national standards relating to quality control, safety, and performance limits. It is intended to propel a model rocket into the air and to activate the model rocket's recovery device at the proper time in flight. All current model rocket motors use solid propellants.

What is a solid rocket propellant?

A solid rocket propellant is a mixture in solid form of a fuel (something to burn) and an oxidizer (something for the fuel to chemically combine with and burn). Various types of solid propellants also contain other chemicals that control the burning rate, storage stability, and other safety factors.

What solid propellants are used in model rocket motors?

Two types of solid propellants are used in model rocket motors.

One type of model rocket motor uses a highly-refined form of black powder whose oxidizer is potassium nitrate (KNO_3) with a fuel and binder consisting of carbon and sulfur. The characteristics of this rocket propellant are well-known and highly predictable. It has the lowest energy content (thrust produced per unit weight of propellant consumed, called "specific impulse" by rocket engineers) of all commercially available propellants. It is dead-pressed into the model rocket motor casing by hydraulic pressure in a motor-making machine. Practically all black powder solid-propellant model rocket motors are made by automatic loading machinery. Black powder is primarily used in small model rocket motors ranging from Type ¼A to Type D. More than

95% of the model rocket motors sold and used since 1958 have been black powder model rocket motors.

A second type of model rocket motor uses a "composite" solid propellant of the sort originally developed in 1942 to provide takeoff rocket boost (JATO) for heavily-laden military aircraft. Since then, composite propellants have been technically refined and improved for military missiles and space launch vehicles. The composite propellant used in a model rocket motor uses ammonium perchlorate (NH_4ClO_4) as an oxidizer in a binder/fuel that is an organic elastomer such as synthetic rubber. Various chemicals are added to control stability, ignition temperature, and burning characteristics. Unlike black powder that must be physically dead-pressed into a motor casing to form a propellant charge or "grain," a composite propellant is usually cast and cured in the motor casing (although it may also be cast in molds and later inserted into the casing). Composites have two to three times the specific impulse (thrust produced per unit weight of propellant consumed) of black powder. Composites are normally used in larger model rocket motors ranging from Type D to Type G. The production process of composite solid propellant model rocket motors does not readily lend itself to mass production by automatic machines as in the case of black powder model rocket motors. Therefore, composite model rocket motors tend to be more expensive.

What's inside a model rocket motor?

Regardless of whether a model rocket motor uses black powder or a composite propellant, the design and operation are basically the same. Please refer to the drawing of a "generic" expendable model rocket motor which shows the location of the various parts and ingredients as though the motor were cut lengthwise down the middle to reveal the interior.

