MODEL ROCKETRY

The Journal of Miniature Astronautics

JANUARY 1969

35 ¢

AVENGER II

VIKING IV SCALE

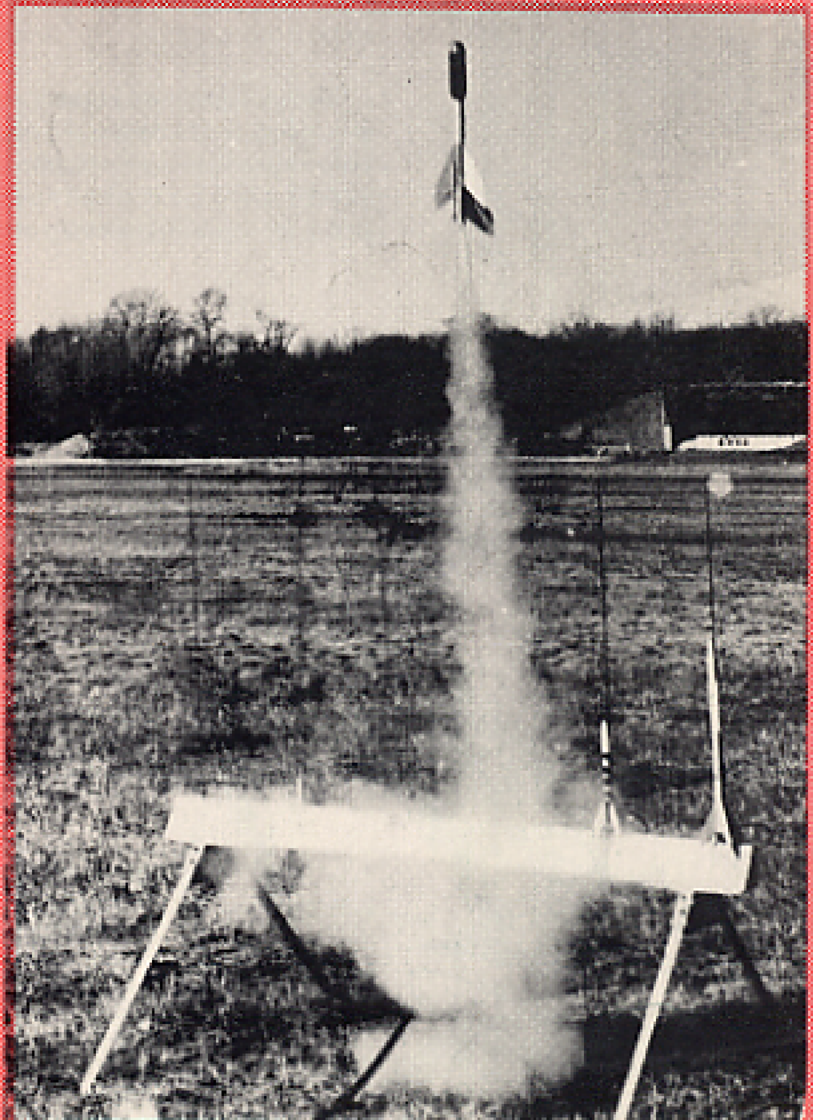
DYNAMIC STABILITY

AERIAL PHOTOGRAPHY

CLUB LAUNCH PANEL

THE STYGION

PLUS REGULAR FEATURES



Model Rocketry

Volume I, No. 3
January 1969

Editor and Publisher George J. Flynn
Managing Editor Gordon K. Mandell
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Distribution Manager Thomas T. Milkie

FEATURES

This month's cover photo shows a Camroc launching during the 1968 MIT National Convention. An article on Camroc modifications begins on page 23 . (Cover photo by George Flynn.)

From the Editor

The initial response to our reader questionnaire (Model Rocketry, October 1968) confirms our suspicions that model rocketeers are indeed interested in the technical aspects as well as the design and construction of model rockets. While some readers objected to the use of "high-level math," a large majority of readers agreed that the hobby will advance only if the experienced modeler considers the technical aspects of model rocket design.

Our survey shows, as was pointed out last month, that the great majority of model rocketeers have not been in the hobby very long. The results were:

% responses	Years as Rocketeer
52%	under 2 years
41%	3 to 5 years
7%	6 to 8 years
1%	9 or more years

We hope that those older modelers, who may be considering leaving the hobby, will instead consider investigating one of the unsolved problems of model rocketry. For example, what is the best model rocket fin shape? Does the nose cone shape significantly affect the performance of the rocket? These questions can be answered, however it will require many hours of work by serious model rocketeers to do so.

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Material submitted for publication should be accompanied by a self-addressed, stamped envelope if return is desired. We can assume no responsibility for material lost or damaged, however care will be exercised in handeling.

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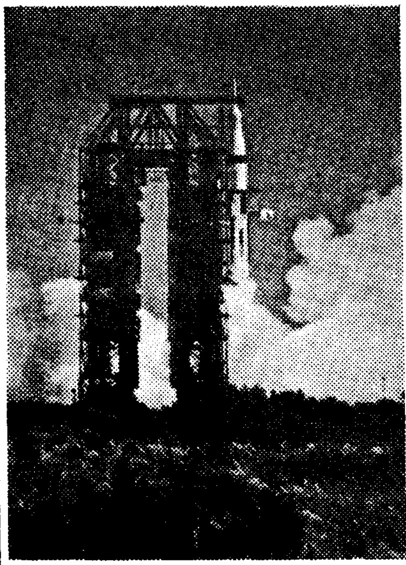
Application to mail at second-class postage ras is pending at Central Square Post Office, Cambridge, Mass. 02139.

SPECIAL OFFER!

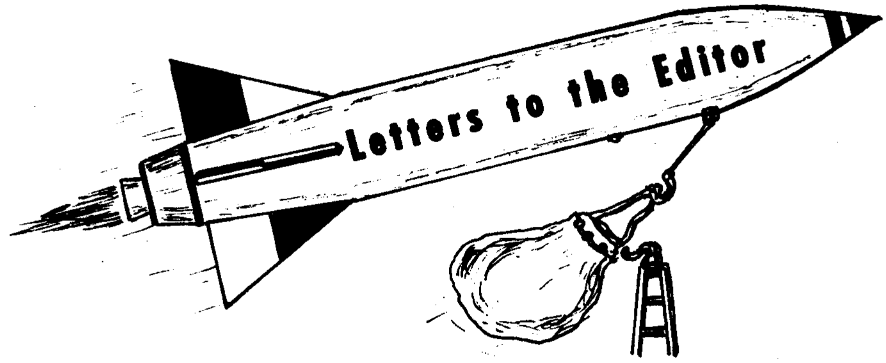
Beautiful, full-color photograph of the Apollo 7, Saturn 1B liftoff of October, 1968



This magnificent photograph of a most historic moment in the history of spaceflight was obtained by **Model Rocketry** editor George Flynn from an advance position not accessible to most Kennedy Space Center visitors. Showing the moment of liftoff, this 7 by 8 inch full-color print will make an inspiring addition to the album of any space enthusiast.

Full-color copies of the photograph, which is reproduced in black and white above, may be obtained by sending 50¢, or $1.00 for 3, to:

Saturn Photo
Model Rocketry
Box 214
Boston, Mass. 02123



Praise

I think that Model Rocketry magazine is a great magazine for the model rocketry enthusiast. It has articles on almost every part of model rocketry. Keep up the great work!

Mike B.
Waco, Texas

I think it could be a great magazine. The world of model rocketry has waited a long time for something like this.

Fred Z.
Southfield, Michigan

I've just finished reading the first issue of Model Rocketry and want to compliment you on its professionalism and literacy. It's a pleasure to read.

Marshall D.
Oak Parks, Michigan

Congratulations on your magazine! I've been expecting an all-rocketry magazine for quite a while due to the enlargement of the hobby. I'm sure you will receive support from all model rocketeers.

Tommy H.
Wilson, North Carolina

It's FANTASTIC!!! I'd never thought anybody would get around to it. Model rocketeers now have a "mag" they can call their own. When the NAR sent me my issue I couldn't believe it. It's not the biggest and best model magazine on the market but it still is a superb beginning. Keep up the good work!

Paul K.
Ann Arbor, Michigan

Thanks for the praise Paul, but you and many others unfortunately thought that the NAR had sent you the October issue of Model Rocketry. The National Association of Rocketry provided us with mailing labels so that we could send a free copy to all NAR members. However, NAR members do not receive a free subscription.

Math Problems?

I found your magazine very interesting. The only trouble I had was to try to figure out all the math in the October issue. It was the "Fundamentals of Dynamic Stability". If it is possible could you send something a little easier for a simple minded algerbra II and trig. student!

John S.
Dalton, Georgia

Calculus just isn't my "bag."

Andrew P.
Chelmsford, Mass.

The technical reports now being produced in great numbers (Barrowman, Malewicki, Mandell, Caporaso, others) are great. They are proving that model rockets are not toys, but serious, scientifically designed research tools.

Andrew S.
Flushing, New York

We have received many comments about our technical articles in recent issues – some people were baffled, others were delighted. In future issues of Model Rocketry, *we will try to present the latest technical advances as they are developed, as well as articles explaining the scientific aspects of modrocs in simpler terms.*

Club News

Would like to see listing of contest meets.

Frank S.
Englewood, New Jersey

Give more club news.

Richard B.
Euclid, Ohio

We are trying to print the latest news from model rocket clubs about launches, meets, demonstrations, developments, or anything newsworthy. But we can only print what people sent us. Therefore, club secretaries, send up your newsletter, or a notice of events. Two months advance notice is necessary for coming events. ***

Notice

Due to arrangements involving the national distribution of Model Rocketry *magazine, it was necessary to advance the cover date of this issue to January 1969. This does not mean that you have missed an issue. To adjust for this change the termination date of all subscriptions will be extended by one month. This change was brought about to enable us to improve the quality of the magazine and to make it available to a greater number of hobbyists.*

Sounding Rockets

Sounding rockets fly in nearly vertical trajectories, carrying packages of scientific instruments to heights of from 50 to several thousand miles above the earth's surface. A sounding rocket's effective lifetime until it drops back to Earth lasts from only a few minutes to several hours. All the scientific data that the rocket will make available must be collected in this brief period. A satellite circles the Earth for at least several hours (if it is at all successful) and it may be in orbit for hundreds of years. The length of time it will deliver data will usually be limited by the life of the components and systems built into it.

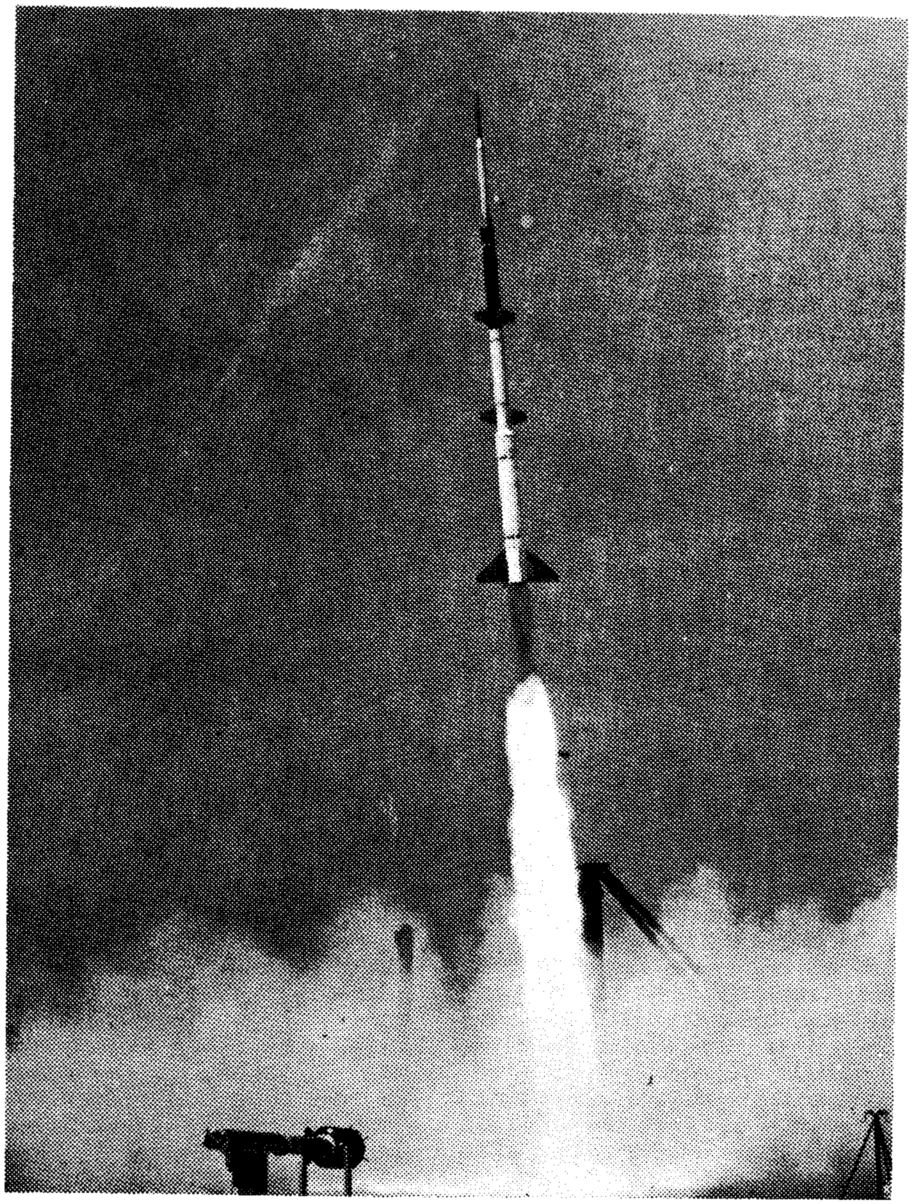
If the sounding rocket is characterized by short scientific life why is it used?

First, the sounding rocket is the only vehicle with which we can make effective scientific investigations in the region from 20 to 100 miles above the Earth. Balloons cannot carry equipment above about 20 miles; satellites are generally impractical to use below altitudes of 100 miles because of their short life due to atmospheric drag. Consequently if we wish to make a measurement between 20 and 100 miles we must use the sounding rocket.

Second, sounding rockets are used for exploratory investigations in geophysics and astronomy; in this way we obtain preliminary data which is used to guide the development of the more elaborate experimental equipment used in follow-on tests.

Third, sounding rockets are used to test prototype instrumentation which will later be used in satellites.

Fourth, the sounding rocket is used by the space scientist to make measurements at this time, and within limits, at the place he selects. This is possible simply because the smaller sounding rockets require relatively little ground support equipment and preflight preparation in the field and so can be expected to be fired at the time that an interesting event is occurring. This event might be an influx of solar particles or a geomagnetic storm, or perhaps it could be an eclipse of the sun.



NASA Photo

The Strong-Arm sounding rocket is shown just after liftoff.

Fifth, for certain experiments, the sounding rocket is used because of the relative ease and low cost of payload recovery operations. Other programs are rapidly developing a capability for the return of satellite payload elements and these techniques will soon supplement those using sounding rockets.

Finally, in the present state of our technology, it is possible to take advantage

TABLE OF SOUNDING ROCKETS

ROCKET	PAYLOAD WEIGHT (LBS.)	DESIGN ALTITUDE (MILES)
Aerobee 100	70	80
Aerobee 150 and 150A	150	150
Aerobee 300	50	300
Argo E-5	50	600
Argo D-4	50	800
Argo D-8	130	1,300
Arcon	40	55
Iris	100	180
Nike-Asp	50	150
Nike-Cajun	50	150
Nike-Deacon	35	60
Skylark	150	150

of the sounding rocket's ability to carry a large expendable power supply. As a result, instrumentation requiring for a limited time a larger amount of power than might now be considered feasible for a satellite, can be used in a sounding rocket.

NASA's sounding rockets range from 25 feet to 65 feet in length. The smallest of them, the Nike-Cajun, is usable with a 50-pound payload to an altitude of 90 miles. The Aerobee-Hi, a work horse for many years now in sounding rocket activities, will carry 150 pounds to an altitude of 160 miles. The Aerobee is a liquid-fueled system, the others are solid fueled.

The Javelin and the Journeyman are adapted for flights to relatively high altitudes. We can expect to reach 800 miles with light payloads with the Javelin and 1,200 miles with heavier payloads with the Journeyman.

Obviously, the last two systems are costlier because of their higher performance capabilities; but because they are not too difficult to handle in the filed, they are valuable members of the sounding rocket family. While the performance capabilities of the Scout are appreciably above those of these sounding rockets, it should be noted that it will be used as a probe vehicle, to carry payloads to altitudes of 4,000 miles and more.

With the addition of some smaller units used for meteorological soundings, much of the NASA science program is carried by rockets of this type. The majority are of the size of the Nike-Cajuns and the Aerobee-Hi and relatively few are of the Javelin or Journeyman types.

The measurement of corpuscular radiation from the Sun is a typical experiment in the sounding rocket program. Many other scientific areas are investigated with the aid of sounding rockets. Much of our understanding of the upper atmosphere's temperature and pressure and of the ionosphere has come from rocket soundings.

The experiments in astronomy that have been conducted with the aid of sounding rockets have led directly to the design of the experiments for the NASA astronomical satellites. These experiments have investigated and still are studying the radiation from the Sun in various wavelengths, including the ultraviolet and X-ray spectral regions, and have resulted in the first surveys of the appearance of the night sky in other than visible light.

Highly significant data on the composition of the atmosphere have been gained through NASA sounding rocket programs. They include:

1. An Aerobee firing to an altitude of 154 miles where composition of the atmosphere was determined by mass and ion spectrometers.

2. Several Nike-Asp payloads that released a trail of sodium vapor from altitudes of about 50 to 120 miles. Results indicate that there are regions of intense turbulence and strong wind shear below about sixty miles and extremely high winds above this altitude.

3. Several Nike-Cajuns that carried grenades timed to explode between 38 and 65 miles to determine atmospheric temperatures. Ground stations photographed the grenade flashes and timed the arrival of the resulting sound waves, thus providing the temperature measurements.

4. Two Aerobee firings which carried cameras to photograph cloud cover and other weather phenomena.

5. Six Aerobees, launched to investigate the ionosphere. Two of these ejected payloads in order to obtain measurements free of influence by the vehicles themselves. The others measured the D-layer conductivity and the E-layer electron densities.

6. Fourteen launchings and an equal number of successes in the Solar Beam Experiment Program, which aimed at determining the types and energies of the particles comprising these beams. For the first time rockets were fired into these relatively rare events which are produced by solar eruptions.

7. An Aerobee firing to an altitude of 130 miles which measured the intensity of neutrons in the upper atmosphere.

8. Four Aerobee firings for astronomical studies of ultraviolet radiation from the stars and nebulae. On one of these flights the first ultraviolet stellar spectra were obtained. On the others, the fluxes of about 100 stars in the 2000-3000 angstrom (about 250 angstroms equal one-millionth of an inch) were obtained. In addition, the 1300 angstrom nebulae were confirmed and the nighttime ozone and ultraviolet airglow measured.

9. Launchings of the first NERV (Nuclear Emulsion Recovery Vehicle) by a four-stage Argo D-8 sounding rocket. An 83.6 pound capsule, fired from the Pacific Missile Range, rached are altitude of 1,260 miles and parachuted into the ocean 1,300 miles from launch point. PMR was used so that the rocket could be fired south to coincide with the magnetic lines of force which govern movement of particles in the Great Radiation Region, purpose of the experiment. The payload also carried three bread mold spore cultures which will be studied by biologists to correlate mutations with the radiation intensities recorded on the photographic film.

10. The first alkali vapor magnetometer was flown and successfully measured the earth's magnetic field to better than one part in a hundred thousand. The rocket attained an altitude of over 600 miles.

Thus sounding rockets have made a significant contribution to our understanding of the upper atmosphere.

Ed. Note: Beause of the importance of sounding rockets in the American space effort, **Model Rocketry** *will, from time to time, present scale plans for these rockets. The February 1969 issue will contain scale plans for the Nike-Deacon sounding rocket.*

TECHNICAL NOTES

GEORGE CAPORASO

I will devote this month's column to the need for experimentation in model rocketry.

In the past few years many questions such as static stability, altitude prediction, dynamic stability, drag prediction, etc. have been answered theoretically. As far as I know, no thorough experimental research has been undertaken by anyone to test the validity of the great bulk of theoretical material now existing in the field of model rocketry. While many people believe that altitude prediction are basically correct, we have no data on just how good those models are. The same applies even more strongly to the case of predicting the drag coefficients of models. In that case, the equations are partly theoretical, partly empirical because no one on earth can calculate the exact drag theoretically. There is a tremendous need to know how well the existing methods work.

This column will print the results of any valid testing done by any model rocketeer on any of the aforementioned subjects. Please send me any logically done experimental results.

The lack of experimental confirmation of current model rocket theories is only part of the general problem. The greatest part of model rocketry's current theoretical confusion stems from the omniscient "armchair scientist" who postulates and expounds upon topics for which he has neither theoretical nor experimental justification. Such people are those who claim that they can intuitively see why the drag coefficient during burning does or does not decrease, those who use aerodynamic data which are completely out of the Reynold's number range for model rockets and merrily extrapolate back to what they think is the right answer. Such people are those who look at supersonic rockets and say surely, the same must apply to subsonic flights. Such people model rocketry does not need.

As G. Harry Stine said at the opening of the MIT Model Rocket Society National Convention in 1968 regarding this same subject, "I WANT DATA", not people's guess work. Propose a theoretical explanation for some effect, make some quantitative predictions and then test to see if your model was valid, there is no other way to scientific progress. And one experiment which seems to support your hypothesis is not enough. The testing must be rigorously and conscientiously done. And above all, it must be published so that others can evaluate it. test its theoretical foundations and question it experimentally.

Until the correct scientific procedure is followed, such questions as how the delay charge affects the drag coefficient, what is the optimum subsonic fin shape, what is the best sweep back angle for fins, etc. will remain unanswered. Many of our "armchair scientists" could make real contributions if they would only follow the scientific procedure outlined above. We are all guilty of transgressing that law from time to time but the important thing is to realize that it is the correct way to proceed.

Below is a section of a letter written to me from a Mr. B.D. from Ohio. It will serve to illustrate the importance of following scientific procedure:

"In reference to George Caporaso's column, I know that he knows darn will what fin shape is best for subsonic models (parabolic leading edge and tapered trailing edge). Also, if you take a look at the results of the wind tunnel tests run by Mark Mercer in Centuri's TIR-100, you will find that for a "Javelin-like" rocket, the drag on the fins very nearly determines the drag coefficient of the entire rocket. As to the effect of the engine exhaust on the drag coefficient, page 66 of the April 1968 issue of the American Aircraft Modeler states that the drag coefficient of the Nike Smoke sounding rocket is 0.45 during thrusting and 0.85 during coasting. The ratio of the "exit mass per second per sq. in" of the Nike booster to the Estes Series I engines is about 6 to 1. I leave just these facts so that you can make your own hypothesis. Whatever difference the exhaust makes, the delay charge would have appreciably less effect because of the lesser mass of the latter. So much for that."

On the surface, this letter is fairly impressive. It looks as though the writer has made some good points, but let's examine them one by one. First, I do not darn well know what fin shape is best. Why does he think his particular shape is ideal. Secondly, he states that the drag coefficient of the fins very nearly determines that of the entire model. Well, if you look at my first column in which I posed this question, you'll see that I asked for pressure drag on the frontal area of the fins. Prof. J. Gregorek's report on calculating drag coefficients claims that the drag coefficient of the fins very nearly determines the drag on the model also, but it is the *friction drag on the side of the fins* which does this and not the pressure drag. Next, he neatly answers the problem of the reduced (or increased) pressure drag due to the engines exhaust by quoting figures from G. Harry Stine's column. The Nike is a supersonic rocket and has much larger Reynold's numbers than our subsonic model rockets and the airflow conditions are much different for each case. Also, after writing this column, Mr. Stine posed the same questions at the MIT Convention. Surely, if the author of the article in question couldn't draw any conclusions about the exhaust gas effects, how can a reader do so so confidantly?

The writer of this letter, Mr. B.D., is only 14 years old. Although I dispute his points and his method of attack, it seems obvious to me that he is a very intelligent and interested hobbyist and he is just the kind of person the hobby so desperately needs provided he accepts the scientific method as his modus operandi. I do not wish to discourage him; we need him, but we need him as a scientifically trained person, for only these people can make the real contributions to the hobby.

Coming Next Month

Cosmic Avenger

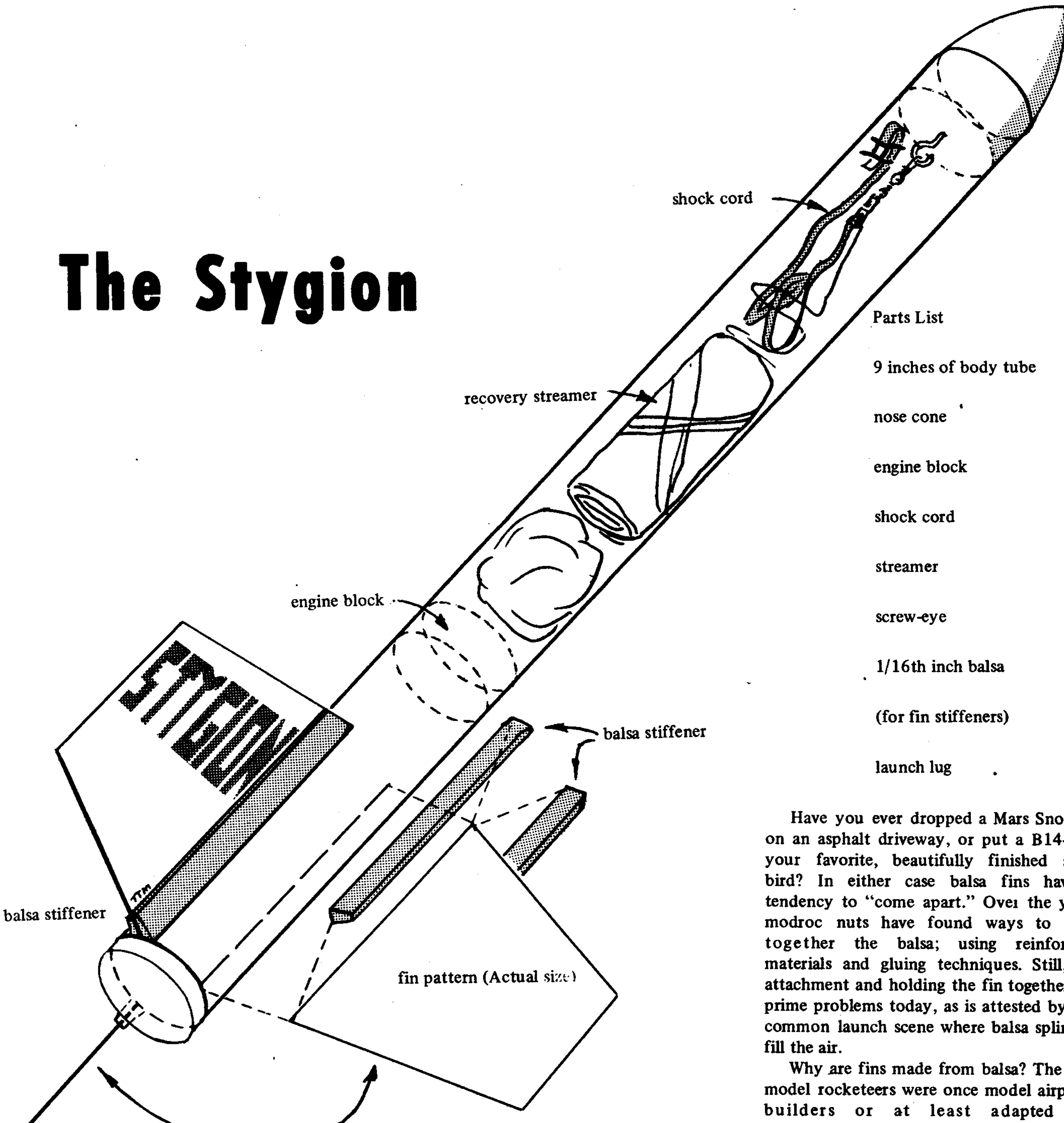
Dynamics: Part IV

Nike-Deacon: Scale

Non-vertical Trajectory Analysis

Turning Nose Cones on a Wood Lathe

The Stygion



Parts List

9 inches of body tube

nose cone

engine block

shock cord

streamer

screw-eye

1/16th inch balsa

(for fin stiffeners)

launch lug

by Tom Milkie

Have you ever dropped a Mars Snooper on an asphalt driveway, or put a B14-5 in your favorite, beautifully finished scale bird? In either case balsa fins have a tendency to "come apart." Over the years modroc nuts have found ways to hold together the balsa; using reinforcing materials and gluing techniques. Still, fin attachment and holding the fin together are prime problems today, as is attested by the common launch scene where balsa splinters fill the air.

Why are fins made from balsa? The first model rocketeers were once model airplane builders or at least adapted the well-developed modeling materials of the model airplane enthusiasts. After all, balsa is easy to obtain, easy to cut and shape, and finishing techniques are generally known. But is balsa the ideal fin material? It is generally pointed out that balsa is the lightest construction material available and thus, necessarily, the only material. However, if you have to use mounds of glue fillet and a very thick fin material, you may lose all weight advantage. Balsa strength is also questionable. The strength is relatively weak. Many model rocket fins have weak points due to one dimension of the fin having a very low strength. The typical modroc fin is subjected to stresses along both dimensions (in high velocity flight, in handling, and in landing), and therefore, the ideal fin material should have about equal strength in bending any direction.

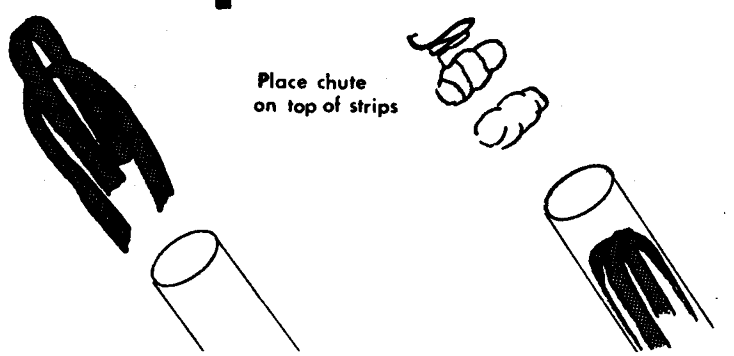
There is one material that people have ignored for some time (due to its "cheap" reputation), that may have possibilities. The white glossy cardboard similar to that which laundries put in shirts is fairly stiff and very shred resistant. It also can be finished neatly if you don't attempt to sand it! The Stygion employs fins made from this material.

The Stygion is modeled after a rocket built by Steve Bainbridge of Harvard College,which used cardboard fins. His rocket used a thin oak-tag stock for the fins. After many flights of high accelerations, the fins remained intact. However, the thin material caused a noticeable vibration of the fins during flight, producing an audible noise. (What can the insane modrucnut develop with this phenomenon?) Substituting oak tag for stiff cardboard in the fins of the Stygion can produce the "humming rocket" effect.

To make the Stygion, begin by cutting a small diameter body tube to 9 inches. Install an engine block in the rear with the aid of an old engine tube. Next add a shock cord to the body tube by cutting 2 slits horizontally, 1 inch from the top of the body tube. Push the shock cord through the slit and glue securely. Attach a screw-eye to the nose cone and assemble the recovery system. Cut the fins out of stiff shirt cardboard and glue 1/16th inch by 1/4th inch gussets to both sides of the roots of the fins. These may be preshaed and should be ready for painting when installed. Glue the fins to the body and add launch lug, and the Stygion is ready to go.

The main problem with thin materials such as cardboard for fins is their lack of stiffness. This may be overcome by developing a built-up fin (such as a model airplane wing is built up) or by adding some sort of stiffening strut of balsa. The stronger nature of cardboard fins and the possibility of reduced drag due to a thinner frontal surface show that further work with such fin materials may produce useful developments.

q & a



I have built a few clustered rockets and every time I try to put a chute in the large body tube, it falls to the bottom. What can I do to keep my chute up near the top?

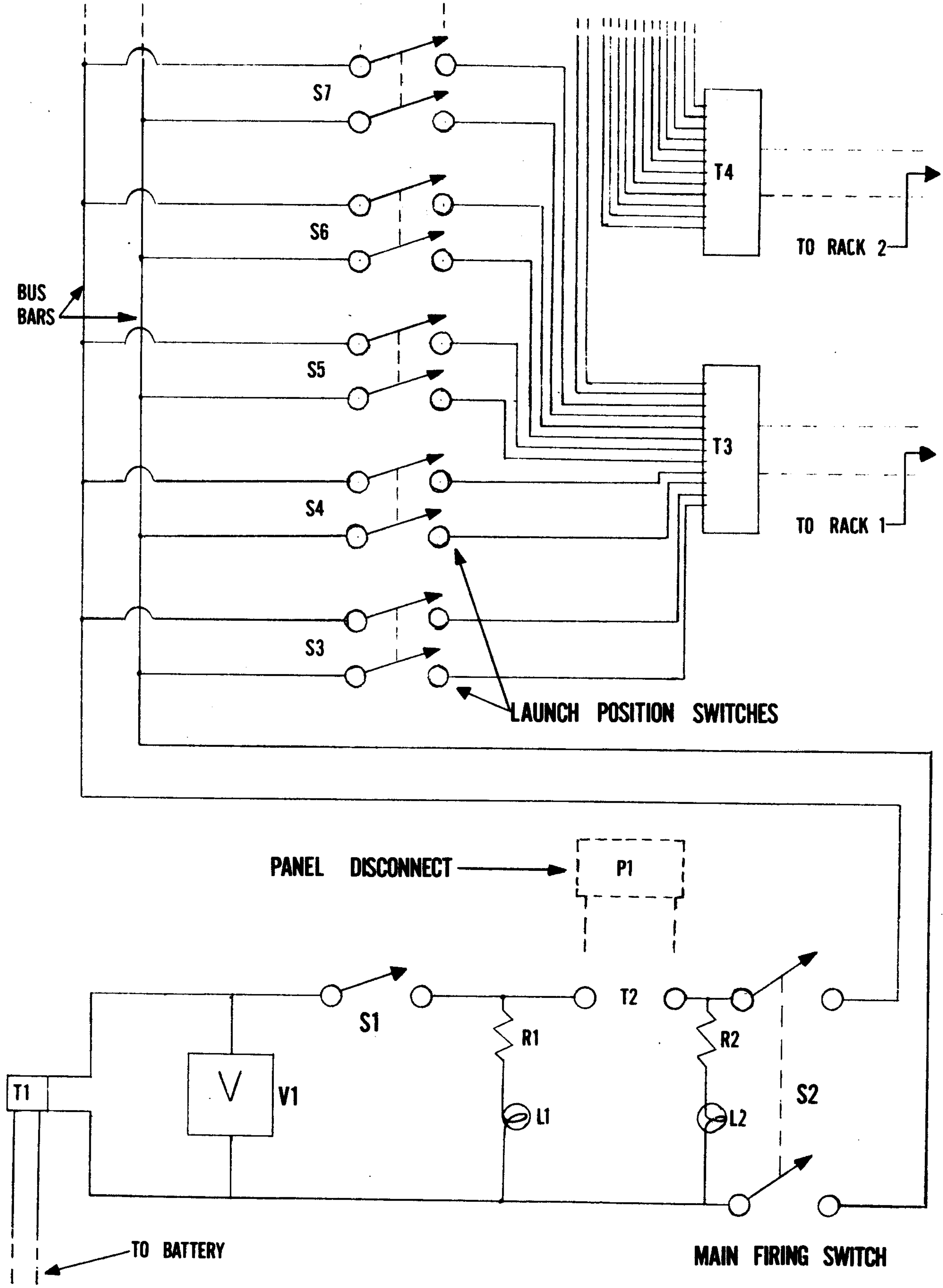
M. B. Miami, Florida

The best way I have found is to cut 2 strips of paper about 3/4 of an inch wide and less than twice as long as the space inside your rocket. Bend one piece in half without creasing it and place the ends of the strip into the body tube. Do the same with the other strip so that it crosses the first strip.

I have been launching rockets for two years but I'm still plagued with an old problem. How do I remove engine casings from my rockets when they are in tight?

J. F., Wattsburg, Pennsylvania

Even a lot of pro's have trouble with spent casings. A strong pair of needle nose pliers, able to grip the nozzle of an engine, sometimes works. A strong wire with a bend on one end can be inserted in the casing to extract the engine. The best solution, however, is to prevent tight engines. On clustered engines and large body tube rockets, it is worth the extra effort to install a flexible wire or bar engine retainer. By simply bending the retainer away from the body tube, the engine can be removed with ease. If you have to resort to a tight fitting engine, use only the minimal amount of masking tape, and apply it carefully, a little at a time. Apply the tape only on the rear of the engine, so that moving the engine will be difficult only when it is almost completely inserted. If you design your rockets so that the engine extends approximately 1/4 inch beyond the body tube when inserted, most engines can be removed with your fingers.


S7
S6
S5
S4
S3
BUS
BARS
T4
T3
TO RACK 2
TO RACK 1
LAUNCH POSITION SWITCHES
PANEL DISCONNECT
P1
S1
T2
R1
R2
L1
L2
V
V1
T1
S2
TO BATTERY
MAIN FIRING SWITCH

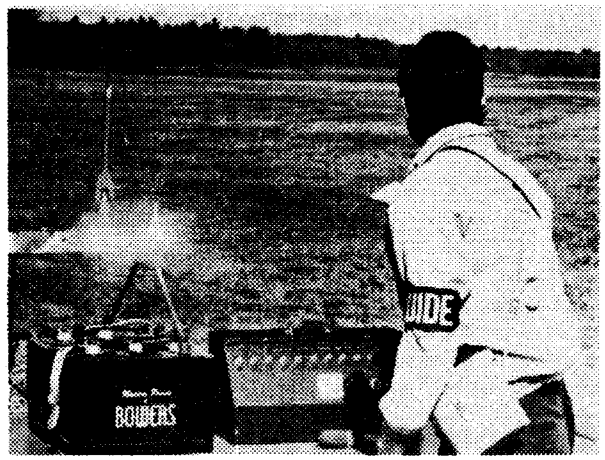
The Design and Construction of a Club Launch Panel

by George Caporaso

If more than five people intend to launch rockets at the same launch site, it is generally desirable to have one centrally controlled launching system that can accommodate all or most of the rockets simultaneously from one panel. Such a system is in actuality, only a large switch box with certain safety features added so that only key personnel can feed power through the switches. The system must also be capable of supplying sufficient power to insure near instantaneous ignition and must provide positive security measures.

Such systems are in common use in sections or chartered clubs of the National Association of Rocketry. This article will center on the design and construction of one such panel operated by the MIT Section of the NAR.

The panel has twelve selecting toggle switches corresponding to twelve possible launch rack positions. A main power circuit delivers power to any of the twelve selected positions through two safety locks. In order to fire a rocket from the panel, the following steps must be taken: first a specially made, internally shorted plug, the disconnect, is inserted into a panel socket. A green light then glows indicating power in the circuit up to that point. Next, a key is inserted into a special switch which is wired in series with the disconnect. When this switch it turned on, a red light glows indicating that the panel is armed and that only the main firing switch need be pushed to ignite the rocket(s). The main firing switch is covered by a metal shield so that it cannot be accidentally tripped. In addition, the switch is normally in an off position; it must be held on. When it is released, it will turn off.



The panel must be able to deliver adequate amounts of power to the launchers or else instant ignition or simultaneous ignition of clusters and single stage rockets will be impossible. For this reason, only the heaviest wire should be used in the panel and in the cables leading form the panel to the launch racks. The MIT panel used No. 12 bus bar for internal wiring of the main power circuit to the individual selector switches. The connections from the selector switches to the panel sockets which lead to the launchers were made with No. 14 wire. The series connections in the main power circuit were make with No. 10 bus bar. The multiconductor cables which lead from the launch panel to the launch racks were the smallest wires in the entire system and were composed of No. 16 wire (the larger the number, the smaller the wire).

The switches were also heavy duty. The twelve selector position toggle switches were all rated at 10 amperes each while the main firing switch was rated at 20 amperes. 3 to 4 amperes are normally required for a single rocket ignition in a 12 volt system. The panel was enclosed in a stainless steel front sloping black cabinet which left adequate room for the possible later construction of communications equipment inside the panel. Connections to the panel terminated at the rear in three sockets. Two of the sockets were used for two cables which went out to two launchers each of which could accommodate 6 rockets. The remaining socket was used for the number 10 wire cable that connected the 12 volt battery to the panel. The panel was equipped with a D.C. voltmeter to constantly monitor the status of the battery supply voltage.

Construction of the actual panel can be accomplished in 50 hours at an approximate expenditure of $60. The parts list is given in figure 3. A soldering gun or large iron, an electric drill, screwdriver, wrench and set of files are the only tools necessary for the construction although access to a drill press would aid considerably in punching out some of the larger panel holes.

Once such a panel is built, it can be used with an integrated launch rack system which is intermally wired or the cables can be run directly to the engine igniters.

PARTS LIST FOR PANEL

New. refers to:
Newark Electronics Corporation
500 North Pulaski Road
Chicago, Illinois 60624

Laf. refers to:
Lafayette Electronics
111 Jericho Turnpike
Syosset, New York 11791

T1, T2	Laf. 39F330	S3,...S14	Laf. 99T6155
T3, T4	Laf. 39F335	Bus Bars	New. 36F294A No. 12 AWG
V1	Laf. 38T3198	No. 14 Wire	New. 36F294A
R1, R2	New. 3F150 40 ohms	No. 10 Wire	New. 39F683 10 feet
L1, L2	Laf. 32T6619	Cables	Simplex Wire & Cable Co., Cambridge, Mass. Order 2, 20-foot, 15-conductor, No. 16 AWG cables
Mounts	Laf. 33T3252 33T3253		
P1	Laf. 39F320 - order 2		
S1	Laf. 33T6401		
S2	Laf. 33T2664		
Panel	New. 91F789		

Using Super-Monokote on Model Rockets

by Tom Milkie

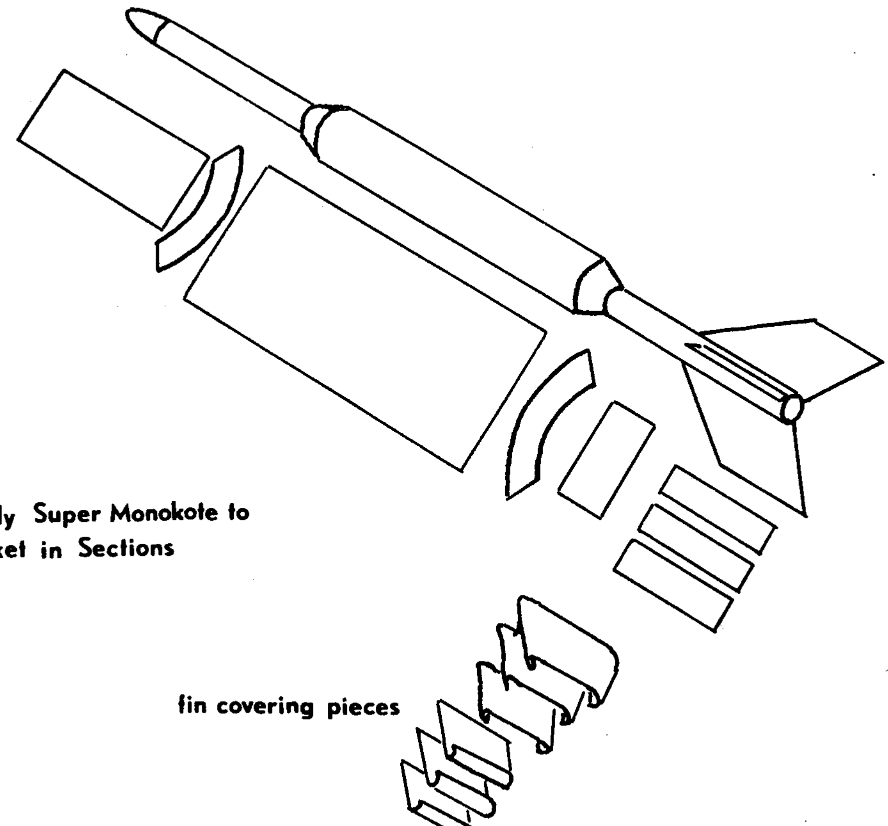
Super Monokote, a new plastic covering material from Top Flite, has been used successfully for covering model airplanes. This amazing material can also be used for covering model rockets. It is sold by the foot in 26 inch width at most hobby stores.

Super Monokote is a thin, glossy plastic with a heat sensitive adhesive on the back. An iron is all that is needed to apply the covering, saving lots of time and mess. It also can do things paint can't do. Super Monokote can cover body tube joints and the slots in spiral-wound tubing, it adheres to any material, and will not crack, peel, or chip. This covering is also moisture-proof and dirt can be wiped right off.

This new covering material is really simple to use. Smooth sand all balsa members of the rocket. No doping or sealing is necessary for a fine finish. It is best to leave off the launch lug until after finishing the rocket. Also, small details such as scoops, antennas, or small fins should be left off. If the body is made up of closely clustered body tubes (such as a Saturn), it would be best to leave them apart and finish them separately.

Next, cut a sheet of Super Monokote to the proper shape of each part of the rocket, with approximately ½ inch overlap on all sides. Separate peices must be cut for the main body tube sections, adapters, body tube areas between fins, and both sides of each fin. The launch lug may be coated (if you want to risk burnt fingers). On some rockets, such as Estes' Mars Snooper, the fins will have to be covered in 4 or more pieces. Forget trying to cover ogive or parabolic nose cones, it's impossible. Even a conical nose cone is tricky. Some scale birds with compound curves in the body, like the V-2, may be next to impossible. (A compound curve is a curve that bends along two dimensions, like a sphere.) A fiber-tipped pen is a nice tool for marking the Super Monokote for cuts.

To apply the coating, use a small travel iron, the smaller the better. Heat the iron to just below the melting point of the plastic – near the cotton-wool setting on the dial. If the iron is too hot the plastic will just form a sticky mess on your iron; if it is too cool the coating will not bond properly. Test the heat on a small sample first. Top Flite suggests using tissue or paper over the iron to prevent damaging the Super Monokote. A teflon coated iron is gentler and makes the job easier too.



Apply Super Monokote to Rocket in Sections

Remove the clear plastic backing from the material. Don't forget which side has the adhesive on it! (You can't feel the dry bonding agent.) If you forget, just touch the iron to one side – it will stick to the adhesive side.

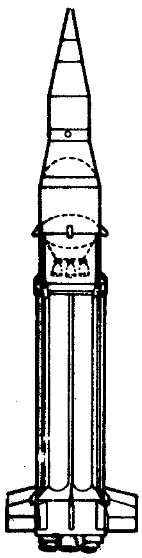
Place the Super Monokote on the model and tack a few points down by touching them with the iron. Then smooth the coating down, working from one edge, keeping a straight line, across the piece. If any air pockets are formed, puncture the area with a pin and reheat. When covering compound curves, heat small areas and gently pull the coating around, smoothing out wrinkles with the iron Trim excess off with a razor blade, leaving a 1/8 inch overlap for the next section.

Super Monokote comes in six colors: yellow, red, orange, aluminum, blue, and white. This leaves plenty of choice for dazzling color schemes. To apply trim just cut peices of coating to shape and iron on. Decals may be used on the coating. Plastic cement works nicely for attaching launch lugs, small fins, etc.

A great advantage over dope that this material possesses is its great strength. The tensil strength is 25,000 p.s.i., and it is very puncture resistant. A friend once built a long (3 foot) payload rocket, ¾ coated with Super Monokote and ¼ just doped. As usual the rocket pranged. When it was examined, it was found that the doped part had crumbled, but that part protected by the covering was intact! The strength factor will make Super Monokote valuable for strengthening the ends of body tubes. It would be useful for single-stage birds where the shock cord snaps the nose cone back to hit the body tube, or for the tops of boosters.

Despite all its advantages, there are some plaes where Super Monokote can't be used. Places where an iron can't reach and compound curves of nose cones must be protected by other means. Just the same, this new material may soon replace dope as the main covering material for model rockets.

DON'T MISS OUT



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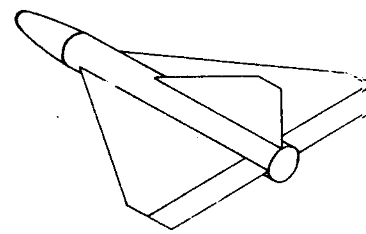

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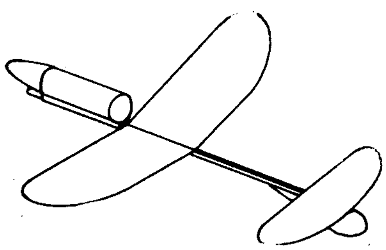

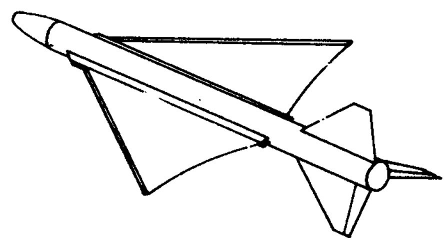

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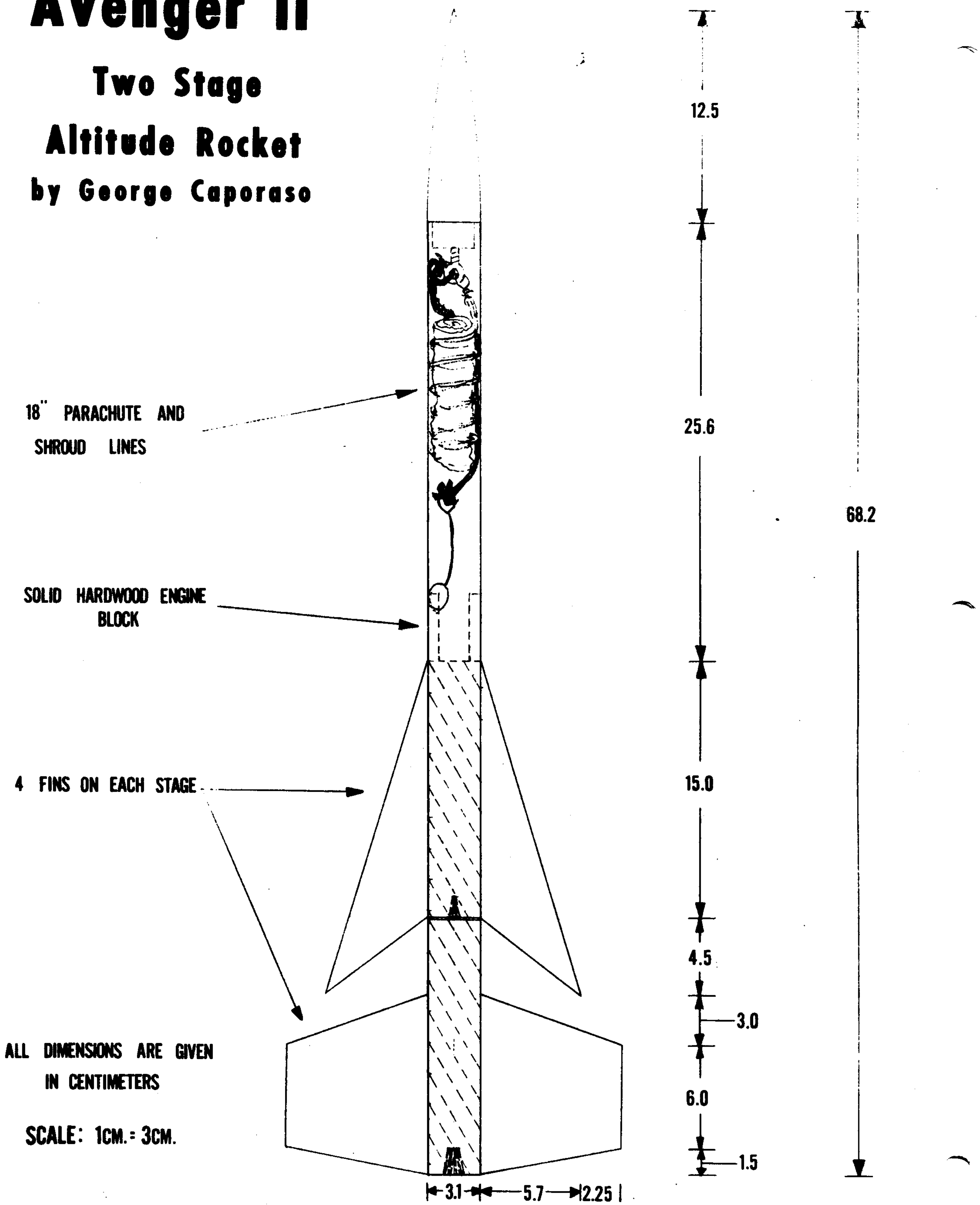
Avenger II

Two Stage Altitude Rocket

by George Caporaso



The Avenger II is a high altitude, two stage rocket designed to be flown using a Flight Systems F 18-0 booster and a Flight Systems F 1.3-6 sustainer. This rocket is capable of reaching an altitude of over a mile. With a first stage drag coefficient of .74 and a second stage drag coefficient of .55, the rocket's altitude was calculated as being 5,690 feet. [1]

The Avenger II is not a high performance rocket. It is a rocket designed for sport flying which can easily be adapted for payload work. If more altitude is desired, the initial weight can be optimized by adding or subtracting weight from the nose cone. [2]

The parts list for the accompanying diagram is given in figure 1. In figure 2 is a velocity profile for the flight path. The first stage, which has a thrust of 18 pounds boosts the rocket to a velocity of 508 ft./sec. at burnout. At this speed, the drag on the second stage is greater than the thrust of the sustainer engine and the rocket *decelerates* during the entire second stage burn, (of course, the rocket would decelerate much faster if there were no seond stage engine). The second stage burns out at a velocity of 389 ft./sec. which is very close to its terminal velocity (i.e., where the thrust minus the drag is almost equal to zero). From burnout, the upper stage coasts another 1,100 or so feet in about 6 seconds. In this type of rocket configuration, the greatest part of the altitude is achieved during the second stage burn. The first stage burnout occurs at approximately 150 ft. The second stage engine, which burns for an incredible 10 seconds adds another 4,400 feet to the altitude. The total upward flight time should be about 16-17 seconds.

It is suggested that an 18 inch parachute be employed for the recovery of the upper stage as anything larger will cause the Avenger to drift miles away from the launch site.

Great care must be taken in the construction of the lower stage fin assembly and upper stage engine block unit as the large drag and thrust forces experienced during the first stage ignition period could result in a catastrophic failure of the structure.

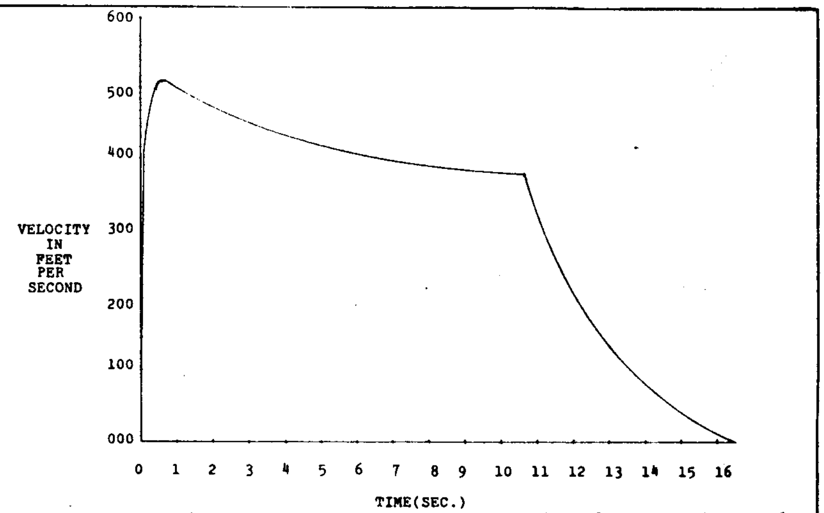


Fig. 2. Velocity Vs. Time for the Avenger II. Note the deceleration of the second stage after first stage burnout.

Cut the upper and lower stage fins from 3/16 inch balsa stock and glue them to the body tube with Ambroid or Duco Cement. After this glue dries, apply fillets of white glue along both sides of each joint. Repeat this several times. Then cut small strips of gauze and glue them to the fin-body joint areas. Make the strips small enough so that they don't overlap on the body tube.

Sand the engine block forward edge and apply Ambroid cement to the forward edge and side of the block. Insert this into the upper stage approximately 140 mm. from the bottom edge so that the second stage engine will protrude about 10 mm. from the end.

Next, attach the shock cord to the metal leader coming from the engine block and connest the free end of the shock cord to the screw eye in engine block and connect the free end of the shock cord to the screw eye in and the metal-leader-shock cord joint should be glued to insure sufficient strength.

To couple the second stage and first stage engines, wrap a single strip of tape almost entirely around the joint between the ejection charge end of the F 18-0 and the nozzle end of the F 1.3-6. Before tapeing, the nozzle of the second stage engine should be stuffed with Jetex wick to insure positive second stage ignition. Wrap tape around the first and second stage engines so that they make tight fits with the booster and sustainer tubes respectively.

Finish the model in the standard way. Seal the nose cone and fins with either Aero-Gloss Balso fillercoat or Testors Sanding sealer. Sand the body either Aero-Gloss Balsa fillercoat or Testors Sandin sealer. Sand the body Then apply the final coats with either brush on or spray paints. At the particular Reynold's numbers encountered in the flight of this model, the boundary layer is probably laminar only on the nose cone and on the upper stage fins, therefore, these surfaces should receive the most attention as far as sanding and painting (smoothly) are concerned.

The top stage of the Avenger may be flown quite successfully as a single stage rocket using either the F 1.3-6 or F 18.8. In either case, bring a pair of binoculars to the launch as tracking these birds in either configuration is very difficult.

The Avenger II is the first in a series of Avenger class rockets. The series will include the Astral Avenger, the Galactic Avenger, the Red Avenger and the Avenger of Mankind. Watch for them in future issues of Model Rocketry lest you miss out on the most terrifying series of rockets ever conceived of by the human mind, or in other words, "you ain't seen nothin yet."

PARTS LIST FOR THE AVENGER II

Nose cone	– Centuri BC 115B
2nd Stage Body Tube 16" Long	– Centuri LT-115A
1st Stage Body Tube 6" Long	– Centuri LT-115A
2nd Stage Engine	– Flight Systems F 1.3-6
1st Stage Engine	– Flight Systems F 18-0
Parachute 18"	– Estes 651-PK-18
Screw Eye	– Estes 651-SE-1
Shock Cord ¼" Wide	– Estes 671-SE-2
Engine Block and Leader	– Flight Systems Inc.
Fin Material 3/16" Thick	– Centuri BFM-16
Reinforcing Gauze	– Estes 651-GR-2
Launching Lug	– Centuri LL-20

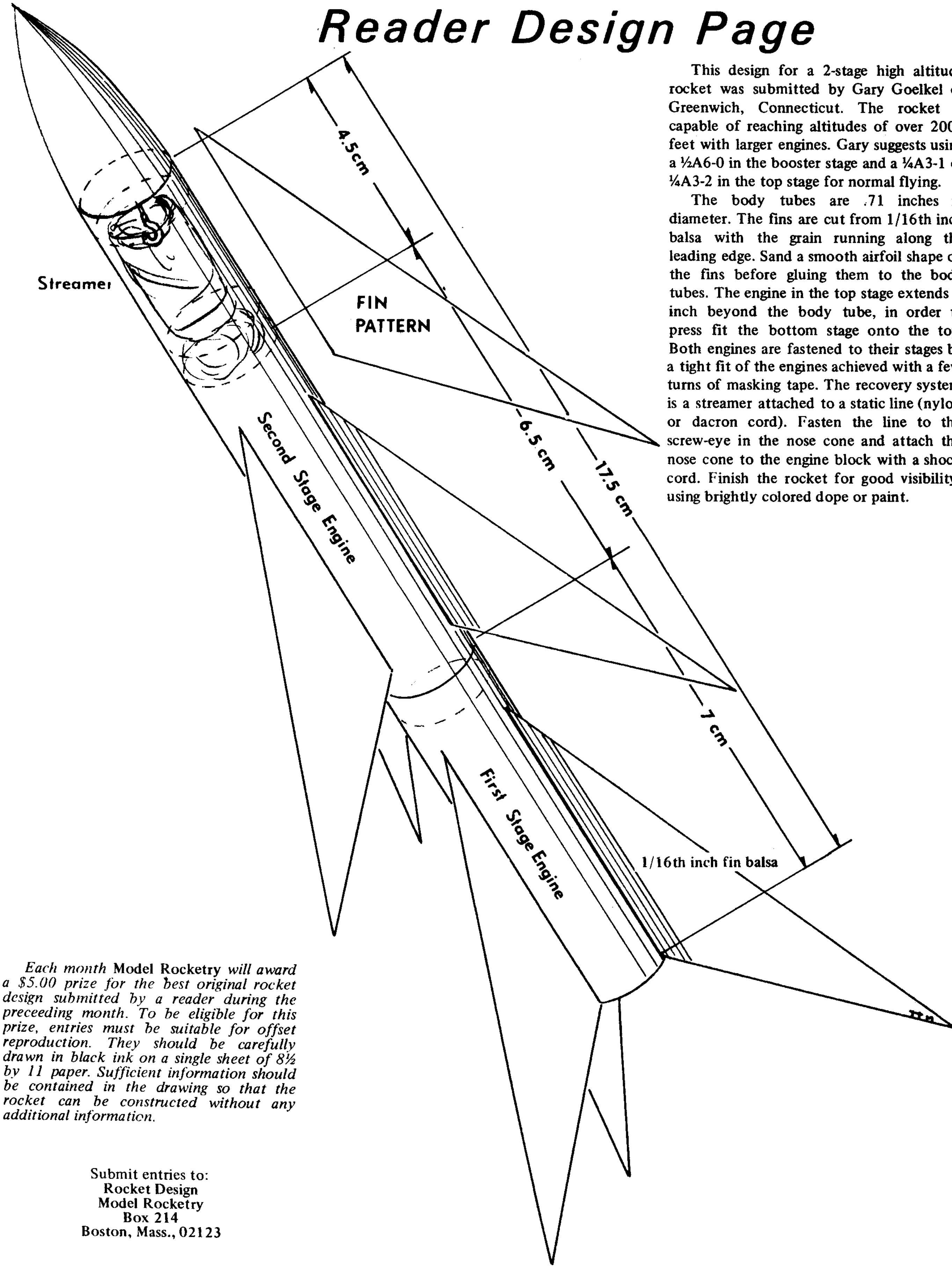
1. "Calculating Drag Coefficients" by G. Caporaso. Model Rocketry, Nov. 1968

2. "Model Rocketry Altitude Prediction Charts" by Douglas J. Malewicki, Centuri Engineering Company

Reader Design Page

This design for a 2-stage high altitude rocket was submitted by Gary Goelkel of Greenwich, Connecticut. The rocket is capable of reaching altitudes of over 2000 feet with larger engines. Gary suggests using a ½A6-0 in the booster stage and a ¼A3-1 or ¼A3-2 in the top stage for normal flying.

The body tubes are .71 inches in diameter. The fins are cut from 1/16th inch balsa with the grain running along the leading edge. Sand a smooth airfoil shape on the fins before gluing them to the body tubes. The engine in the top stage extends ¼ inch beyond the body tube, in order to press fit the bottom stage onto the top. Both engines are fastened to their stages by a tight fit of the engines achieved with a few turns of masking tape. The recovery system is a streamer attached to a static line (nylon or dacron cord). Fasten the line to the screw-eye in the nose cone and attach the nose cone to the engine block with a shock cord. Finish the rocket for good visibility, using brightly colored dope or paint.



Each month Model Rocketry *will award a $5.00 prize for the best original rocket design submitted by a reader during the preceeding month. To be eligible for this prize, entries must be suitable for offset reproduction. They should be carefully drawn in black ink on a single sheet of 8½ by 11 paper. Sufficient information should be contained in the drawing so that the rocket can be constructed without any additional information.*

Submit entries to:
Rocket Design
Model Rocketry
Box 214
Boston, Mass., 02123

Scale Design:

Viking IV

by George Flynn

When the supply of captured German V-2 rockets began to run out, the need for a successor was recognized. Thus the Viking, the first American produced rocket designed to carry large payloads aloft, was designed to carry one-half ton of instrumentation to about 100 miles.

The Viking incorporated several significant improvements over the V-2. The Viking engine, built by Reaction Motors, pivoted in gimbal mounts to steer the rocket. In the V-2, on the other hand, steering was accomplished by carbon deflection vanes which changed the direction of thethrust.

Beginning in 1959, some 14 Viking rockets carried scientific payloads to altitudes of about 100 miles. The early Viking's 1 through 7 were of basically the same design, with a diameter of 32 inches and 47 feet 8 inches long. Later Viking's were 45 inches in diameter and 41 feet 8 inches long.

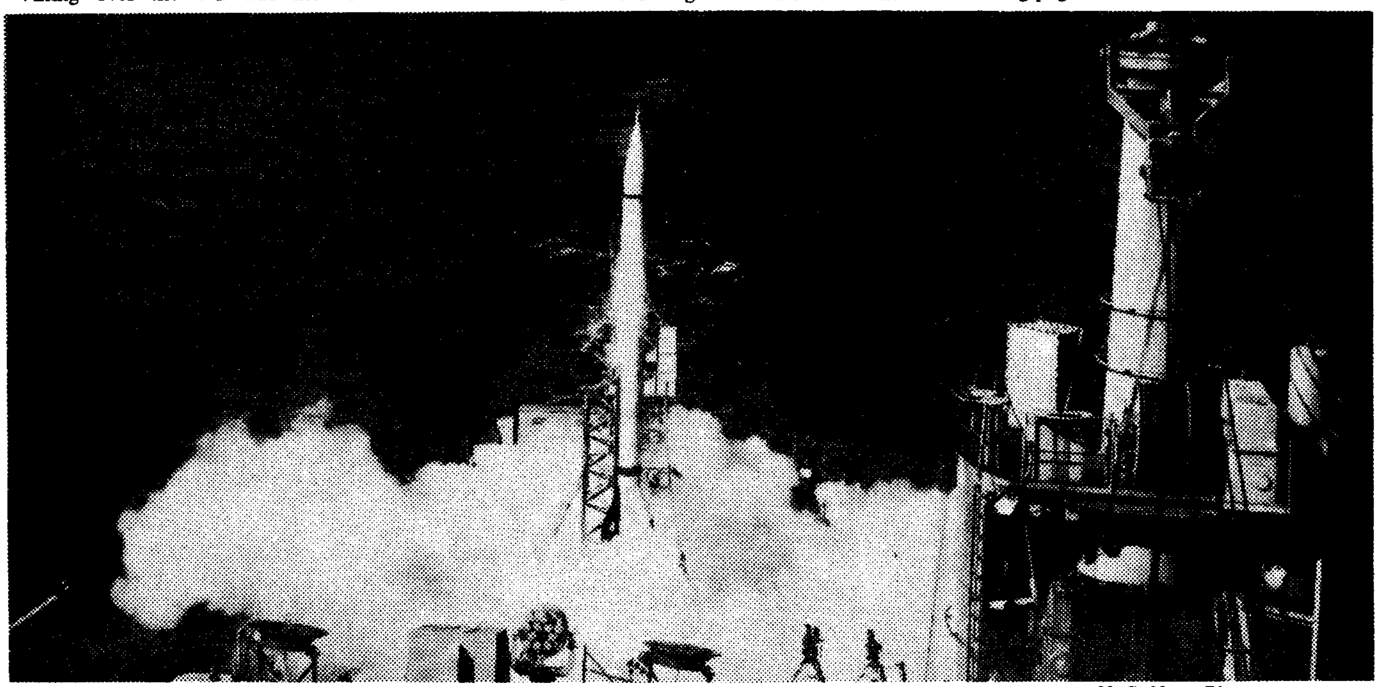
One of the major improvements of the Viking over the V-2 was the use of an integral alchol tank (ie. the skin of the rocket was used as the wall of the tank), resulting in a low takeoff weight to payload weight ratio, integral tanks, with plumbing running down the outside of the rocket, which have become common with such missiles as the Atlas, were first employed on large rockets in the Viking series. This highly efficient design allowed the Viking to capture the world altitude record for a single stage rocket – 158 miles.

Perhaps the most unusual Viking flight came on May 11, 1950 when the Viking IV was launched in mid-pacific from the *USS Norton Sound.* The *USS Norton Sound* had previously served as a launching platform for several Aerobee rockets (in 1949), and was later to launch a series of X-17's carrying nuclear weapons in a nuclear explosion detection test.

The Viking IV rocket engine was successfully static tested at White Sands before shipment to the West Coast, where the rocket was loaded aboard thes, USS Norton Sound. Though the static test was successful, there was considerable apprehension on the part of project engineers aboard the *USS Norton Sound* none of the previous three Viking test vehicles had carried its payload above 50 miles (the design altitude was over 100 miles.)

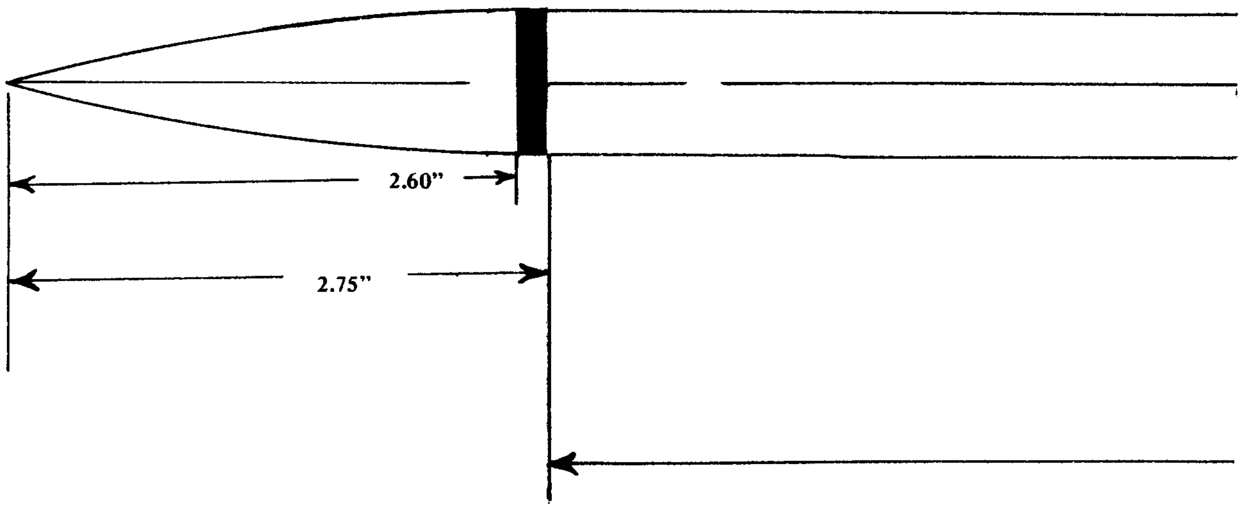
At 4PM local time on May 11, 1950, the Viking IV engine was ignited and burned for 74 seconds – one second shorter than planned. This vehicle carried 959 pounds of instrumentation to 105 miles – a record altitude for an American built rocket. The flight of Viking IV was the first completely successful flight in the Viking series, and only the second large rocket to be launched from shipboard. (Earlier, a V-2 had been launched from the aircraft carrier *Midway.*)

A scale model of the Viking IV can be constructed around 10.40" of a 0.736" diameter body tube. A BNC-20N (Estes) nose cone should be used, and the fins should be cut from 3/32 inch sheet balsa. A complete set of scale plans is on the following page.



U. S. Navy Photo

The Viking IV launching from the *USS Norton Sound.*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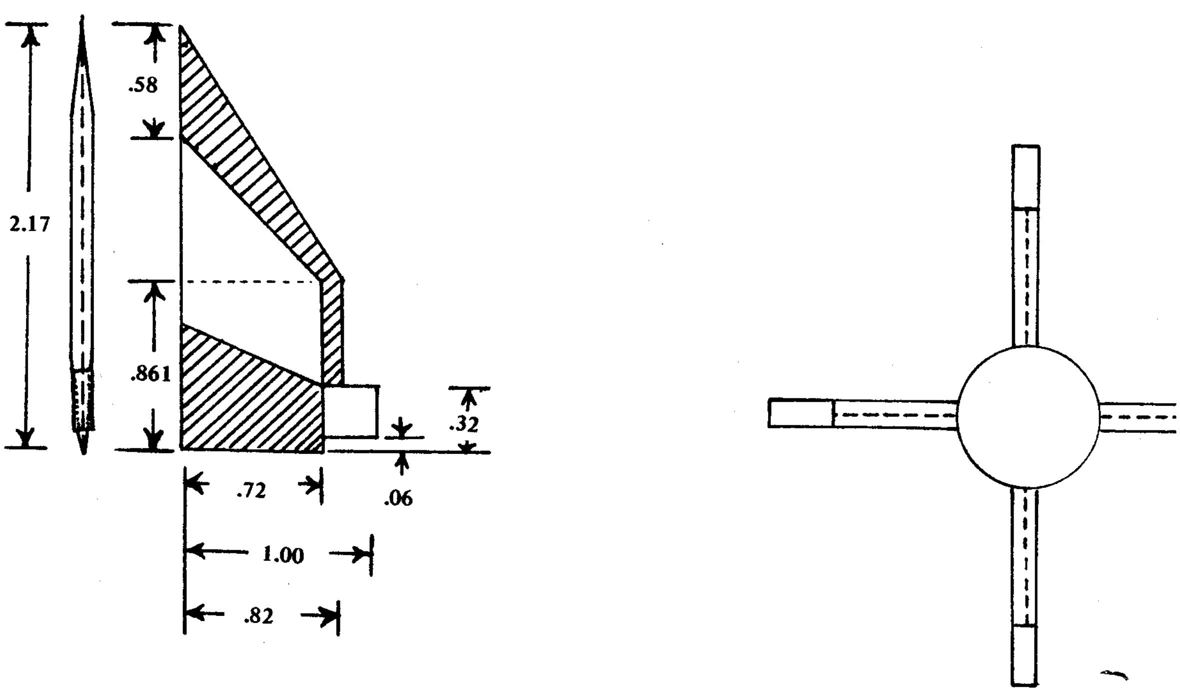
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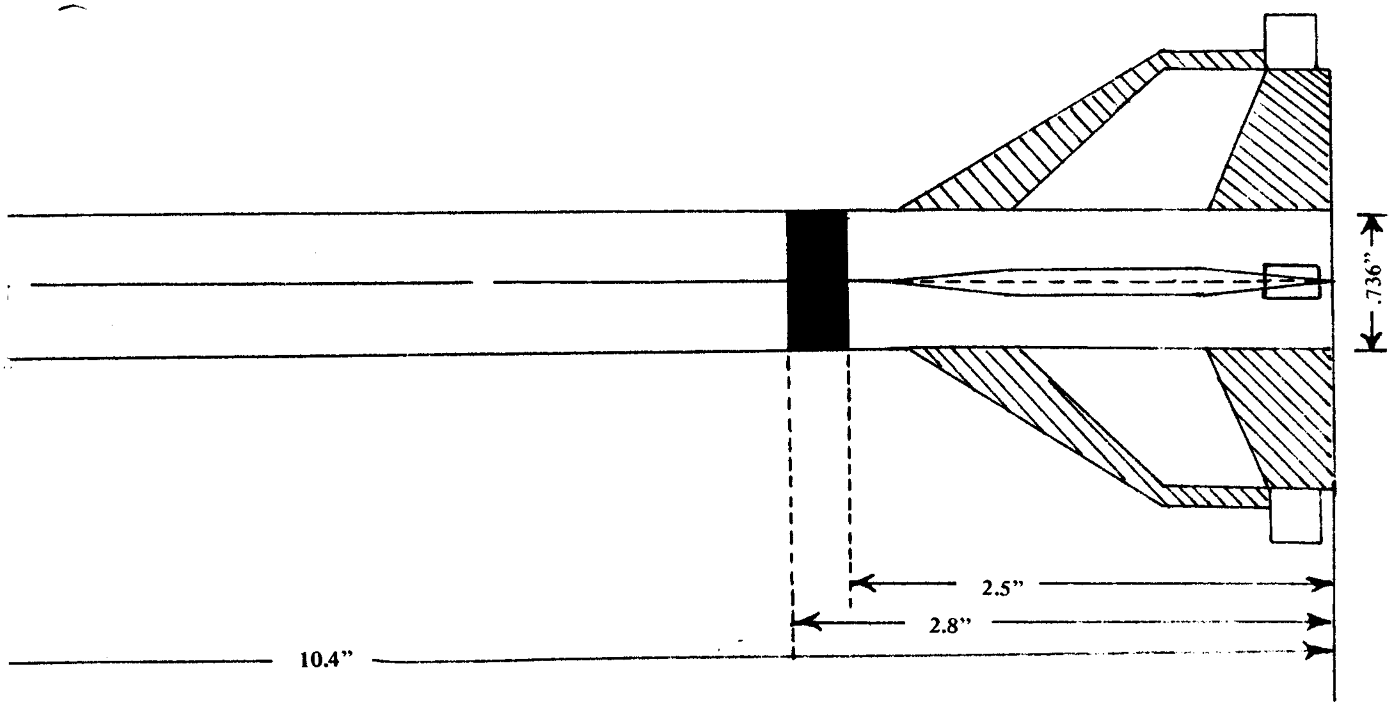


Viking IV

Viking IV Specifications

Single stage, liquid fuel, research rocket

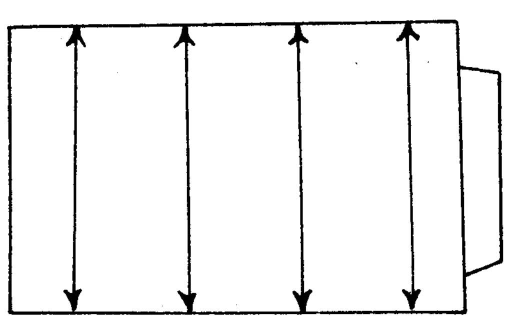
Length: 47 feet 8 inches

Diameter: 32 inches

Weight: 11,440 pounds

Payload: 950 pounds

Altitude: 105 miles



Fin Placement Guide

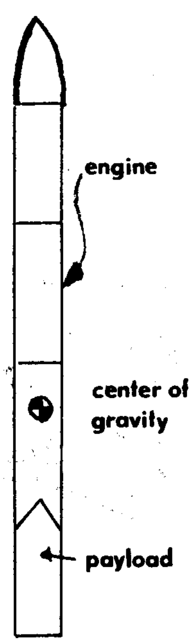
A Problem in Stability

Rocket stability by placing the engine ahead of the payload? . . . Even Dr. Goddard fell for it . . .

by Tom Milkie

Many model rocketeers, searching for something new, have tried to get rid of the perpetual fins, found on nearly every rocket that flys where you want it to go. Many young Von Brauns then thought up the apparently obvious method of stabilizing a rocket: Don't push it from behind so it can go where it wants, just pull it instead, going where you want. As a result, many rockets have been built putting the engine ahead of the payload. (See diagram) The inventor usually claims that the "center of thrust" is ahead of the center of gravity. Therefore, the rocket will be pulled to Earth by gravity through the center of gravity, and the engine will pull the rocket upwards through the "center of thrust." Since the "center of throust" is ahead of the CG, the rocket flys straight up – no forces can disturb it. Sorry, it doesn't work.

I once built a simple design to test this idea, and when it flew straight, I proudly thought that the above theory really worked. However, at the 1968 Pittsburgh Model Rocket Convention there was a discussion group on R & D. This old theory of stability was brought up. Jim Barrowman, a NASA engineer, NAR board member, and engineer for Centuri was a discussion group leader, and he flatly rejected this theory. I later found that many people had thought that they had also invented the Goddard-stability method, as it was called.



Many argue that this design for a rocket should work because a famous rocket of Dr. Goddard was built this way for stability. Dr. Robert H. Goddard, the father of modern rocketry, unfortunately, also was mistaken in this design.

Dr. Goddard was one of the pioneers of rocketry in this country and is given credit for over 200 patents on rocket developments. He worked with liquid fuels, turbine fuel pumps, gyroscopic stability, clustered engines, and multi-staging, back when others were tooling with the brand-new horseless carriage.

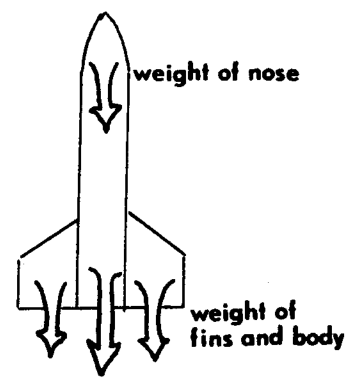
He started working with liquid fuel in some of his earliest rockets because of the greater power available, despite the greater reliability and simplicity of solid fuel systems. The fuel was gasoline, burned in liquid oxygen, in most of his early flights. The large weight of fuel tanks, lines, pumps, and other paraphernalia, coupled with the weak engines, would result in a low and slow flight. In order to acquire the needed stability, Dr. Goddard constructed his rocket with the engine above the fuel tanks, which were protected from the engine exhaust by a deflector. His first flight on March 16, 1926 at his Aunt Effie's farm in Auburn, Mass. was a success. The rocket rose off its launcher to a height of 41 feet and traveled about 100 feet, landing in Aunt Effie's cabbage patch. The first successful liquid-fuel rocket had been launched.

Dr. Goddard, however, soon realized that his rocket stability system did not work. He later wrote:

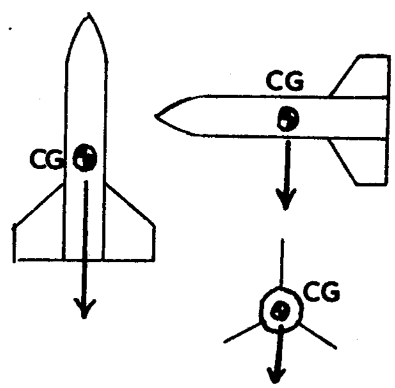
"It will be seen that the combustion chamber and nozzle were located forward of the remainder of the rocket, to which connection was made by two pipes. This plan was of advantage in keeping the flame away from the tanks, but was of no value in producing stabilisation. This is evident from the fact that the propelling force lay along the axis of the rocket, and not in the direction in which it was intended the rocket should travel, the condition therefore being the same as that in which the chamber is in the rear of the rocket. The case is altogether different from pulling an object upward by a force which is constantly vertical, when stability depends merely on having the force applied above the centre of gravity."

His later rockets were all built along traditional lines, with the engine at the rear, though many of his rockets still were open-framed and finless.

Why doesn't the Goddard-stability method work? The best way to analyse the problem would be to use vectors. Vectors are just arrows used to represent the forces acting at a point in the rocket. For instance, the weight of a rocket is a force that can be represented by a vector. The fins, the nose cone, and the body tube all weigh something, and the force of gravity can be represented by drawing arrows downward from each piece, the length of the arrow representing the amount of force on the piece:

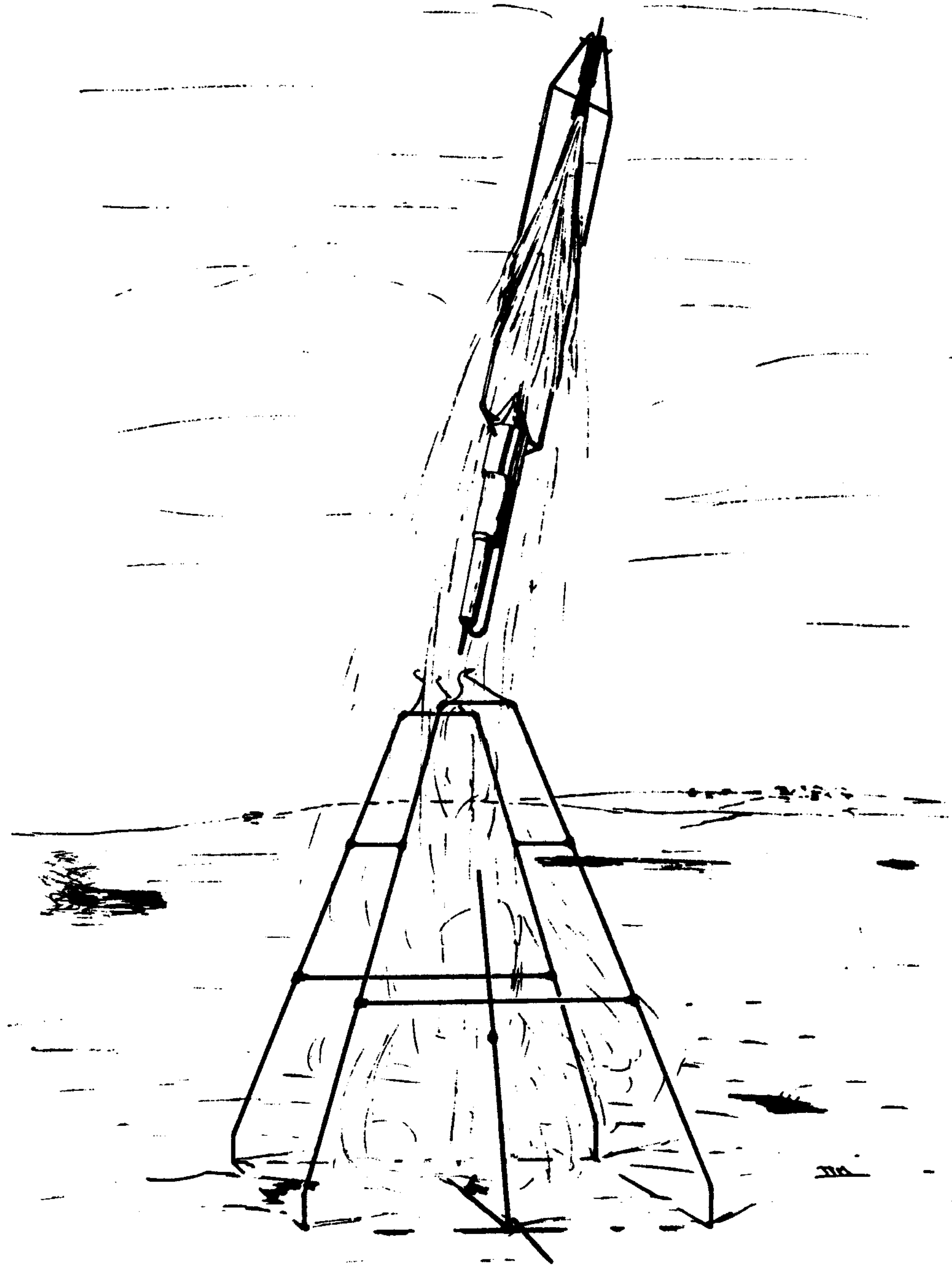


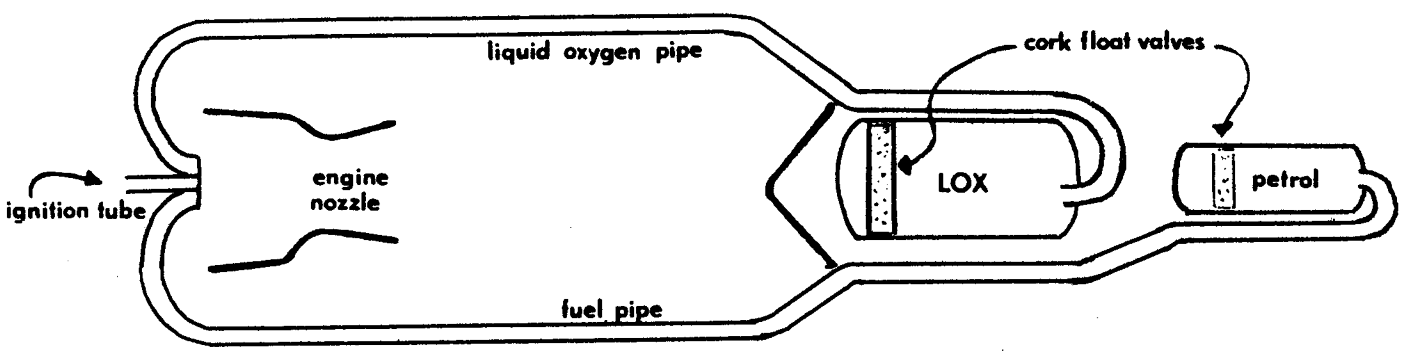
Now, if you were to try to find a point in the rocket where we might place just one arrow to equal the *total* weight of the rocket, it would probably be somewhere in the center of the rocket:



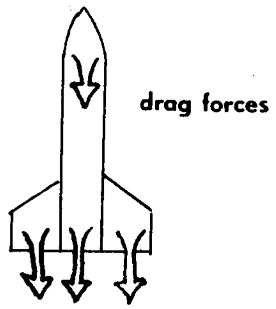
This is the point where you would have to grab the rocket in order to balance it. No matter which way the rocket is tilted, it will balance at this point. This point is familiar to many as the *center of gravity* or the CG.

In a rocket with the common fin stability, we must also include aerodynamic forces. The drag on the fins, nose cone, and body can all be represented by vectors:

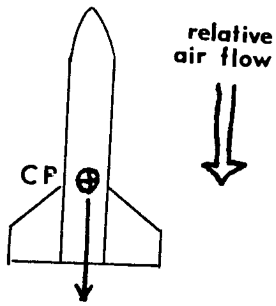




GODDARD'S 1926 ROCKET

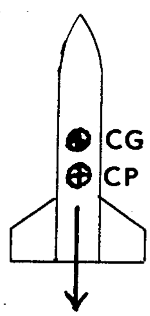


Totaling these vectors, as we did those for gravity, we arrive at the *center of pressure* of a rocket or the CP.

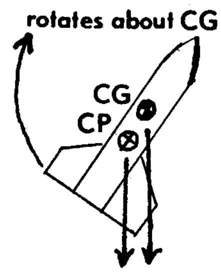


Unlike gravity, the CP will be different when the rocket is held in a different position relative to the air flow. However, we are only concerned about conditions when the rocket is vertical or nearly vertical.

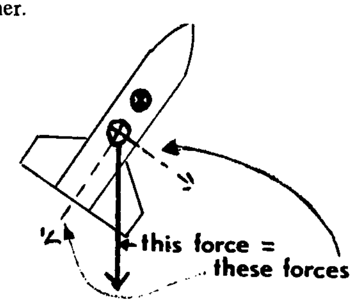
In most rockets the CP is behind the CG like this:

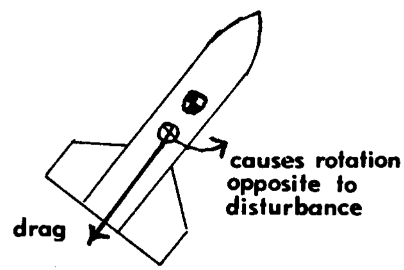


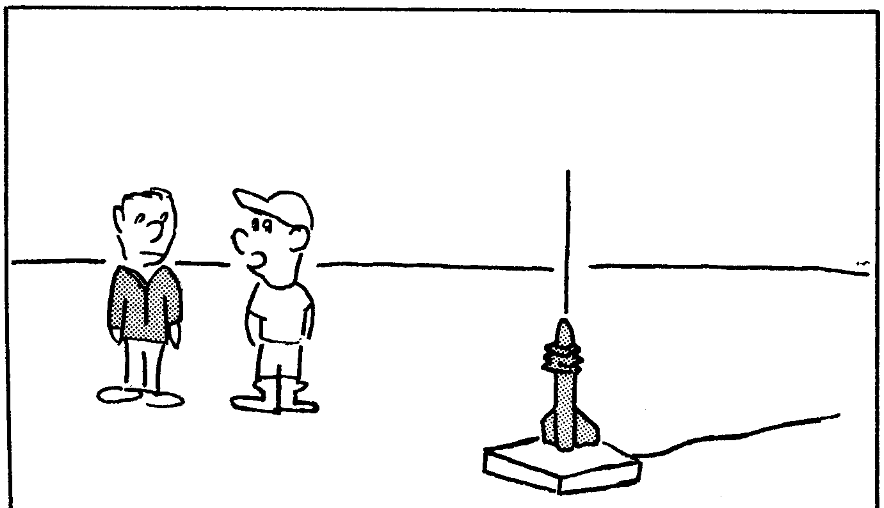
If, because of some interference, the rocket starts to rotate, *it will always rotate about the CG.* This statement is actually how you define rotation for a moving rocket.



The downward force at the CG will have no effect on the rotating rocket, because the rocket rotates about the CG. The force at the CP, however, does two things: It pulls the rocket backwards (drag force), and it puts a rotating force on the rocket, *opposite to that of the disturbance.* In this way the rocket is kept from rotating or going any way but straight up, and flys in a stable manner.

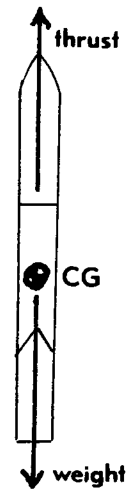






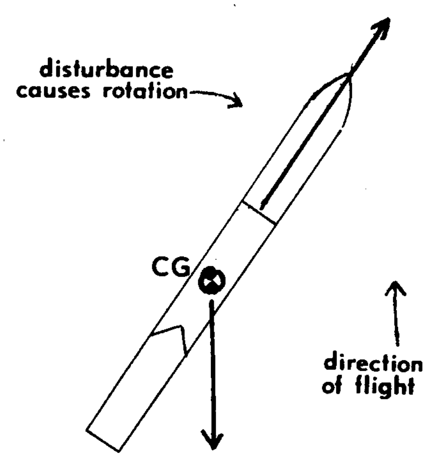
"His rockets use the impact recovery system."

Now, in the proposed Goddard-stability rocket, we must add the thrust of the engine as a force. In an ordinary rocket the thrust only counteracts the drag force and doesn't affect the stability to a great extent. In the Goddard type rocket, the thrust and weight vectors, ignoring drag this time, look like this:



There is no "center of thrust" because if you rotate the rocket, the thrust still goes in only one direction, toward the nose of the rocket, and there is no way of telling where the thrust "takes hold" of the rocket.

Even if you still think there is a "center of thrust," watch what happens when you disturb this rocket:



Since the rocket always rotates about the CG when disturbed, the force of gravity will have no effect on the rotation, as in the last situation. However, the thrust also cannot stop the rotation effect, since its force is only straight along the body. The thrusting engine will then move the rocket in a new direction. Thus the rocket will career about the sky until its rotation is stopped by solid ground.

Well, I hope this clears the air of a lot of mistaken ideas (and a lot of unstable rockets). Now all I have to do is figure out why my finless rocket (with the CG behind the engine) is able to fly . . .

A Minimum Resistance Launch System

by Stephen A. Chessin

One cause of misfires and slow ignitions with many model rocket launch systems is decrease in current due to the resistance of the wires connecting the launch control panel to the launching pad. This loss is noticeable in both six-volt and twelve-volt systems. A launch system whereby the current flowing through the igniter would only have to pass through at most two feet of wire instead of at least twenty feet of wire, as is necessary to provide a minimum distance of ten feet from launch control panel to launching pad, would improve performance.

The simplest way to minimize the length of wire used to connect the igniter to the power supply, and still allow the placement of the launch control panel at least ten feet away from the launching pad, is by use of a relay. Figure (1) is a schematic describing the simplest type of circuit using a relε yIt is really two separate circuits, one for the relay coil, and one for the igniter. Battery A provides the current to energize the relay when the interlock is in and the push button is depressed, and can be located at the launch control panel, at the launching pad, or anywhere in between. Battery B provides the current for the igniter, and is only connected to the igniter when the relay is energized. Both the relay and battery B are placed as close as possible to the launching pad so as to minimize resistance by minimizing the length of the connecting wire.

If the relay being used is rated at six volts, and it is desired to use twelve volts for the igniter, this circuit would require both a six volt and a twelve volt battery. Figure (2) shows a slightly more complex circuit which uses two six volt batteries to accomplish the same thing. In this circuit, when the launch control panel is armed (by inserting the interlock) and the push button is depressed, the current from battery A flows through the relay coil, which closes the contact connecting the igniter to both batteries A and B, which together provide twelve volts. If only six volts is desired, battery B can be eliminated.

One feature provided in a standard circuit that neither of the above contains is a continuity check (see Figure 3). A simple addition to the circuit illustrated in Figure (2) will remedy this. (See Figure (4)). One end of a twelve volt light bulb is connected between the interlock and the push button, the other end connected to the normally-closed contact of the relay. When the panel is armed, twelve volts from batteries A and B flows through the interlock, through the light bulb, making it glow, and through ten feet or so of connecting wire to the normally-closed contact of the relay, which connects it to the igniter, and from the igniter back to the batteries. When the push button is depressed (Figure (5)). current from only battery A flows through the relay coil. This causes the relay to disconnect the igniter from the light

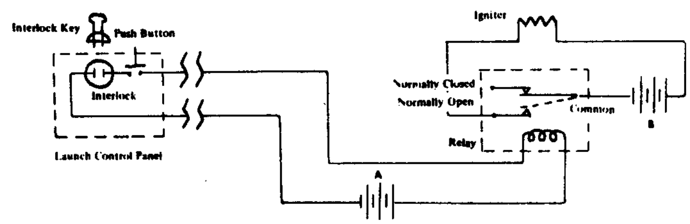


Figure (1)

Simple Relay Launch System

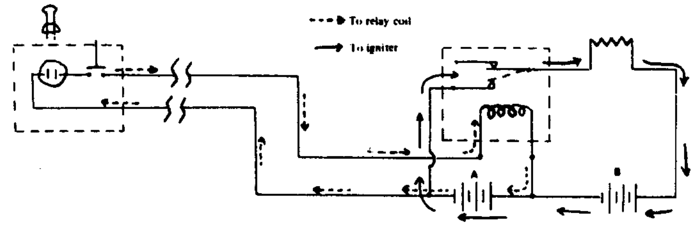


Figure (2)

Another Relay Launch System

(Arrows show flow of current when armed and push button depressed)

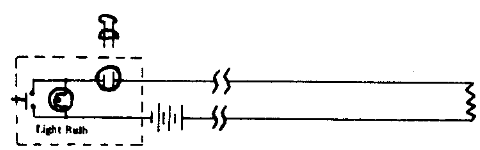


Figure (3)

Standard Launch System
(With Continuity Check)

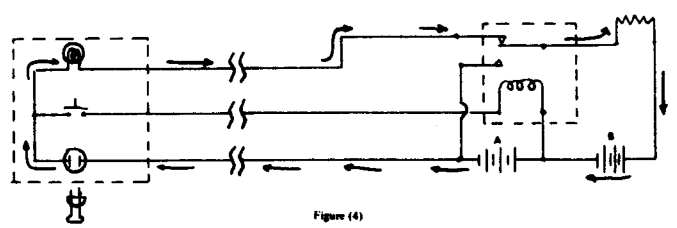


Figure (4)

Relay Launch System with Continuity Check bulb and connect it directly to the batteries. This allows only six volts to be used to energize the relay, yet allows twelve volts to be used for both the continuity check and ignition. By making the connections between the relay, the igniter, and the batteries as short as possible, loss of current due to resistance in the wire can be minimized.

A continuity check for the circuit in Figure (1) can also be obtained (Figure (6)). However, a switch would have to be installed in the continuity check circuit, otherwise it would be on all the time, and accidents could occur if, say, the wrong type of bulb were installed, or if there was a short across the bulb.

With any of these circuits using a relay, more reliable and faster ignition is obtained since loss of current due to resistance is minimized. I have used the circuit illustrated in Figure (4) exclusively, and have had better results than many people who use a system similar to that illustrated in Figure (3).

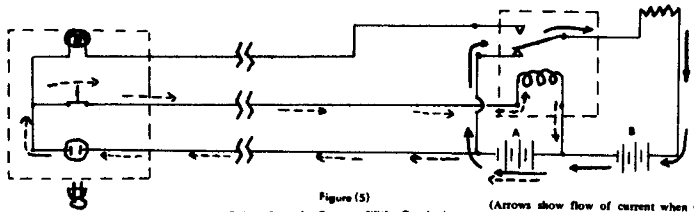


Figure (5)
Relay Launch System With Continuity Check

(Arrows show flow of current when push button depressed)

- - -▸ To Relay Coil
——▸ To Igniter

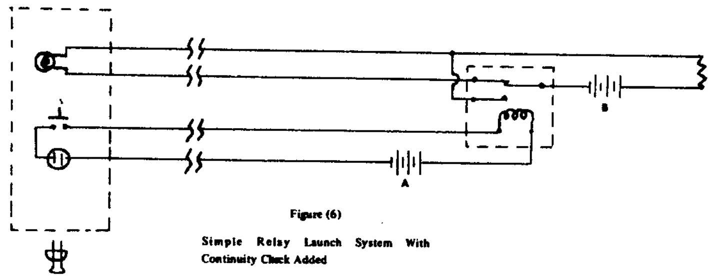


Figure (6)
Simple Relay Launch System With Continuity Check Added

SOLICITATION OF MATERIAL

In order to broaden and diversify its coverage of the hobby, MODEL ROCKETRY is soliciting written material from the qualified modeling public. Articles of a technical nature, research reports, construction and scale projects, and material relating to full-scale spaceflight will be considered for publication under the following terms:

1. Authors will be paid for material accepted for publication at the rate of forty cents (40c) per column inch, based on a column of eight-point type thirteen picas wide, for text and one dollar fifty cents ($1.50) per line cut for drawings accompanying text. Payment will be made at the time of publication.

2. Material submitted must be typewritten, double-spaced, on 8.5 x 11 inch paper with reasonable margins. Drawings must be done in India ink and must be neat and legible. We cannot assume responsibility for material lost or damaged in processing; however our staff will exercise care in the handling of all submitted material. An author may have his manuscript returned after use by including a stamped, self-addressed envelope with his material.

3. Our staff reserves the right to edit material in order to improve grammar and composition. Payment for material will be based upon the edited copy as its appears in print. Authors will be given full credit for published material. MODEL ROCKETRY will hold copyright on all material accepted for publication.

Editor

Model Rocketry Magazine

P.O. Box 214

Boston, Mass., 02123

High Quality Aerial Photography

Part II

by Richard Q. Fox

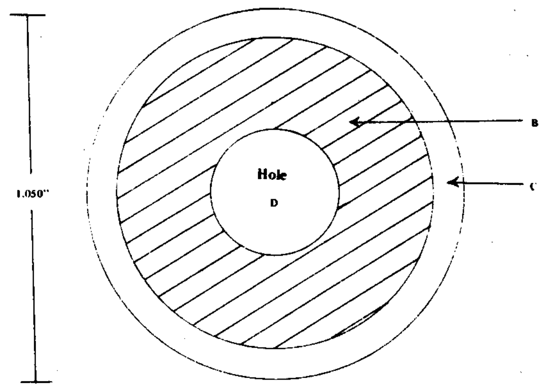
Mounting a Glass Lens in the Camroc

Part One of this series presented the general theory behind the operation of the Camroc, and some information on developing Camroc film at home. This article covers specific information on installing a commercially available glass lens in the Estes Camroc The reason for replacing the plastic lens supplied by Estes with a glass lens is that the pictures taken with the glass lens can show much more detail.

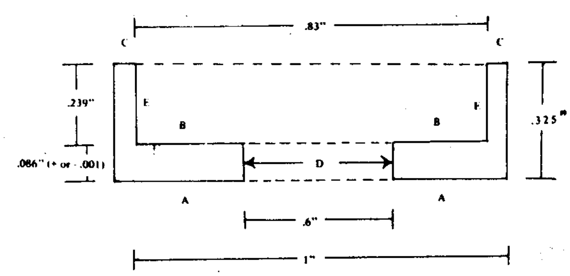
Pictures taken with the glass lens described in this article have such fine detail that they can be enlarged to ten times their original size before the small details become vague! Specifically, the make and model of a car over a quarter-mile away from the camera can be made out in an enlargement of a Camroc picture made with a glass lens, while the car appears as a blob in a similar picture taken with a plastic lens.

The parts needed for installing the glass lens are listed in Table 1. Because a suitable lens holder is not commercially available, this article includes instructions for machining one out of plastic. If you do not have access to a metal lathe or the skill to use one, there are several alternatives. Most high schools and colleges have machine shops, and the lens holder described here is so easy to make, that you should be able to

Top View of Lens Holder



Cross Section of Lens Holder



Reproduced above are 6X magnifications of the central area of photographs taken with and unmodified Camroc (left) and with an Estes Camroc modified, as described in the article, to accept an Edmund glass lens.

have someone make it for you, or possibly show you how to make it. Another alternative would be to have a pattern shop or other business make the part for you. The total labor involved should not run more than an hour.

In order to take pictures with the lens installation described here, the film used must be *flat* disks of Tri-X film. Estes film is designed to curve when it is placed in the Camroc film holder. The film used with the glass lens must sit flat in the back part of the film holder assemble, not curved in the film retainer ring. Refer figures 3 and 4.

The only way to produce disks of Tri-X film which are the proper size to lie flat at the back of the film holder is to cut the disks yourself. The first article in this series (November 1968 **Model Rocketry** described how to make and use a film disk cutter.

Assembly

Briefly, the assembly procedure is to machine a lens holder out of plastic, glue the lens into the lens holder, and glue the lens holder into the Camroc body.

The first step is to remove the lens collar from the inside of the Camroc body section. The lens collar is part of the body section, and does not simply snap out. One removal procedure is to machine the lens collar away on a lathe. Another, less desirable method, is to mill it away using the side of a drill bit held in an electic drill.

The second step is to prepare the lens holder. This is done by machining the piece of plastic to the dimensions shown in figure 1. The only crucial dimension is the distance from face 'A' to face 'B'. This dimension must be within one thou sandth of an inch. In addition, face 'A' and face 'B' must be perfectly parallel to each other.

Caution: the lens is a delicateprecision instrument. In the same sense that you would not stick your finger against the lens of an expensive camera and then clean the lens with your shirt tail, do not mistreat this lens. Keep the lens free of dirt and finger prints.

Check the lens for snug fit in the lens holder, and check the lens holder for proper dimensioning. Remember, the distance from faces 'A' to 'B' is the crucial dimension.

When you are satisfied with the fit of the lens in the lens holder, place the lens in the lens holder with the more curved of the two faces positioned toward the open end of the lens holder. (See figure 2). Make sure the flatter face of the lens sits all the way against face 'B'.

Apply a light coat of white glue to the lens – lens holder joint at face 'C'. Do NOT apply glue to either face 'B' or face 'E' of the lens holder, or to the area of the lens

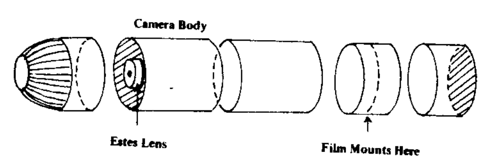
(continued on page 32.)

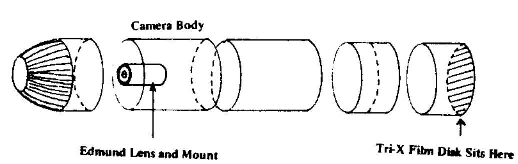
Parts List

1	Edmund Scientific Co., Barrington, N.J.	Glass lens, coated, achromatic, compound, focal length 67 mm., diameter 21 mm.	30,570	$2.00
1		"Delrin" or other Machinable plastic stock, 1" highx 1" diameter		
1		white glue, bottle		
1	Estes Industries, Inc. Penrose, Colo.	Camroc	651-C-1	4.00

In addition some of the following parts may be desired for experimentation, even though they are not necessary for the project:

1	Estes	Camroc body, shutter, shutter guide	651-CBS-1	.60
1	Estes	Camroc styrofoam padding	651-PSP-2	
1	Estes	Camroc nose cone	651-PNC-60AC	.50
1	Estes	Camroc Nose window	651-CW-1	.15
1	Estes	Camroc rubber band	651-CSB-1	.05
1	Estes	Film holder assembly, empty	651-FH-1	.75
1	Estes	Camroc Adapter	651-TA-5060C	.05





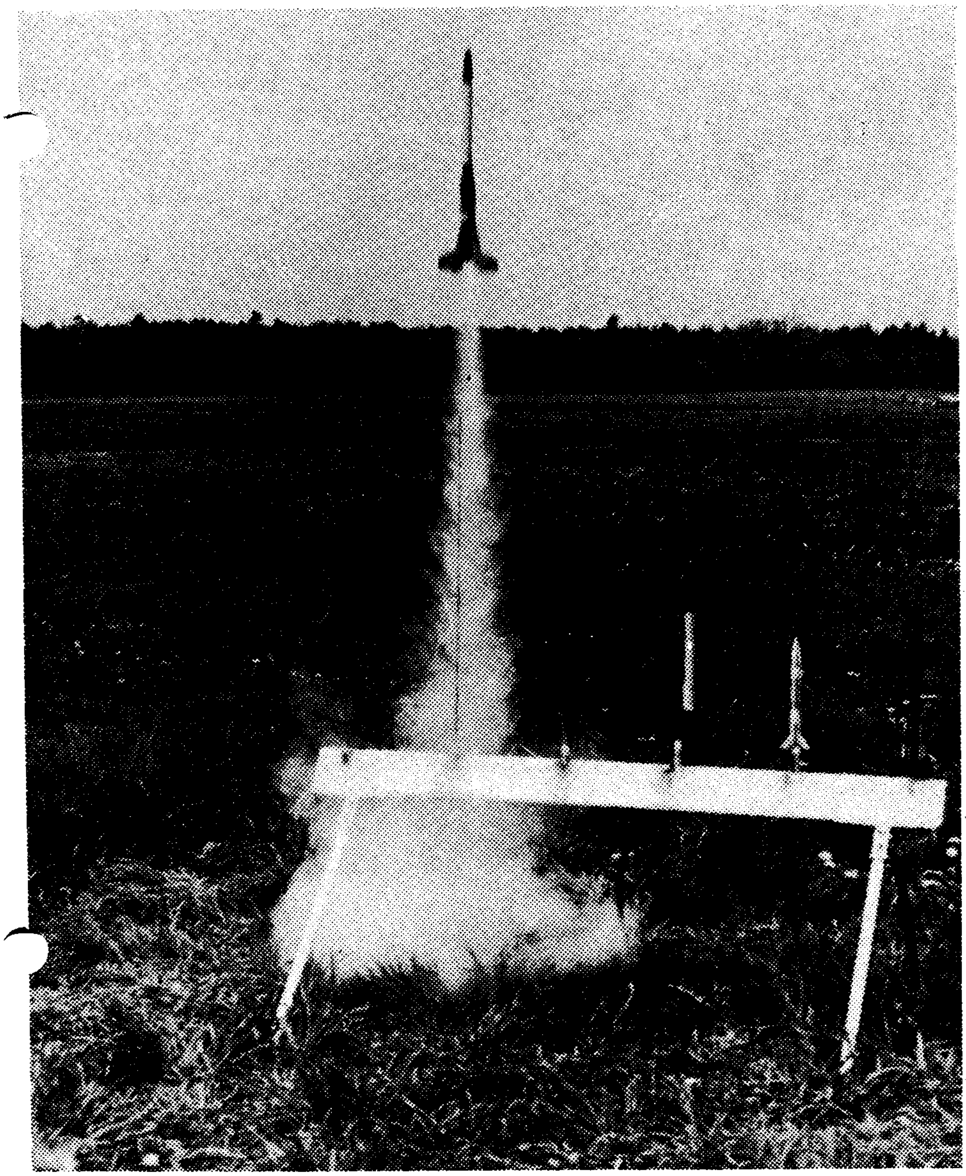


PHOTO GALLERY

Readers are invited to submit photographs of their model rockets for publication on this page. Our staff will select those photographs having superior quality and composition for inclusion in the **Model Rocketry** *Photo Gallery. Send your photos to:*

Photo Gallery
Model Rocketry
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Boston, Mass. 02123

Fundamentals of Dynamic Stability

Gordon K. Mandell

In the first two parts of this series we presented the results of an analytical investigation of the dynamic behavior of model rockets and computed the responses of models having various aerodynamic and inertial characteristics to a variety of disturbing influences. In doing this we necessarily assumed that the following body of information concerning the rocket in question, called the set of dynamic parameters, was known:

- C_1, the corrective moment coefficient
- C_2, the damping moment coefficient
- I_L, the longitudinal moment of inertia
- I_R, the radial moment of inertia
- ω_z, the roll rate

It had been our original intention to conclude the series with a single, third article in which analytical and experimental methods for determining these quantities would be presented and in which criteria governing the design of model rockets for favorable dynamic behavior would be set forth. So much new material on these subjects of application has been compiled in the last few months, however, that it has become necessary to further subdivide the presentation. Accordingly, the present article will be restricted to *analytical* techniques for computing the dynamic parameters. Future issues of Model Rocketry will contain a presentation of *experimental* methods for determining the dynamic parameters and the formulation of an overall philosophy of designing models for favorable dynamic characteristics.

PART III

COMPUTING THE DYNAMIC PARAMETERS

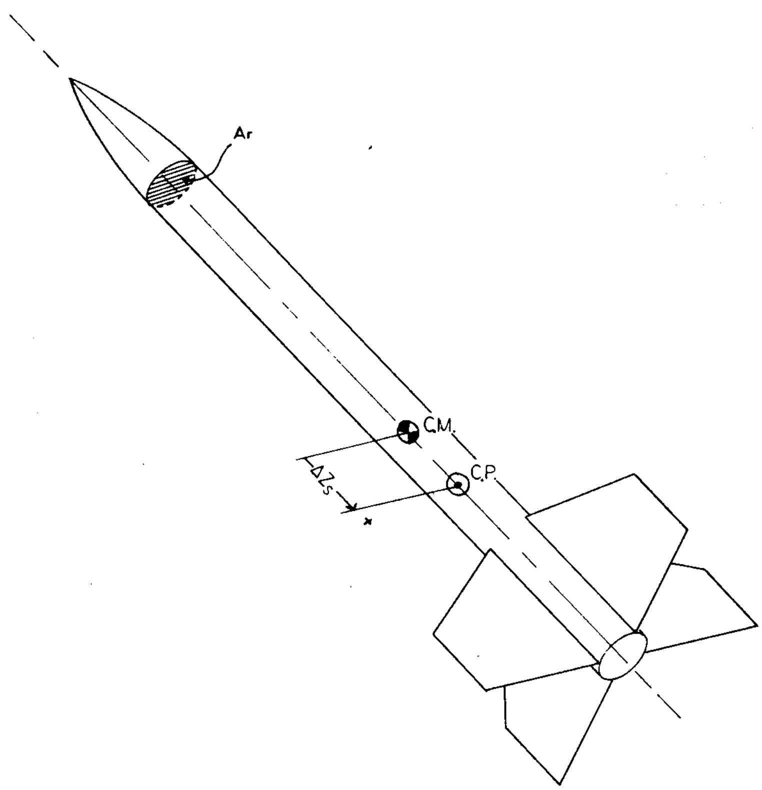


Figure 1. The definitions of static stability margin and reference area used in computing the corrective moment coefficient. Static stability margin is considered positive only if the CP lies behind the CG; otherwise it is negative.

In this section we present equations for computing the corrective moment coefficient, the damping moment coefficient, and the longitudinal and radial moments of inertia of a rocket. There also exist theoretical techniques for determining roll rate; however we shall treat this quantity as an "input" which may be set to zero or any other value at will by means of fin tabs, asymmetrical airfoiling, or canted fins.

In order to use the equations in a meaningful way and to obtain numerical results of use in application, it is necessary that the reader by familiar with the methods currently in use for determining the center of mass ("center of gravity"), center of pressure, and normal force coefficient" of a rocket, as well as the normal force coefficients and centers of pressure of its individual components. These topics are treated in detail in the following publications:

(1) **Calculating the Center of Pressure of a Model Rocket**, by James Barrowman; Centuri Engineering Company Technical Information Report TIR-33. Obtainable at a price of $1.00 fron Centuri Engineering Company, Box 1988, Phoenix, Arizona 85001.

(2) **Designing Stable Rockets**; Estes Industries Technical Report 651-TR-9. Available at a price of 25 cents fion Estes Industries, Inc., Box 227, Penrose, Colorado 81240.

Information on these subjects is also contained in the most recent edition of G. Harry Stine's **Handbook of Model Rocketry.** The best general reference on the hobby available, this book can be obtained for $4.95 paper-bound, or $6.95 clothbound, in many bookstores and hobby shops or by writing directly to W.B. Burger, Department R, Follett Publishing Company, 1010 West Washington Boulevard, Chicago, Illinois 60607. All of the above are excellently written and highly recommended.

The Corrective Moment Coefficient

On the assumption that the reader has read and understood the material in these references pertinent to our discussion, we proceed to state that the corrective moment coefficient of a rocket satisfying the conditions given in reference (1) is computable according to

(1) $C_l = \frac{1}{2}\rho V^2 A_r C_{n\alpha}(\Delta Z_s)$

where $C_{n\alpha}$ = normal force coefficient of complete rocket

ρ = density of the air

V = air speed of the rocket

ΔZ_s = static stability margin

The definitions of static stability margin and reference area are shown in Figure 1. Note that the static stability margin is *positive* if the center of pressure (CP) is *aft* of the center of mass (CM), negative if it is *forward* of the CM. Note also that the reference area is computed on the basis of the body radius at the base of the nose.

At sea level,

$\rho = 1.225 \times 10^{-3}$ grams/cubic centimeter

so that, in CGS (centimeter-gram-second) metric physical units,

(2) $C_l = (0.6125 \times 10^{-3} \times (\Delta Z_s) \times C_{n\alpha} V^2 A_r)$

dyne-centimeters

Equation (2) can be used to obtain the CGS numerical value of C_l if Z_s is given in centimeters, V in centimeters/second, and A_r in square centimeters.

The Damping Moment Coefficient

Although none of the recommended references contain any detailed consideration of the effects of damping, NASA engineer James S. Barrowman has performed a linearized analysis of pitch and yaw damping as a part of his Master's

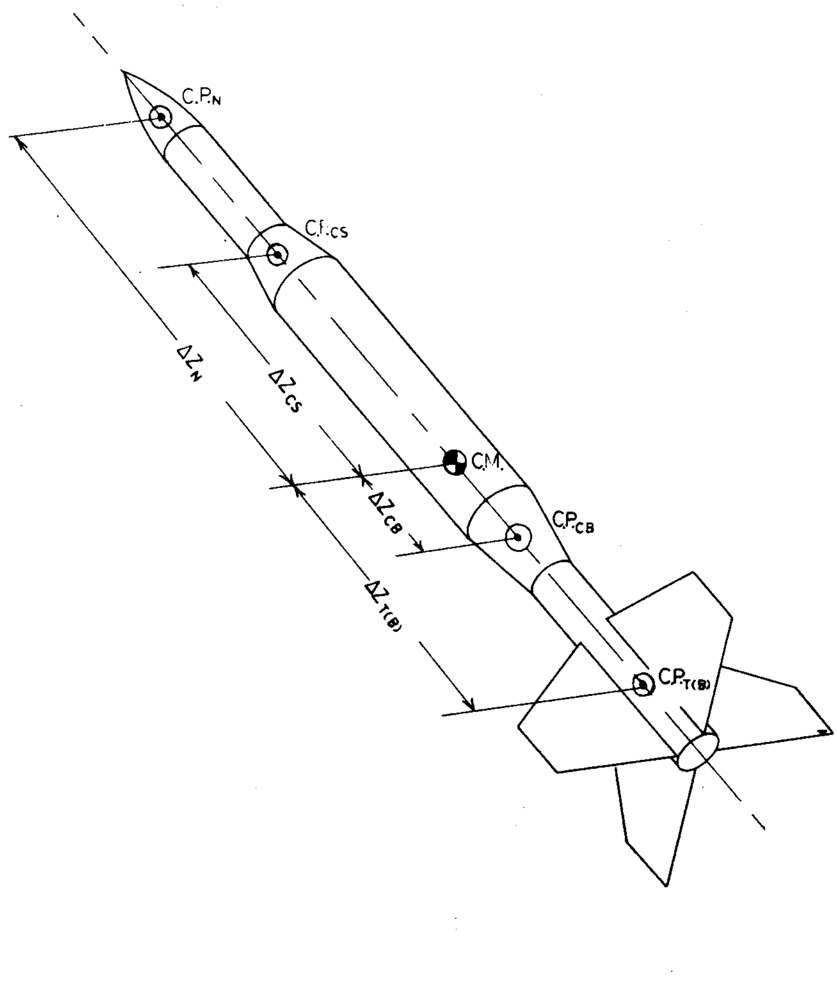


Figure 2. The definitions used in computing the aerodynamic contribution to the damping moment coefficient. The CM of the complete rocket and CP's of the individual components are shown. The signs of the distances involved are not needed, since the distances appear in squared form in the computation.

thesis[1]. It would appear that his treatment considers only the fins to be significantly contributory to damping behavior, as only their role is analyzed. Model rockets are more heavily damped than their professional counterparts, however, and it is probable that greater accuracy will be obtained if Jim Barrowman's analysis is formally extended to include all airframe components having a significant normal force coefficient. If this is done we obtain

(3) $$C_{2A} = \tfrac{1}{2}\rho V A_r((C_{n\alpha})_{T(B)} \times (\Delta Z_t)^2 + (C_{n\alpha})_n(\Delta Z_n)^2 + (C_{n\alpha})_{cs}(\Delta Z_{cs})^2 + (C_{n\alpha})_{cb}(\Delta Z_{cb})^2)$$

where C_{2A} = aerodynamic damping moment coefficient

$(C_{n\alpha})_{T(B)}$ = normal force coefficient of the tail fin assembly in the presence of the body

$(C_{n\alpha})_n$ = normal force coefficient of the nose

$(C_{n\alpha})_{cs}$ = normal force coefficient of conical shoulder

$(C_{n\alpha})_{cb}$ = normal force coefficient of conical boattail

ΔZ_t = distance from CM of rocket to CP of fin

ΔZ_n = distance from CM of rocket to CP of nose

ΔZ_{cs} = distance from CM of rocket to CP of shoulder

ΔZ_{cb} = distance from CM of rocket to CP of boattail

The definitions, as they apply to a rocket containing all these components, are illustrated in Figure 2. For rockets without shoulders or boattails the terms accounting for these components are deleted from the expression. If the equation is evaluated in CGS units the numerical result becomes

(4) $$C_{2A} = (0.6125\times10^{-3} \times V A_r \times ((C_{n\alpha})_{T(B)}(\Delta Z_t)^2 + (C_{n\alpha})_n(\Delta Z_n)^2 + (C_{n\alpha})_{cs}(\Delta Z_{cs})^2 + (C_{n\alpha})_{cb}(\Delta Z_{cb})^2))$$ dyne-cm-sec

While the rocket motor is firing there is an additional contribution to the damping moment coefficient due to the expulsion of mass from the rocket nozzle[2]. This additional damping moment coefficient, C_{2R}, is given by

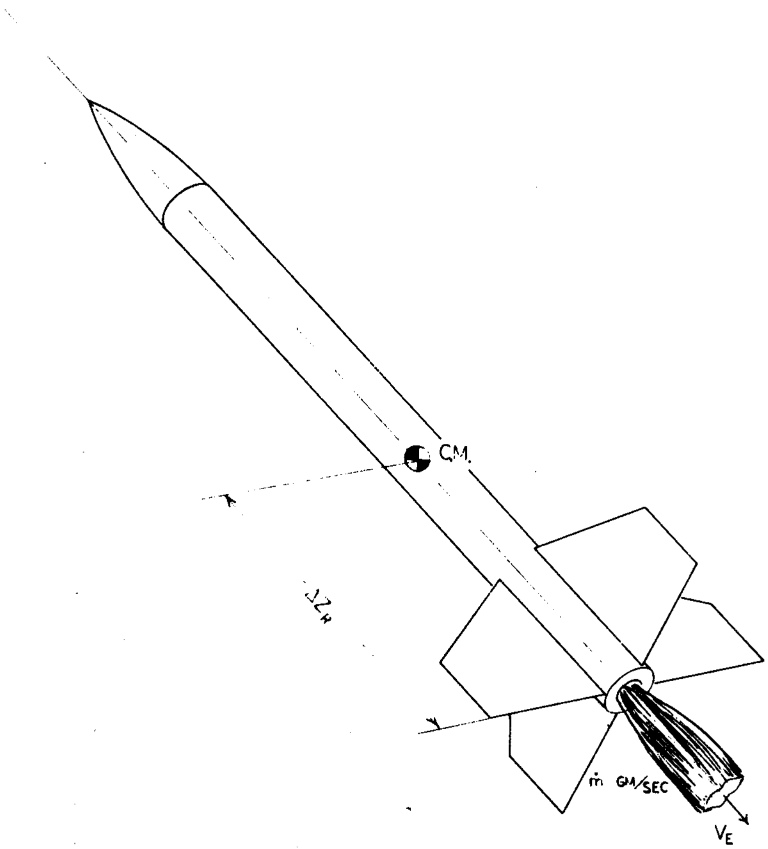


Figure 3. Jet damping terminology.

(5) $$C_{2R} = \dot{m}(\Delta Z_R)^2$$

where $\dot{m}$ = rate of mass expulsion from the rocket nozzle

Z_R = distance of nozzle exit from rocket CM

These quantities are illustrated in Figure 3. The rate of mass expulsion depends on the motor's thrust F and exhaust velocity V_e according to

$$\dot{m} = \frac{F}{V_e}$$

Since both these quantities generally vary with time during the burning of the motor, the determination of $\dot{m}$ with precision can be quite difficult. Fortunately, many model rocket motors have a thrust and exhaust velocity that are virtually constant over much of the burning time. A rough average of the mass expulsion rate may them be computed by dividing the mass of propellant, m_p, contained in the motor before firing, by the duration of burning, t_b:

$$\dot{m} = m_p/t_b$$

When this approximation is valid the damping due to the rocket motor is

(6) $$C_{2R} = \frac{m_p}{t_b}(\Delta Z_R)^2$$

If mass is expressed in grams, time in seconds, and distance in centimeters, C_{2R} will be obtained in dyne-cm-sec. The value of the damping moment coefficient is thus

(7a) $$C_2 = C_{2A} + C_{2R}$$

during the time that the rocket motor is operating and

(7b) $$C_2 = C_{2A}$$

[1] James S. Barrowman: **The Practical Calculation of the Aerodynamic Characteristics of Slender Finned Vehicles**, A Dissertation Submitted to the Faculty of the School of Engineering and Architecture of the Catholic University of America in Partial Fulfillment of the Requirements for the Degree of Master of Science in Aerospace Engineering. March, 1967; Washington, D.C.

[2] see Davis, Follin, and Blitzer: **The Exterior Ballistics of Rockets** for an explanation of this phenomenon, called "jet damping".

after burnout.

The Longitudinal Moment of Inertia

A model rocket consists largely of coaxial, circular cylindrical objects, of which some – such as the propellant grain, nose block, or the NAR competition payload – are solid and others – the body tube and motor casing, for example – are hollow. The nose cone may be any one of a number of radially-symmetrical geometrical solids: conical, ogival, ellipsoidal, or paraboloidat, to give some examples. There is less restriction on the geometry of fins, and in addition a model usually carries some small, dense, irregularly-shaped objects such as the bits of lead which are sometimes used as nose weights. The longitudinal moment of inertia of the complete rocket is computed by determining the contributions due to each of these components and adding all the contributions together.

The contribution of a solid, right, circular cylinder of uniform density to the longitudinal moment of inertia is given by

(8a) $$I_{LCS} = M_c\left((z_1^2 + z_0^2 + z_0 z_1)/3 + R^2/4\right)$$

where M_c = mass of cylinder
z_0 = position of rear of cylinder with respect to CM of complete rocket
z_1 = position of front of cylinder with respect to CM of complete rocket
R = radius of cylinder

The contribution due to a hollow cylindrical object is

(8b) $$I_{LCH} = M_c\left((z_1^2 + z_0^2 + z_0 z_1)/3 + (R_o^2 + R_i^2)/4\right)$$

where R_o = outer radius of cylinder
R_i = inner radius of cylinder

Figure 4 illustrates this notation. It is important to realize that values of z *forward* of the CM of the rocket are here considered *positive*, while those aft of the CM are negative.

There also exist precise expressions for the contributions of various nose cone shapes, and in principle the contribution of any object whatsoever, no matter what its shape or density properties, is exactly computable by the methods of integral calculus. In practice, however, the complixity of the algebraic solutions obtained is sufficiently great that the hobbyist would prefer to resort to an approximation if at all possible. There does, fortunately, exist an approximate technique for taking these components into account. By this precedure, called the "point-mass approximation", we consider all the object's mass to be concentrated at its own CM and compute its moment of inertia by multiplying its mass by the square of the distance from its own CM to the CM of the complite rocket as shown in Figure 5. The point-mass approximation always results in an underestimate of the contribution of the object being considered to the longitudinal moment of inertia, since it ignores the mass-distribution properties of the object. The true contribution is equal to the result obtained by the point-mass approximation, *plus* the moment of inertia of the object about an axis drawn through its own CM. It is this second component that we have neglected in order to achieve algebraic simplification. The point-mass approximation is most accurate when the object being considered is far from the CM of the complite rocket in comparison with its own dimensions; we thus speak of the method as computing the inertial contribution of a "remote object." Fortunately, nose cones, nose weights, and irregularly-shaped payloads usually obey the point-mass approximation rather well. The technique is not always as good when applied to fins; the modeler may wish to use the distance from the CM of the complete rocket to the trailing edge of the fin assembly in computing its contribution in order to increase the magnitude of the estimate. In assuming the point-mass approximation, we have for the nose moment of inertia

(9a) $$I_{LN} = M_n z_n^2$$

for the contribution of an irregularly-shaped payload or ballast,

(9b) $$I_{LW} = M_w z_w^2$$

and for the contribution of the tail fin assembly,

(9c) $$I_{LT} = M_t z_t^2$$

The modeler may extend the technique of approximating components by point masses or by cylinders expressing the

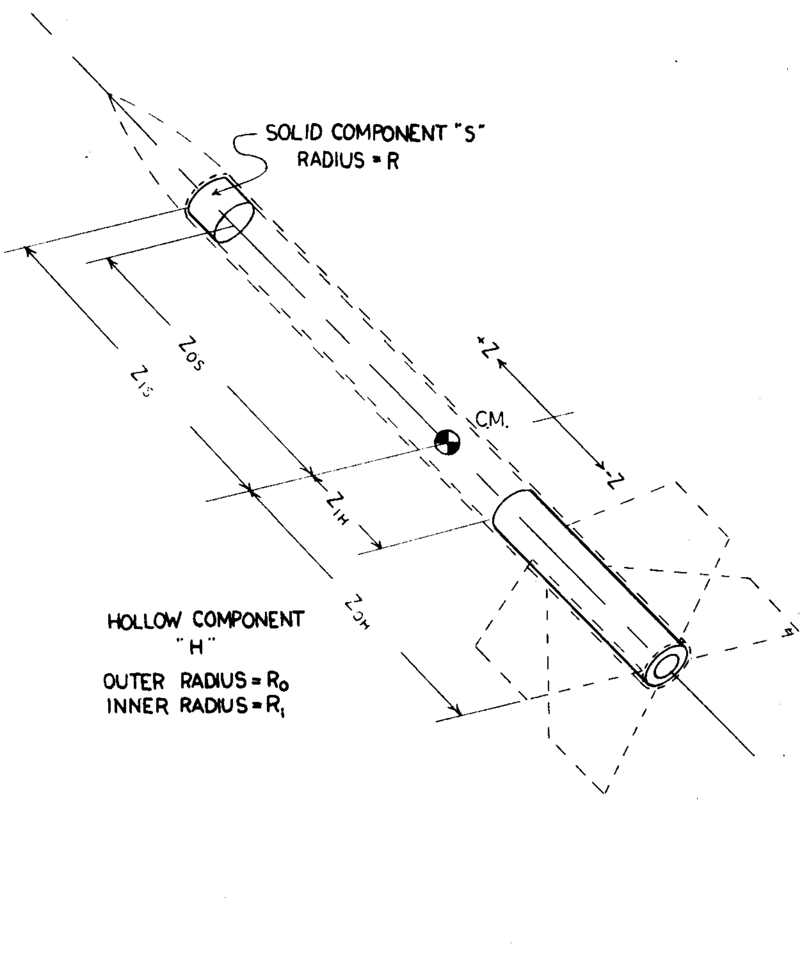


Figure 4. Notation used in computing the contributions of cylindrical components to the longitudinal moment of inertia.

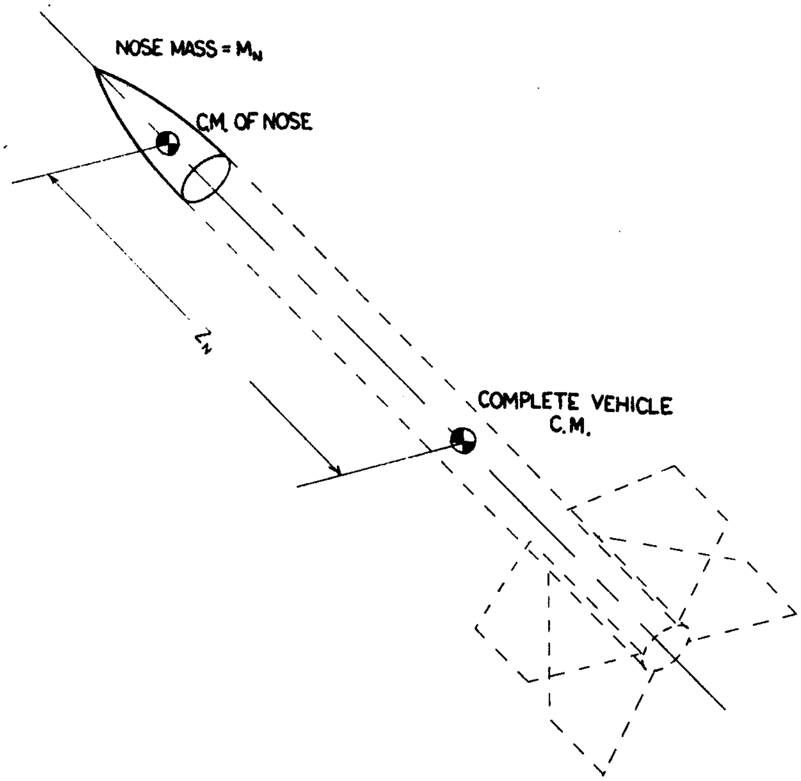


Figure 5. The point-mass approximation applied to a nosecone. The CM of the nosecone itself can easily be determined by balancing. The mass of the nosecone can be determined by weighing, and the contribution to I_L can then be computed directly.

average geometrical properties of such extended objects as adapters, shoulders and boattails until he has taken into account every component of consequence. The longitudinal moment of inertia of the complkte rocket may them be written in a mathematical shorthand called "summer notation" as follows:

(10) $$I_L = \sum I_{Li}$$

where the group of symbols means simply "the sum of the contributions of all the components."

The Radial Moment of Inertia

The radial moment of inertia is computed by an entirely analogous procedure. The contribution due to a solid cylindrical component is given by

(11a) $$I_{HCS} = M_c R^2/2$$

while that due to a hollow cylindrical component is

(11b) $$I_{HCH} = M_c(R_o^2 + R_i^2)/2$$

The algebraic formulae for most nose cone shapes are much more tractable in the case of the radial moment of inertia than in the case of the longitudinal moment of inertia. A few of the more elementary ones are those for a solid cone,

(12) $$I_{HNC} = 0.3 M_{nc} R^2$$

where M_{nc} = mass of cone
R = radius at base

and for a hemispherical solid,

(13) $$I_{HHS} = 0.2 M_{hs} R^2$$

where M_{hs} = mass of hemisphere
R = radius at base

Fins, unfortunately, are hard to treat analytically in any great generality due to the great variety of planform shapes possible. They cannot be ignored in computing the radial moment of inertia, though it is true that their mass is often small, because it is also true that they extend farther from the body centerline than any other component of the model. Nor can the point-mass approximation be made, as the spanwise extent of a fin is of comparable magnitude to the radius of the body tube. If we idealize the fin planform to a right trapezoid, however, we can obtain a good approximation to the radial moment of inertia due to a thin, flat fin of uniform density in the form

(14a) $$I_{RF} = ((R_t^3 - R_r^3)a/3 - (a-b) \times (R_t^4 - R_r^4)/(4R_t))M_f/A$$

where M_f = mass of fin
A = lateral area of one side of fin
R_t = radius of fin root from centerline of rocket
a = root chord of fin
b = tip chord of fin

It follows that the contribution of a tail assembly containing N identical fins is

(14b) $$I_{RT} = N((R_t^3 - R_r^3)a/3 - (a-b) \times (R_t^4 - R_r^4)/(4R_t))M_f/A$$

The notation associated with computing the radial moment of inertia contributions is illustrated in Figure 6.

Equations (11) through (14) supply the modeler with sufficient information to obtain reasonably good approximations to the inertial contributions of the majority of component shapes he will encounter in most model rockets. The sum of these contributions then gives the radial moment of inertia of the complete model:

(15) $$I_R = \sum I_{Ri}$$

The CGS units of all moments of inertia, both longitudinal and radial, are gram-c m^2. CGS numerical calculations should thus be done with all linear dimensions expressed in centimeters and all masses expressed in grams.

Concluding Remarks

Analytical methods are powerful and elegant tools that permit the designer to obtain a wealth of information concerning the properties of his model before he has even begun construction. Engineering results of analytical computation. The subject of experimental methods for determining the dynamic parameters will be discussed in Part IV.

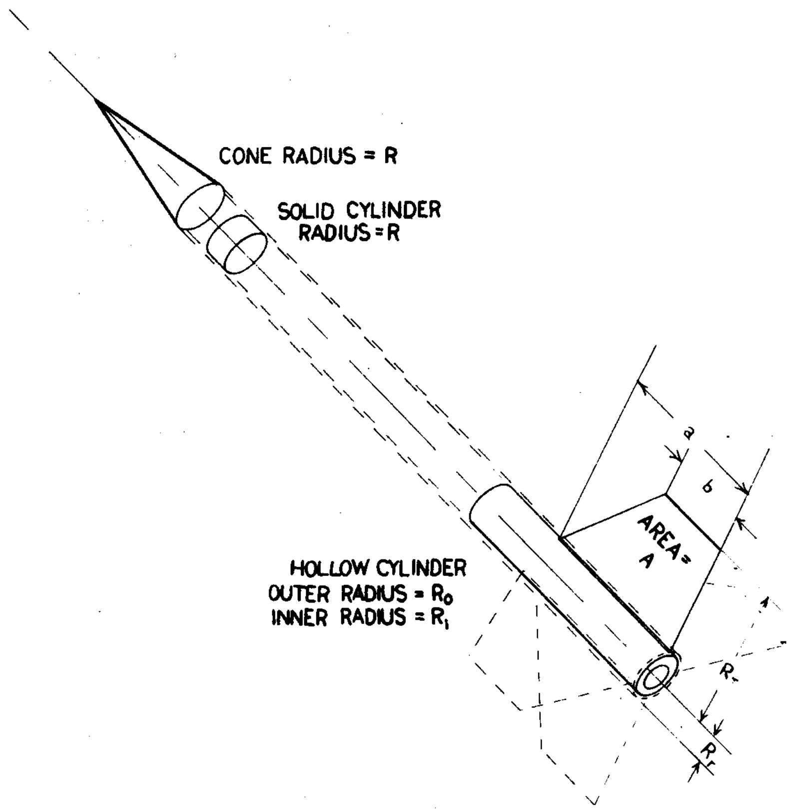


Figure 6. Notation used in computing the contributions of various components to the radial moment of inertia.

analysis, however, is always based on approximations to the phenomena under consideration, for there inevitably exist factors for which it is either impossible or impractical to account precisely. The value of an approximation is based on the fact that the errors it introduces under normal circumstances are small, while the analytical simplification it permits is considerable. Even the most valuable approximations, however, are likely at one time or another to encounter conditions under which they become inadequate.

Consider, for instance, equation (3) for the aerodynamic damping moment coefficient and notice its linear dependence on velocity. Equation (1) for the corrective moment coefficient, however, indicates that the corrective moment exhibits quadratic velocity dependence. It will be recalled that in Part I we defined the damping ratio ζ of a rocket as

$$\zeta = C_2/(2\sqrt{C_1 I_L})$$

so that it would seem, based on equations (1) and (3), that the damping ratio is independent of velocity – a highly desirable property from the standpoint of design. Unfortunately, it is observed that model rockets are more heavily damped at very low airspeeds than at the higher velocities which characterize the greater part of the flight. The analytical technique, although accurate over almost the entire trajectory, fails to detect a condition that could be catastrophic: the so-called "overdamped launch," in which the model leaves the launcher at too low a velocity for safe, predictable flight. As it turns out, the difficulty is that one of the approximations on which equation (3) is based is invalid at very low airspeeds, necessitating our falling back on observation and experiment to determine the value of C_{2A}.

The limitations of analysis, of which the above is but one example, make it essential that we have recourse to empirical measurement to supplement and check the

NEW PRODUCT NEWS

A new company will soon offer model rocket supplies including a line of seven prefabricated rocket kits. These birds, to be offered by the Bo-Mar Development Corporation, will come complete with preshaped hardwood nosecones. The easy-to-construct, single- staged models offer sturdy structure and unusually favorable inertial characteristics, painstakingly-edited instruction sheets, and moderate pricing.

Estes Industries has introduced two new rocket kits this month. The Astron Avenger, a two-staged rocket, is designed to take advantage of the thrust of the Estes class C engines. The 32- inch ship, weighing 2.7 ounces, can be flown with or without a payload. The Astron Avenger sells for $2.75.

Also new from Estes is the Astron Scrambler, a clustered model with three-engine power. It is designed with an extra- large payload section, 1.796 inches in diameter, which can hold an egg or other large payload. This 2.8-ounce rocket comes complete with two chutes for gentle recovery. The price is $3.00.

SEMROC has introduced a seven-engine cluster model called the Hydra VII. This rocket, weighing 1.1 newtons, should reach spectacular altitudes when powered by a cluster of seven C's. The Hydra VII is available for $4.98 including all components and instructions (engines must be purchased separately!).

The Aphelion, also new from SEMROC, is a beginner's model which weighs 0.25 newtons. This 38.5-centimeter rocket, having a fin span of 12.5 centimeters, is priced at $1.98.

SEMROC's two-staged offering is called the Sigma II. Featuring parachute recovery of the upper stage, this bird comes with components, instructions, one NAR type A5-5 and one B4-0 rocket engine, for the upper and lower stages respectively. The completed kit has a length of 45 centimeters and a diameter of 1.9 centimeters. Weighing in at 0.17 newtons ready to launch, the kit is offered for $1.98.

Club Notes

The Beardstown Rocket Research Association Hotline reports that the club has just purchased an army surplus trailer. The trailer will be used by the group as mobile unit. Money for the purchase was raised by selling candy.

The Steel City Section of the NAR has aanounced that the Fourth Annual Pittsburg Spring Convention of model rocketeers will be held on March 28, 29, 30. Further details are available from Alan Stolzenberg, Chairman, 5002 Sommerville St., Pittsburg, Pa., 15201.

Send your club newsletters, contest announcements and results, and other news items for this column to:
Club News Editor
Model Rocketry Magazine
P.O. Box 214
Boston, Mass., 02123

(Aerial Photography, cont.)

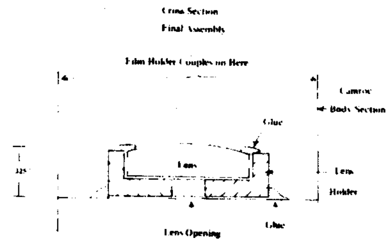
through which light will be passing. The positioning of the lens is critical, and the thickness of a coat of glue under the lens would throw the image on the film out of focus.

When the glue has set, carefully place the lens - lens holder combination over the center of the lens opening inside the body section of the Camroc, and then apply a coat of glue around the edge of the lens holder - body section joint.

The rest of the Camroc may be assembled in the usual manner when the glue has dried. The focus of the lens may be checked with the Estes frosted acetate disk. Viewing the image on the disk with a ten power magnifying glass will give a more exact indication of the focus of the image. An enlargement of a photograph taken with the lens will provide an even more critical test.

If a mistake was made, the white glue can be dissolved away in warm water.

The increased light transmission, and increased clarity which this achromatic, coated, compound lens offers will create exciting aerial photographs.



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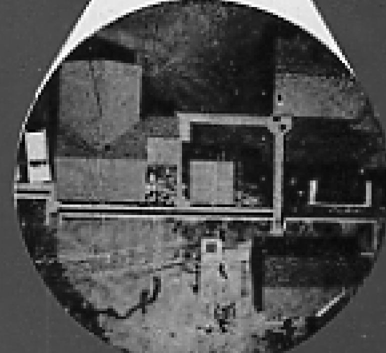

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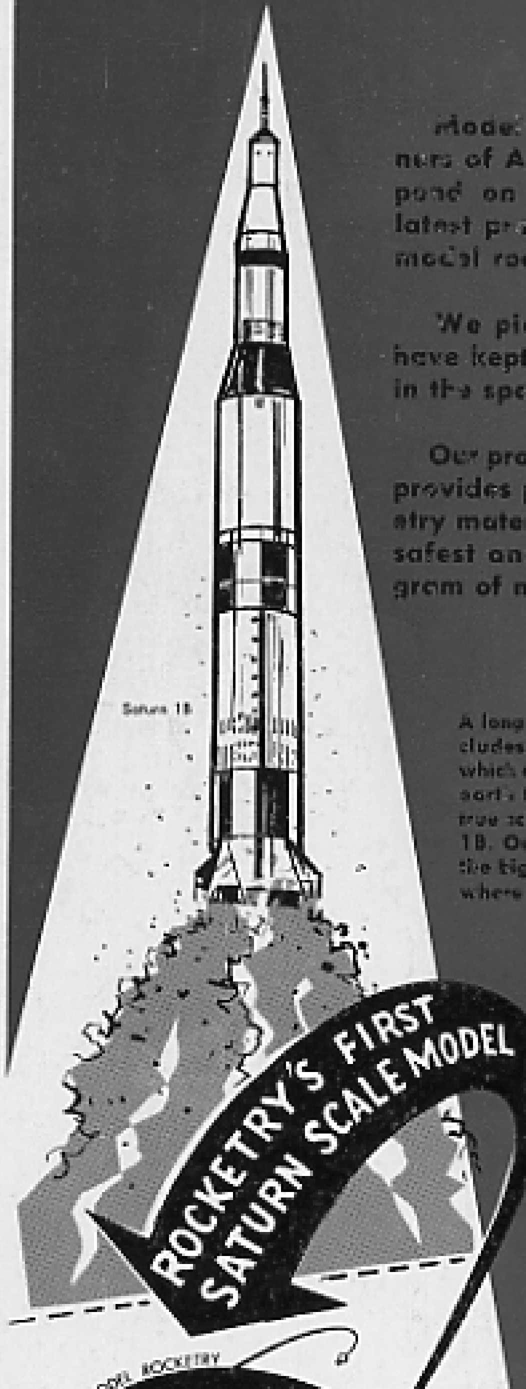

A long list of model rocketry "firsts" includes the CAMROC aerial camera, which automatically takes a photo of the earth from its peak of flight, and the true scale model of the Uprated Saturn 1B. Our selection of rocket kits offers the biggest choice of scale models anywhere and over 35 exciting kits in all.

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