THE ART OF SCALE MODEL ROCKETRY

Peter Alway

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Left: Fred Williams displays his Japanese Mu-3S-II model, featuring wooden interstage struts and rolled paper cones. (Mark O'Brien photo)
Right: Al de la Iglesia and Evan Nau load their tiny Terrier model into a launch tower. (Fred Williams photo)
Opposite page: Scenes from Ukrainian scale competition. Left photo: Alexander Ageev (at right) prepares his M-100B for flight. Right photo: Sergei Baibikov (at left) prepares his Ariane. (Yuri Hapon photos)

Contents

NAR Model Rocket Safety Code

1: Materials
My model rocket will be made of lightweight materials such as paper, wood, rubber, and plastic suitable for the power used and the performance of my model rocket. I will not use any metal for the nose cone, body, or fins of a model rocket.

2: Engines
I will use only commercially-made NAR certified model rocket engines in the manner recommended by the manufacturer. I will not alter the model rocket engine, its parts or its ingredients in any way.

3: Recovery
I will always use a recovery system in my rocket that will return it safely to the ground so it may be flown again. I will use only flame-resistant recovery wadding if required.

4: Weight Limits
My model rocket will weigh no more than 1500 grams (53 oz) at liftoff, and its rocket engines will produce no more than 320 Newton-seconds (4.45 Newtons equal 1.0 pound) of total impulse. My model rocket will weigh no more than the manufacturer's recommended maximum lift-off weight for the engines used, or I will use engines recommended by the manufacturer for my model rocket.

5: Stability
I will check the stability of my model rocket before its first flight, except when launching a model rocket of already proven stability.

6: Payloads
Except for insects, my model rocket will never carry live animals or a payload that is intended to be flammable, explosive, or harmful.

7: Launch Site
I will launch my model rockets outdoors in a cleared area, free of tall trees, power lines, buildings, and dry brush and grass. My launch site will be at least as large as that recommended in the following table.

Launch Site Dimensions

Installed Total Impulse (Newton-seconds)	Equivalent Engine Type	Minimum Site Dimension (feet)	(meters)
0-1.25	1/4A & 1/2 A	50	15
1.26-2.50	A	100	30
2.51-5.00	B	200	30
5.01-10.00	C	400	120
10.01-20.00	D	500	150
20.01-40.00	E	1000	300
40.01-80.00	F	1000	300
80.01-160.00	G	1000	300
160.01-320.00	2 G's	1500	450

8: Launcher
I will launch my model rocket from a stable launching device that provides rigid guidance until the model rocket has reached a speed adequate to ensure a safe flight path. To prevent accidental eye injury, I will always place the launcher so that the end of the rod is above eye level or I will cap the end of the launch rod when approaching it. I will cap or disassemble my launch rod when not in use and I will never store it in an upright position. My launcher will have a jet deflector device to prevent the engine exhaust from hitting the ground directly. I will always clear the area around my launch device of brown grass, dry weeds, and other easy-to-burn materials.

9: Ignition System
The system I use to launch my model rocket will be remotely controlled and electrically operated. It will contain a launching switch that will return to "off" when released. The system will include a removable safety interlock in series with the launch switch. All persons will remain at least 15 feet (5 meters) from the model rocket when I am igniting model rocket engines totalling 30 Newton-seconds of total impulse or less and at least 30 feet (9 meters) from the model rocket when I am igniting model rocket engines totalling more than 30 Newton-seconds of total impulse. I will use only electrical igniters recommended by the engine manufacturer that will ignite the model rocket engine(s) within one second of the actuation of the launching switch.

10: Launch Safety
I will ensure that people in the launch area are aware of the pending model rocket launch and can see the model rocket's liftoff before I begin my audible five-second countdown. I will not launch a model rocket using it as a weapon. If my model rocket suffers a misfire, I will not allow anyone to approach it or the launcher until I have made certain that the safety interlock has been disconnected from the ignition system. I will wait one minute after a misfire before allowing anyone to approach the launcher.

11: Flying Conditions
I will launch my model rocket only when the wind is less than 20 miles (30 kilometers) an hour. I will not launch my model rocket so it flies into clouds, near aircraft in flight, or in a manner that is hazardous to people or property.

12: Pre-Launch Test
When conducting research activities with unproven model rocket designs or methods, I will, when possible, determine the reliability of my model rocket by pre-launch tests. I will conduct the launching of an unproven design in complete isolation from persons not participating in the actual launching.

13: Launch Angle
My launch device will be pointed within 30 degrees of vertical. I will never use model rocket engines to propel any device horizontally.

14: Recovery Hazards
If a model rocket becomes entangled in a power line or other dangerous place, I will not attempt to retrieve it.

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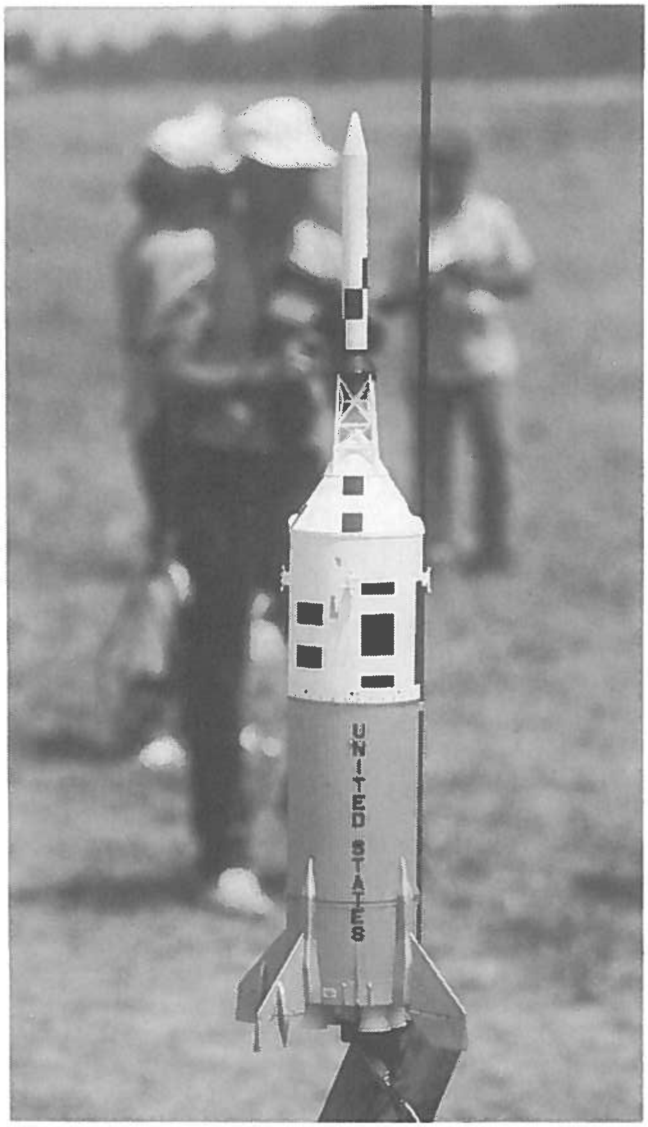


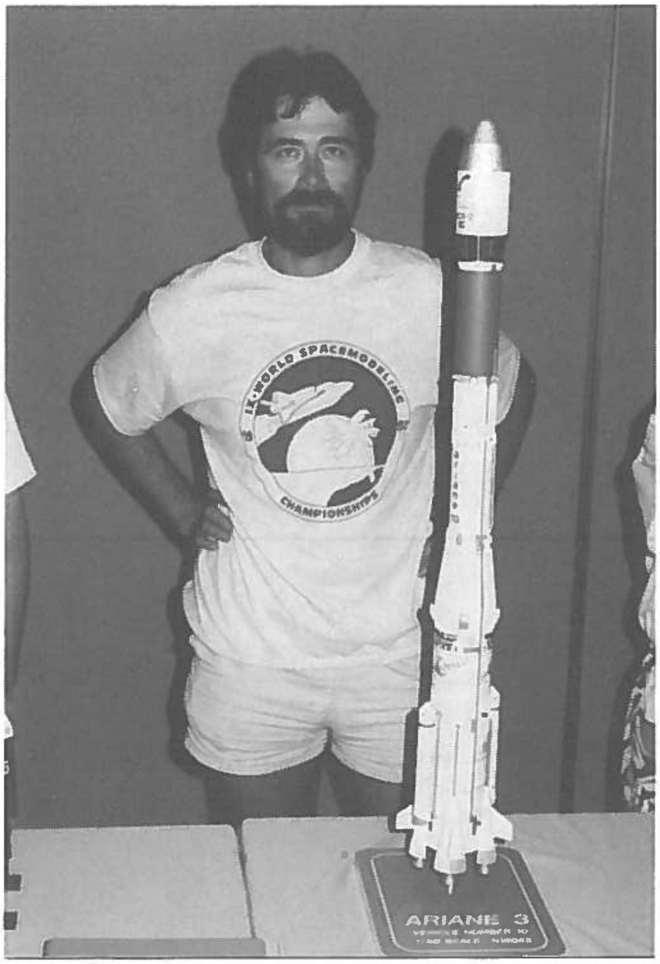
George Gassaway's highly detailed Little Joe II. (Robert Alway photo)

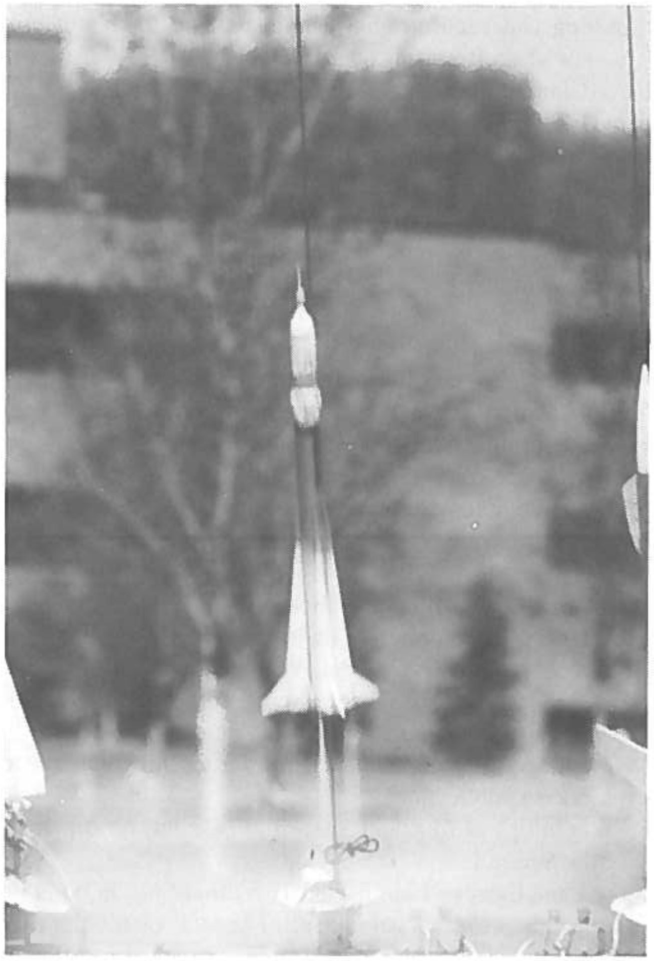
Introduction

Traditionally, scale modeling has been regarded as an elite, or even elitist, category of model rocketry. This is nonsense. While the best scale modelers may take years to build incredibly fine creations, there is no reason why you or I can't join the fun with our own unique, if less perfect, replicas of our favorite research rockets, missiles, and space boosters. This book will help you build your first scale model rockets, and will start you on your way toward building fine models you will display and fly with pride.

The Art of Scale Model Rocketry, the present volume, presents scale plans (instructions, diagrams and patterns for making a specific scale model), modeling tips, and information on locating scale data (drawings and photos of real rockets). I have added a small sampling of scale data to document models made from the plans. For more scale data, consult *Rockets of the World: A Modeler's Guide*, the companion to this volume.

If you design and build a scale model rocket that you would not have attempted otherwise, these books will have served their purpose. You might even use these books to build a model of a rocket that has never been modeled outside the manufacturer's wind tunnel shop. Go Forth and Build!





Left: Scale model rocketry as art. Bob Biedron stands with his precision scale Ariane III (above). Earning first place in scale at the 1992 World Spacemodeling Championships, this model is currently the world's most finely crafted model rocket. It features hand-wound fiberglass tubes, cast corrugations, individually installed bolts, and subtle weld joints made from plastic rod heated and stretched into fine filaments. Construction took two years. (photo courtesy Bob Biedron)
Right: Scale model rocketry as play. Fred Williams turned a pair of simple Estes Starbird kits and their packaging material into this fun scale Soyuz overnight at a model rocket convention. Clever use of paper and cardboard is central to scale model rocketry. (Jeff Wagner photo)

What is Model Rocketry?

With model rocket supplies available in hobby and toy shops all over the country, most people know at least part of the answer to this question. But there may be more to model rocketry than you think. Model rockets can use high technology of space exploration such as composite materials, digital data acquisition, radio telemetry, and computer simulation. Model rockets can introduce youth to trigonometry, physics, circuitry, and photography. Scale model rocketry can involve obscure historical research and precise craftsmanship. And most importantly, a model rocket launch is a great way for would-be spacefarers of all ages to get outside and enjoy a fine sunny day.

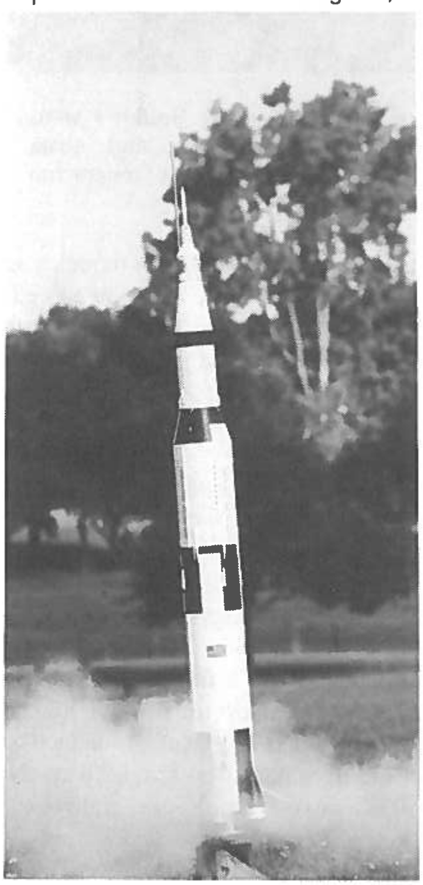
The heart of the hobby is the model rocket engine. These small brown or black cylinders provide all the thrust a rocket needs to reach an altitude of hundreds or even thousands of feet. Once at altitude, they even provide an ejection charge—a small kick of hot gas to deploy a recovery system. After the flight, only the spent engine is discarded, leaving the rocket ready for another flight. It was the invention of the model rocket engine in the late 1950's that freed the rocketeer from the dangerous task of mixing and packing chemical propellants, making model rocketry a safe, legal hobby.

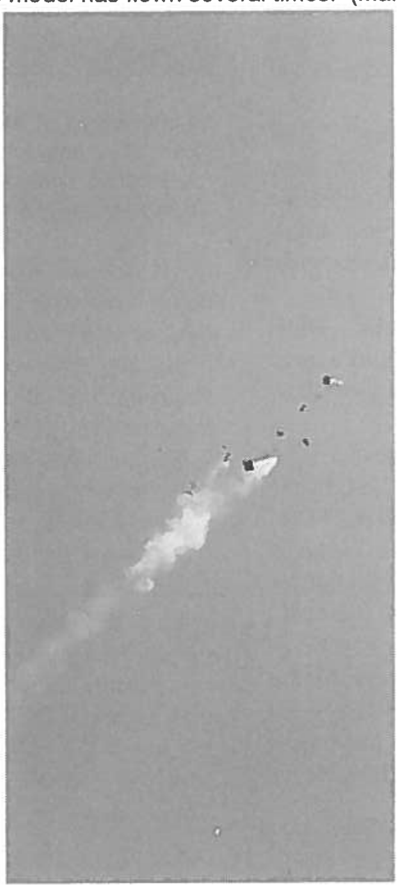
Safety is an important part of the hobby, and the NAR safety code, included with most model rocket products, must be followed by all who engage in the hobby. A model must be lightweight and made of wood, plastic, and paper. Launches must be conducted according to specific rules, including electrical ignition from a safe distance, a vertical trajectory, and a functioning recovery system. The safety code has worked well for over 30 years.

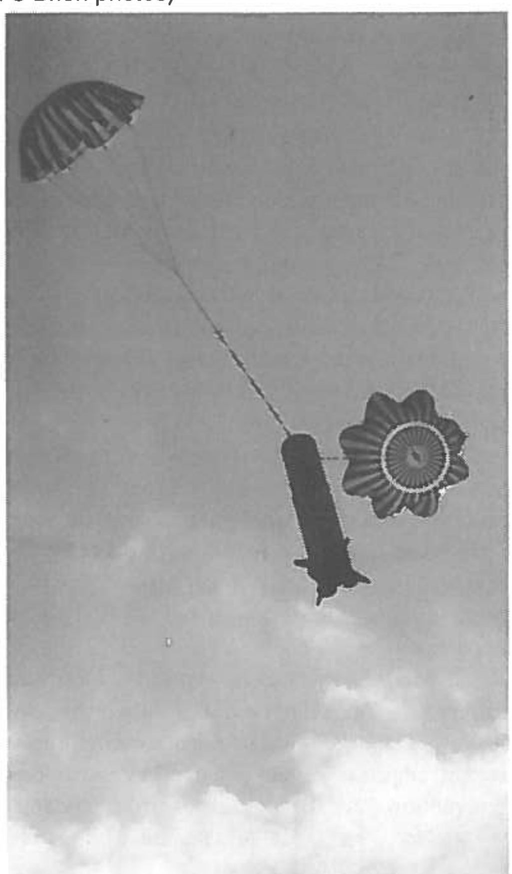
In recent years a new hobby, high power rocketry, has grown from model rocketry. High power rocketeers fly models weighing several pounds with H, I, J and even more powerful motors (as high power flyers call their engines). High power rocketry has its own safety standards. Special certification is required for this hobby.

If you are a beginner in the hobby, I highly recommend G. Harry Stine's *Handbook of Model Rocketry* to get you started on the right track. It is available by mail order from the National Association of Rocketry Technical Services (NARTS) and from Quest Aerospace Education. *Basics of Model Rocketry* by Doug Pratt is another good introduction. It is inexpensive and available at many hobby shops. Estes Industries' *Model Rocket Technical Manual*, included in their 1994 catalog, is another valuable reference for basic construction methods. The catalog is free, so pick one up at your hobby shop or write Estes.

Flight phases of a model rocket are displayed by this model of the Saturn V Moon rocket: Liftoff, Coast (not pictured), Ejection, and Recovery (the top portion of this model was recovered on a separate parachute). Thanks to replaceable pre-manufactured rocket engines, this model has flown several times. (Mark O'Brien photos)







The Art of Scale

Most hobbies represented in hobby shops revolve around scale modeling. But in model rocketry, scale kits are rare. Major manufacturers will tell you that the young first-time modelers who buy most model rocket kits don't know or care about space history. Certainly the difficulty of making stable models of the most famous manned rockets discourages manufacturers as well. Many modelers are reluctant to fly finely crafted models when a rocket stands about a 10% chance of being lost or badly damaged on each flight. But those of us who came to model rocketry by way of a fascination with the exploration of space find scale modeling irresistible. Fortunately, standardized interchangeable parts make scratchbuilding easy. Most kits are just collections of standard parts and make fine starting points for scratchbuilt models. Kitbashing—building your own design from kit parts—is one of the best (and cheapest) ways to build scale models.

Every hobby has its own set of standards for accuracy and detail. Those who fly scale model aircraft forgive protruding cylinders on their gas motors, but cringe at a bad profile. Model railroaders dismiss non-scale locomotives as toys, but spend years building rail systems with fictitious names whose cross-country routes scale up to only a few hundred yards. Plastic modelers build microscopic details into their aircraft, and make heroic efforts to match colors exactly, but don't even measure the wing span of a kit. Model rocketry has its own standards, driven by the contest rules found in the NAR *Model Rocket Sporting Code*, known to most modelers as the "Pink Book." Even if you never enter a contest, the Pink Book's judging criteria can guide your model making.

A good scale model is well proportioned. Most rockets are built from easily defined cylinders, cones, and flat fins. With some careful measurements, you can build a precisely proportioned scale model without too much difficulty. The overall shape is about all you can see when your model is in flight. Get it right.

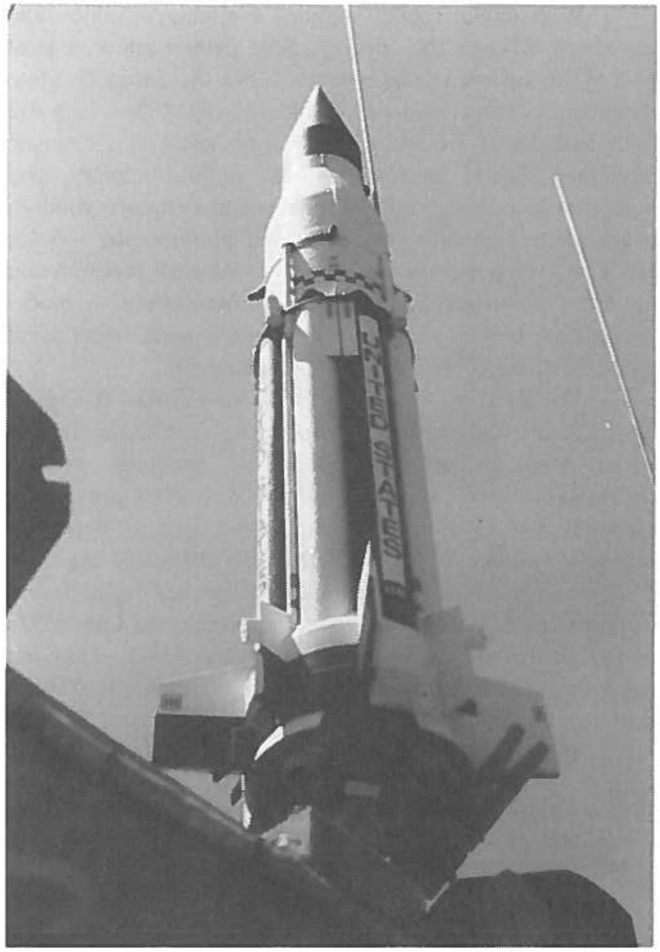
A good scale model displays nifty details. Most flying models don't carry detail down to the level of a good plastic kit, however. Only the finest model rockets show weld lines or rivet details.

Accurate paint schemes and markings are the final touch on your scale model. Clean, well-placed edges are more important than matching exact shades of colors.

The quality of finish is particularly critical in model rocketry because of the materials used. The spiral joints of body tubes and the grain of balsa wood can spoil a model's appearance.

Model rocketeers must sometimes compromise accuracy to make a model flightworthy. Modelers often leave off scale engine nozzles to accommodate live model rocket engines. Clear plastic fins, considered invisible by convention, stabilize models of finless rockets.

Not every scale model must be a precision work of art. If you take weeks to build a precision scale model, you may be reluctant to fly it more than once. But you can put together a "fun scale" model in a weekend. You don't have to put any more effort into a fun scale model than you would put into an Estes Alpha or Quest Astra. It's just a model shaped like and painted like a real rocket. I enjoy flying fun scale models over and over.



Dimensions of the author's 1/69 scale Saturn I were carefully measured during construction and scale competition judging. NAR scale models represent the hobbyist's best efforts. (Daniel Alway photo)

If a fun scale model turns out well you may even wish to enter it in a contest. If a fun scale model isn't so hot, you can just fly it for the thrill of flying a miniature of a favorite rocket. After building fun scale models, you may find a subject that really strikes your fancy. You may wish to try a "really good" model next.

While there is no reason why a finely crafted scale model must be flown in an NAR contest (or flown at all, for that matter), a scale competition is an excellent chance to show off a model, and the documentation standards of the Pink Book will give you incentive to build an accurate one.

The NAR sanctions three measured *Scale* events:

The launch complex accompanying Norbert Vance's 1/100 scale Saturn IB (left) qualifies it for NAR Super Scale. (Mark O'Brien photo)

Scale, *Scale Altitude*, and *Super Scale*. In each event, your model is measured, examined closely, and judged for accuracy and craftsmanship. The objective of *Scale Altitude* is to build as good a scale model as possible, and send it to the highest possible altitude. A *Super Scale* entry includes a scale launcher to accompany the rocket.

The most popular NAR scale competition is *Sport Scale*. A *Sport Scale* model is not measured, and details are examined only from a distance. This event has virtually replaced the measured *Scale* event in NAR competition, as most modelers prefer its relaxed rules regarding documentation. Two variations of *Sport Scale* are *Giant Scale* for large models and *Peanut Scale* for tiny models.

Some people consider NAR *Scale* to be just for the very best models (modestly meaning better than anything they've built) and *Sport Scale* to be for models of lesser quality. In fact, you can fly your precision scale model or fun scale model in either contest event. The only extra requirements for scale are documentation (covered in the "Flying Scale" section of this book). Of course, a better-proportioned, detailed, and well-finished model will do better in either event.

Manufacturers use the term "semi-scale" to refer to kits whose scale characteristics aren't up to the best the company has to offer. Sometimes this means an excellent kit's limitations are recognized by the manufacturer. But beware—some of these kits may be poor representations of the prototype. Typically, semi-scale kits have slightly enlarged tail fins or reduced forward fins, or some other compromises to improve flight performance or simplify construction.

The term "scale-like" is occasionally applied to pseudo-scale kits which, in the minds of their creators, resemble real rockets (as one modeler put it, "this is what a real rocket would look like if it looked like this"). On occasion, the resemblance to a genuine prototype is so strong that the model can be converted into a scale model. Modelers love to create their own pseudo-scale models, incorporating features of their favorite real rockets.

Plastic Model Conversion is an NAR contest event for plastic model kits adapted for rocket flight. While space subjects are not especially popular among plastic modelers, occasionally a rocket model from the 1950's or 1960's is re-issued. Often these models can be converted to fly with a little ingenuity. Science fiction designs and even jet aircraft are popular plastic conversion subjects as well.

Beware of any advice on selecting a good prototype to model. I hope you try something unique, but the most important thing is to choose a subject you find so attractive that you can't bear to give up halfway through. If your choice is a bit beyond your abilities, you have a great chance to learn. If your choice is clearly way beyond your abilities, try a simplified (or even pseudo-scale) version first. At the very worst, you will have a flying model that incorporates some of the features you liked in the prototype. If a model is well within your abilities, you can try detailing it so much that it is a challenge.

Once your first model is finished, you will see things you wish you had done differently. If I like a given prototype, and I still like it after building a fun scale model, I build more, learning from experience and often picking up new scale data along the way. Some serious modelers advocate building pairs of scale models simultaneously, but I doubt the value of this approach. I'd rather build in sequence, each model being a different scale or different round (individual vehicle). Building identical models in pairs saves a little work, but the only work it eliminates is the fun, creative stuff, like picking subjects, figuring out optimum scales, and scheming up construction techniques. You still have to do the full amount of tedious sanding and sealing. And when you are done building a pair, you will have *two* models you wish you had done differently. Of course, if you experiment with casting or vacuforming, or other batch-production techniques, it is wise to produce extra parts for future models.

The most common problems that I have noticed at *Scale* and *Sport Scale* competitions have been a limited range of subjects and poor finishing. *Rockets of the World*, the companion to this volume, addresses the first problem. In this book, I offer a few techniques that should help with the second. You may find better methods through experimentation or contact with other modelers.

A D-Region Tomahawk model built by Andrew Tomasch flies.

Designing a Scale Model

The joy of scale modeling lies in creating a unique model of an impressive (or obscure) prototype. The plans in this book demonstrate techniques and can help you get started, but nothing beats the pleasure of showing your fellow fliers a new scale model of your own design. The recognition of a known prototype and the excitement of flying a novel model design are two of the greatest pleasures in model rocketry.

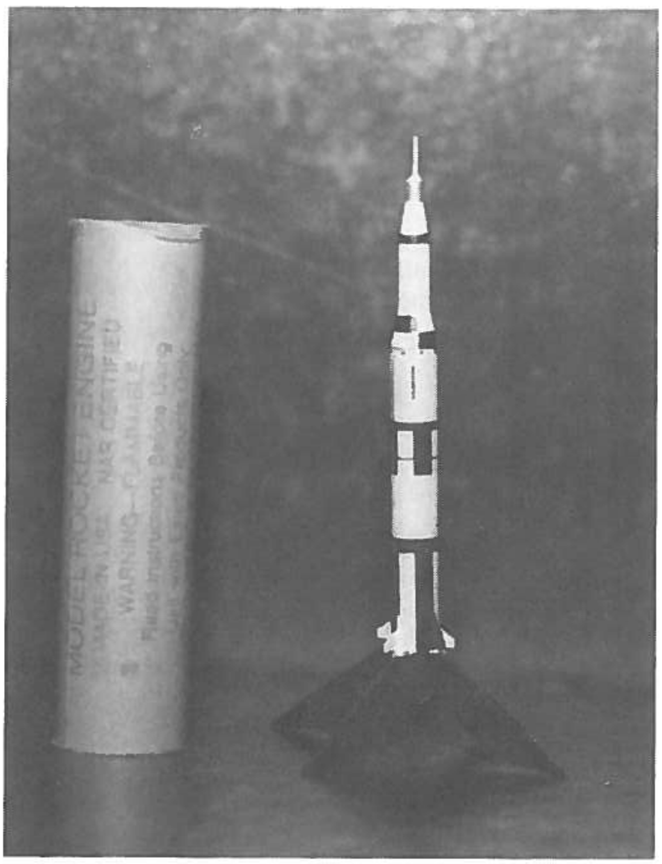
While scale models can be as simple as non-scale models, you should build and fly at least one or two model rocket kits before designing your own model. This will acquaint you with the insides of a functioning model rocket. The following will help you design the outside accurately. Don't forget to follow the stability tips to insure a safe flight.

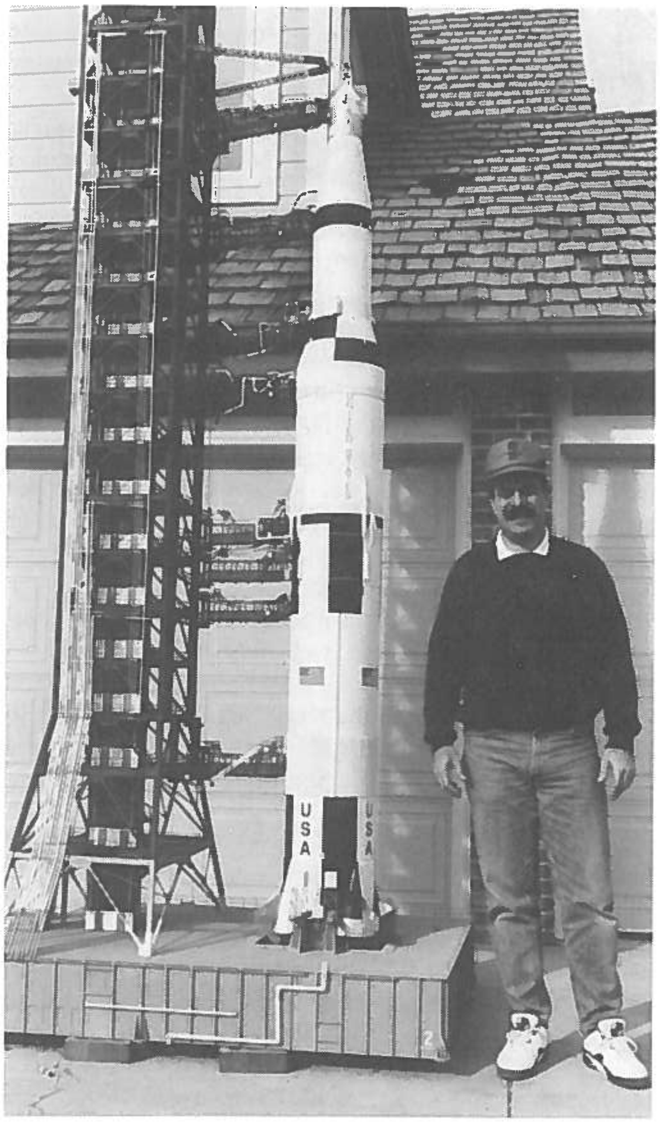
Selecting a Scale

In model rocketry, we do not usually build to standard scales. Instead we usually model with standard tube diameters. Thanks to the availability of good commercial tubes and components designed to be used with them, US modelers rarely roll tubes themselves (Eastern European modelers frequently roll their own). Most subjects can be modeled fairly well with commercial tubes. Turning nose cones and transitions is easier and more satisfying than making tubes, but commercial parts make life simpler here, as well. The trick of selecting a scale, then, is determining which scales allow you to use the most commercial parts with reasonable accuracy for a reasonably sized model.

For simple, single diameter models, start by looking for commercial nose cones. Don't just look at catalog listings of nose cones, but keep an eye on kits as well. Hard core modelers continually scout out hobby and toy shops for kits with discontinued nose cones and other parts that may

Two Saturn V's: Jim Flis selected a scale based on a rare opportunity when he managed to obtain some tiny Russian model rocket engines. His Saturn V is shown here at full size, next to a standard Estes engine. (Jim Flis photo) Dave Gianakos built at a larger scale to take advantage of high power rocket technology. (Photo courtesy Dave Gianakos)





provide kitbashing opportunities. Most prototype rockets have ogive (ogives have a rounded shape terminating in a point), conical, or hemisphere-tipped conical nose cones. Table 1 lists some commercially manufactured nose cones suitable for scale models. To use it, divide the length of the prototype nose cone by its diameter to find its aspect ratio. Search the table for cones with closely matching aspect ratios. If you aren't satisfied with the choices, then you'll have to turn your own nose cone.

More complex models with various tube sizes require a different approach. Table 2 lists the ratios of the diameters of several manufacturers' tubes. Use this table to choose the scale for a model on a two-diameter prototype.

Divide one diameter by the other to give a diameter ratio. Look through the table for a close match to your diameter ratio. You will find possible tubes to use at the top of the column of your match and the left end of the row of your match.

For example, if you were to build a Sparrow-HV Arcas, with prototype diameters of 4.5" and 8.0", you would first find the diameter ratio, 8.0 ÷ 4.5 = 1.778. If you limit yourself to Estes tubes, some good fits are BT-50 with BT-5, BT-55 with BT-20, and BT-101 with BT-70.

With three choices of scale, now it's time to think of other considerations, such as weight, available tools and supplies, and parts. For instance, the BT-50/BT-5 size allows the use of a plastic nose cone found in many inexpensive Estes kits. Plans for such a model appear in this book. High-power modelers might find the BT-101/BT-70 model appealing, although they would have to turn a nose cone. By mixing brands of tubing, even more scales are possible. One appealing combination is a mix of FSI HT-225 tubing and Estes BT-55. This would use the Estes PNC-55AC, a nose cone originally made for an Arcas kit.

If you are building for a contest, larger models can impress judges, especially if you are a modeler of ordinary skill building in a lot of detail. Unusually tiny models can showcase your talents if you can build jewel-like miniatures. In the case of *Peanut Scale* and *Giant Scale* contests, you are required to build unusually small or large models.

When selecting a scale, consider the flight characteristics you'd like to see. Almost every real rocket takes off more slowly (with respect to its size) than almost any model rocket. The Saturn rockets gave a glorious display as they crept off the pad—accelerating at 0.2 g's, the Saturn V took roughly 10 seconds to travel its own length—no model rocket could safely take off so slowly. Sounding rockets take off much faster. The Nike-Apache, for instance, took off with an acceleration of 30 g's. Although this is fast even for a model rocket, the Nike-Apache did not appear to move as fast as a model rocket because of its greater size. A good measure of the appearance of a liftoff is the time it takes a rocket to travel its own length. The notoriously slow-moving Estes Saturn V kit takes about a quarter-second to clear its own length—about the same time as the real-life Nike-Apache. Smaller models are gone in a flash, clearing their own length in as little 1/20 of a second. In most cases, the slower the liftoff, the more realistic. Unfortunately, slow, realistic takeoffs increase the risks of weathercocking and random pointing from thrust misalignment. Obey the engine manufacturer's maximum lift weight limits to avoid dangerously slow liftoffs.

Table 1: Some Commercial Conical and Ogive Nose Cones

Source	Shape	Part No.	Tube	Exposed Length (inches)	Diameter (inches)	Aspect Ratio	Angle (Full)
Estes	Cone	BNC-5S	BT-5	1.5	0.541	2.77	20.4°
Estes	Cone	BNC-20R	BT-20	2.75	0.736	3.74	15.2°
Estes	Cone	(Kit only)	BT-55	5.4	1.325	4.91	11°
FSI	Cone	NC-191	RT-19	10.7	2.04	5.25	10.9°
Estes	Ogive	BNC-5E	BT-5	1.38	0.541	2.54	
Estes	Ogive	BNC-5W	BT-5	2.8	0.541	5.18	
Estes	Ogive	(Kits only)	BT-5	2.1	0.541	3.9	
Estes	Ogive	(Kits only)	BT-20	2.8	0.736	3.8	
Estes	Ogive	BNC-50K	BT-50	2.75	0.976	2.82	
Estes	Ogive	BNC-50Y	BT-50	4.35	0.976	4.46	
Estes	Ogive	PNC 50Y	BT-50	4.1	0.976	4.2	
Estes	Ogive	PNC-55AC	BT-55	5.4	1.325	4.08	
Estes	Ogive	(Kits only)	BT-60	4.7	1.637	4.91	
Estes	Ogive	BNC-70AJ	BT-70	4.4	2.217	1.98	
Estes	Ogive	PNC-80K	BT-80	8.15	2.6	3.13	
Quest	Ogive	PNC-20	T-20	2.53	0.787	3.20	
Quest	Ogive	PNC-25	T-25	3.15	0.984	3.20	
Quest	Cyl-ogive	PNC-35	T-35	4.125	1.378	3.00	
	Ogive section of PNC-35			3.125	1.378	2.3	
Aerotech	Ogive	11191	1.9"	9.1	1.9	4.8	
Aerotech	Ogive	11261	2.6"	13	2.6	5	
LOC	Ogive	PNC-1.52	BT-1.52	8.00	1.635	4.89	
LOC	Ogive	PNC-2.14	BT-2.14	9.50	2.260	4.20	
LOC	Ogive	PNC-2.56	BT-2.56	9.00	2.630	3.42	
LOC	Ogive	PNC-3.00	BT-3.00	11.25	3.100	3.63	
LOC	Ogive	PNC-3.90	BT-3.90	12.75	4.000	3.19	
LOC	Ogive	PNC-5.38	BT-5.38	13	5.540	2.35	
LOC	Ogive	PNC-7.51	BT-7.51	22	7.675	2.87	

Table 2: Body Tube Diameter Ratios

				PT-6	BT-5	TT-14	T15	BT-20	TT-19	T20	RT-8	BT-50	MMT-0.95	T30	BT-11	MMT-1.14	BT-55	T35	BT-60
Source	No.	OD	ID	0.25	0.54	0.57	0.59	0.74	0.77	0.79	0.92	0.98	1	1.18	1.21	1.26	1.33	1.38	1.64
Apogee	PT-6	0.25	0.22	1	2.16	2.26	2.36	2.94	3.06	3.15	3.68	3.9	4	4.72	4.84	5.04	5.3	5.51	6.55
Estes *	BT-5	0.541	0.518	0.46	1	1.04	1.09	1.36	1.41	1.45	1.7	1.8	1.85	2.18	2.24	2.33	2.45	2.55	3.03
Apogee	TT-14	0.565	0.545	0.44	0.96	1	1.04	1.3	1.35	1.39	1.63	1.73	1.77	2.09	2.14	2.23	2.35	2.44	2.9
Quest	T15	0.59	0.55	0.42	0.92	0.96	1	1.25	1.3	1.33	1.56	1.65	1.69	2	2.05	2.14	2.25	2.34	2.77
Estes *	BT-20	0.736	0.71	0.34	0.74	0.77	0.8	1	1.04	1.07	1.25	1.33	1.36	1.6	1.64	1.71	1.8	1.87	2.22
FSI *	RT-6	0.755	0.718	0.33	0.72	0.75	0.78	0.97	1.01	1.04	1.22	1.29	1.32	1.56	1.6	1.67	1.75	1.83	2.17
Apogee	TT-19	0.765	0.745	0.33	0.71	0.74	0.77	0.96	1	1.03	1.2	1.28	1.31	1.54	1.58	1.65	1.73	1.8	2.14
Quest	T20	0.787	0.747	0.32	0.69	0.72	0.75	0.94	0.97	1	1.17	1.24	1.27	1.5	1.54	1.6	1.68	1.75	2.08
FSI	RT-8	0.921	0.903	0.27	0.59	0.61	0.64	0.8	0.83	0.85	1	1.06	1.09	1.28	1.31	1.37	1.44	1.5	1.78
Apogee	PT-24	0.975	0.945	0.26	0.55	0.58	0.61	0.75	0.78	0.81	0.94	1	1.03	1.21	1.24	1.29	1.36	1.41	1.68
Estes *	BT-50	0.976	0.95	0.26	0.55	0.58	0.6	0.75	0.78	0.81	0.94	1	1.02	1.21	1.24	1.29	1.36	1.41	1.68
LOC *	MMT-0.95	1	0.95	0.25	0.54	0.57	0.59	0.74	0.77	0.79	0.92	0.98	1	1.18	1.21	1.26	1.33	1.38	1.64
FSI	RT-10	1.17	1.13	0.21	0.46	0.48	0.5	0.63	0.65	0.67	0.79	0.83	0.85	1.01	1.03	1.08	1.13	1.18	1.4
Quest	T30	1.18	1.14	0.21	0.46	0.48	0.5	0.62	0.65	0.67	0.78	0.83	0.85	1	1.03	1.07	1.12	1.17	1.39
NCR	BT-11	1.21	1.14	0.21	0.45	0.47	0.49	0.61	0.63	0.65	0.76	0.81	0.83	0.98	1	1.04	1.1	1.14	1.35
LOC	MMT-1.14	1.26	1.14	0.2	0.43	0.45	0.47	0.58	0.61	0.62	0.73	0.77	0.79	0.94	0.96	1	1.05	1.09	1.3
PML	PT-1.145	1.269	1.145	0.2	0.43	0.45	0.46	0.58	0.6	0.62	0.73	0.77	0.79	0.93	0.95	0.99	1.04	1.09	1.29
Estes	BT-55	1.325	1.283	0.19	0.41	0.43	0.45	0.56	0.58	0.59	0.7	0.74	0.75	0.89	0.91	0.95	1	1.04	1.24
FSI	RT-12	1.34	1.3	0.19	0.4	0.42	0.44	0.55	0.57	0.59	0.69	0.73	0.75	0.88	0.9	0.94	0.99	1.03	1.22
Quest	T35	1.378	1.338	0.18	0.39	0.41	0.43	0.53	0.56	0.57	0.67	0.71	0.73	0.86	0.88	0.91	0.96	1	1.19
LOC *	BT-1.52	1.635	1.525	0.15	0.33	0.35	0.36	0.45	0.47	0.48	0.56	0.6	0.61	0.72	0.74	0.77	0.81	0.84	1
Estes *	BT-60	1.637	1.595	0.15	0.33	0.35	0.36	0.45	0.47	0.48	0.56	0.6	0.61	0.72	0.74	0.77	0.81	0.84	1
PML	PT-1.525	1.649	1.525	0.15	0.33	0.34	0.36	0.45	0.46	0.48	0.56	0.59	0.61	0.72	0.73	0.76	0.8	0.84	0.99
NCR	BT-15	1.65	1.53	0.15	0.33	0.34	0.36	0.45	0.46	0.48	0.56	0.59	0.61	0.72	0.73	0.76	0.8	0.84	0.99
FSI	RT-17	1.84	1.8	0.14	0.29	0.31	0.32	0.4	0.42	0.43	0.5	0.53	0.54	0.64	0.66	0.68	0.72	0.75	0.89
NCR	BT-18	1.88	1.8	0.13	0.29	0.3	0.31	0.39	0.41	0.42	0.49	0.52	0.53	0.63	0.64	0.67	0.7	0.73	0.87
Aerotch	1.9"	1.9	-----	0.13	0.28	0.3	0.31	0.39	0.4	0.41	0.48	0.51	0.53	0.62	0.64	0.66	0.7	0.73	0.86
FSI	RT-19	2.04	2.0	0.12	0.27	0.28	0.29	0.36	0.38	0.39	0.45	0.48	0.49	0.58	0.59	0.62	0.65	0.68	0.8
CCA	MMT-2.17	2.17	1.97	0.12	0.25	0.26	0.27	0.34	0.35	0.36	0.42	0.45	0.46	0.54	0.56	0.58	0.61	0.64	0.75
Estes	BT-70	2.217	2.18	0.11	0.24	0.25	0.27	0.33	0.35	0.35	0.42	0.44	0.45	0.53	0.55	0.57	0.6	0.62	0.74
LOC *	BT-2.14	2.26	2.14	0.11	0.24	0.25	0.26	0.33	0.34	0.35	0.41	0.43	0.44	0.52	0.54	0.56	0.59	0.61	0.72
PML	PT-2.152	2.276	2.152	0.11	0.24	0.25	0.26	0.32	0.34	0.35	0.4	0.43	0.44	0.52	0.53	0.55	0.58	0.61	0.72
FSI	RT-22	2.34	2.25	0.11	0.23	0.24	0.25	0.31	0.33	0.34	0.39	0.42	0.43	0.5	0.52	0.54	0.57	0.59	0.7
Estes	BT-80KD	2.6	2.558	0.1	0.21	0.22	0.23	0.28	0.29	0.3	0.35	0.38	0.38	0.45	0.47	0.48	0.51	0.53	0.63
Aerotch	2.6"	2.6	-----	0.1	0.21	0.22	0.23	0.28	0.29	0.3	0.35	0.38	0.38	0.45	0.47	0.48	0.51	0.53	0.63
LOC	BT-2.56	2.63	2.56	0.1	0.21	0.21	0.22	0.28	0.29	0.3	0.35	0.37	0.38	0.45	0.46	0.48	0.5	0.52	0.62
NCR *	BT-26	2.7	2.62	0.09	0.2	0.21	0.22	0.27	0.28	0.29	0.34	0.36	0.37	0.44	0.45	0.47	0.49	0.51	0.61
LOC	BT-3.00	3.1	3.00	0.08	0.17	0.18	0.19	0.24	0.25	0.25	0.3	0.31	0.32	0.38	0.39	0.41	0.43	0.44	0.53
PML	PT-3.002	3.126	3.002	0.08	0.17	0.18	0.19	0.24	0.24	0.25	0.29	0.31	0.32	0.38	0.39	0.4	0.42	0.44	0.52
CCA	MMT-3.9	3.9	3.7	0.06	0.14	0.14	0.15	0.19	0.2	0.2	0.24	0.25	0.26	0.3	0.31	0.32	0.34	0.35	0.42
Estes	BT-101SV	3.938	3.896	0.06	0.14	0.14	0.15	0.19	0.19	0.2	0.23	0.25	0.25	0.3	0.31	0.32	0.34	0.35	0.42
LOC *	BT-3.9	4	3.9	0.06	0.14	0.14	0.15	0.18	0.19	0.2	0.23	0.24	0.25	0.3	0.3	0.32	0.33	0.34	0.41
CCA	BT-4.10	4.1	3.9	0.06	0.13	0.14	0.14	0.18	0.19	0.19	0.22	0.24	0.24	0.29	0.3	0.31	0.32	0.34	0.4
LOC	BT-5.38	5.54	5.38	0.05	0.1	0.1	0.11	0.13	0.14	0.14	0.17	0.18	0.18	0.21	0.22	0.23	0.24	0.25	0.3
PML	PT-6.007	6.131	6.007	0.04	0.09	0.09	0.1	0.12	0.12	0.13	0.15	0.16	0.16	0.19	0.2	0.21	0.22	0.22	0.27
LOC *	BT-7.51	7.675	7.675	0.03	0.07	0.07	0.08	0.1	0.1	0.1	0.12	0.13	0.13	0.15	0.16	0.16	0.17	0.18	0.21
NCR *	BT-8	8	7.8	0.03	0.07	0.07	0.07	0.09	0.1	0.1	0.12	0.12	0.13	0.15	0.15	0.16	0.17	0.17	0.2
PML	PT-8.710	8.87	8.71	0.03	0.06	0.06	0.07	0.08	0.09	0.09	0.1	0.11	0.11	0.13	0.14	0.14	0.15	0.16	0.18

		RT-17	BT-18	AT 1.9"	RT-19	MMT-2.17	BT-70	BT-2.14	RT-22	BT-80	BT-2.56	BT-26	BT-3	MMT-3.9	BT-101	PT-3.9	BT-4.1
Source	No.	1.84	1.88	1.9	2.04	2.17	2.22	2.26	2.34	2.6	2.63	2.7	3.1	3.9	3.94	4.02	4.1
Apogee	PT-6	7.36	7.52	7.6	8.16	8.68	8.87	9.04	9.36	10.4	10.52	10.8	12.4	15.6	15.75	16.1	16.4
Estes *	BT-5	3.4	3.48	3.51	3.77	4.01	4.1	4.18	4.33	4.81	4.86	4.99	5.73	7.21	7.28	7.44	7.58
Apogee	TT-14	3.26	3.33	3.36	3.61	3.84	3.92	4	4.14	4.6	4.65	4.78	5.49	6.9	6.97	7.12	7.26
Quest	T15	3.12	3.19	3.22	3.46	3.68	3.76	3.83	3.97	4.41	4.46	4.58	5.25	6.61	6.67	6.82	6.95
Estes *	BT-20	2.5	2.55	2.58	2.77	2.95	3.01	3.07	3.18	3.53	3.57	3.67	4.21	5.3	5.35	5.47	5.57
FSI *	RT-6	2.44	2.49	2.52	2.7	2.87	2.94	2.99	3.1	3.44	3.48	3.58	4.11	5.17	5.22	5.33	5.43
Apogee	TT-19	2.41	2.46	2.48	2.67	2.84	2.9	2.95	3.06	3.4	3.44	3.53	4.05	5.1	5.15	5.26	5.36
Quest	T20	2.34	2.39	2.41	2.59	2.76	2.82	2.87	2.97	3.3	3.34	3.43	3.94	4.96	5	5.11	5.21
FSI	RT-8	2	2.04	2.06	2.21	2.36	2.41	2.45	2.54	2.82	2.86	2.93	3.37	4.23	4.28	4.37	4.45
Apogee	PT-24	1.89	1.93	1.95	2.09	2.23	2.27	2.32	2.4	2.67	2.7	2.77	3.18	4	4.04	4.13	4.21
Estes *	BT-50	1.89	1.93	1.95	2.09	2.22	2.27	2.32	2.4	2.66	2.69	2.77	3.18	4	4.03	4.12	4.2
LOC *	MMT-0.95	1.84	1.88	1.9	2.04	2.17	2.22	2.26	2.34	2.6	2.63	2.7	3.1	3.9	3.94	4.02	4.1
FSI	RT-10	1.57	1.61	1.62	1.74	1.85	1.89	1.93	2	2.22	2.25	2.31	2.65	3.33	3.37	3.44	3.5
Quest	T30	1.56	1.59	1.61	1.73	1.84	1.88	1.92	1.98	2.2	2.23	2.29	2.63	3.31	3.34	3.41	3.47
NCR	BT-11	1.52	1.55	1.57	1.69	1.79	1.83	1.87	1.93	2.15	2.17	2.23	2.56	3.22	3.25	3.33	3.39
LOC	MMT-1.14	1.46	1.49	1.51	1.62	1.72	1.76	1.79	1.86	2.06	2.09	2.14	2.46	3.1	3.13	3.19	3.25
PML	PT-1.145	1.45	1.48	1.5	1.61	1.71	1.75	1.78	1.84	2.05	2.07	2.13	2.44	3.07	3.1	3.17	3.23
Estes	BT-55	1.39	1.42	1.43	1.54	1.64	1.67	1.71	1.77	1.96	1.98	2.04	2.34	2.94	2.97	3.04	3.09
FSI	RT-12	1.37	1.4	1.42	1.52	1.62	1.65	1.69	1.75	1.94	1.96	2.01	2.31	2.91	2.94	3	3.06
Quest	T35	1.34	1.36	1.38	1.48	1.57	1.61	1.64	1.7	1.89	1.91	1.96	2.25	2.83	2.86	2.92	2.98
LOC *	BT-1.52	1.13	1.15	1.16	1.25	1.33	1.36	1.38	1.43	1.59	1.61	1.65	1.9	2.39	2.41	2.46	2.51
Estes *	BT-60	1.12	1.15	1.16	1.25	1.33	1.35	1.38	1.43	1.59	1.61	1.65	1.89	2.38	2.41	2.46	2.5
PML	PT-1.525	1.12	1.14	1.15	1.24	1.32	1.34	1.37	1.42	1.58	1.59	1.64	1.88	2.37	2.39	2.44	2.49
NCR	BT-15	1.12	1.14	1.15	1.24	1.32	1.34	1.37	1.42	1.58	1.59	1.64	1.88	2.36	2.39	2.44	2.48
FSI	RT-17	1	1.02	1.03	1.11	1.18	1.2	1.23	1.27	1.41	1.43	1.47	1.68	2.12	2.14	2.19	2.23
NCR	BT-18	0.98	1	1.01	1.09	1.15	1.18	1.2	1.24	1.38	1.4	1.44	1.65	2.07	2.09	2.14	2.18
Aerotch	1.9"	0.97	0.99	1	1.07	1.14	1.17	1.19	1.23	1.37	1.38	1.42	1.63	2.05	2.07	2.12	2.16
FSI	RT-19	0.9	0.92	0.93	1	1.06	1.09	1.11	1.15	1.27	1.29	1.32	1.52	1.91	1.93	1.97	2.01
CCA	MMT-2.17	0.85	0.87	0.88	0.94	1	1.02	1.04	1.08	1.2	1.21	1.24	1.43	1.8	1.81	1.85	1.89
Estes	BT-70	0.83	0.85	0.86	0.92	0.98	1	1.02	1.06	1.17	1.19	1.22	1.4	1.76	1.78	1.82	1.85
LOC *	BT-2.14	0.81	0.83	0.84	0.9	0.96	0.98	1	1.04	1.15	1.16	1.19	1.37	1.73	1.74	1.78	1.81
PML	PT-2.152	0.81	0.83	0.83	0.9	0.95	0.97	0.99	1.03	1.14	1.16	1.19	1.36	1.71	1.73	1.77	1.8
FSI	RT-22	0.79	0.8	0.81	0.87	0.93	0.95	0.97	1	1.11	1.12	1.15	1.32	1.67	1.68	1.72	1.75
Estes	BT-80KD	0.71	0.72	0.73	0.78	0.83	0.85	0.87	0.9	1	1.01	1.04	1.19	1.5	1.51	1.55	1.58
Aerotch	2.6"	0.71	0.72	0.73	0.78	0.83	0.85	0.87	0.9	1	1.01	1.04	1.19	1.5	1.51	1.55	1.58
LOC	BT-2.56	0.7	0.71	0.72	0.78	0.83	0.84	0.86	0.89	0.99	1	1.03	1.18	1.48	1.5	1.53	1.56
NCR *	BT-26	0.68	0.7	0.7	0.76	0.8	0.82	0.84	0.87	0.96	0.97	1	1.15	1.44	1.46	1.49	1.52
LOC	BT-3.00	0.59	0.61	0.61	0.66	0.7	0.72	0.73	0.75	0.84	0.85	0.87	1	1.26	1.27	1.3	1.32
PML	PT-3.002	0.59	0.6	0.61	0.65	0.69	0.71	0.72	0.75	0.83	0.84	0.86	0.99	1.25	1.26	1.29	1.31
CCA	MMT-3.9	0.47	0.48	0.49	0.52	0.56	0.57	0.58	0.6	0.67	0.67	0.69	0.79	1	1.01	1.03	1.05
Estes	BT-101SV	0.47	0.48	0.48	0.52	0.55	0.56	0.57	0.59	0.66	0.67	0.69	0.79	0.99	1	1.02	1.04
LOC *	BT-3.9	0.46	0.47	0.48	0.51	0.54	0.55	0.57	0.59	0.65	0.66	0.68	0.78	0.98	0.98	1.01	1.03
CCA	BT-4.10	0.45	0.46	0.46	0.5	0.53	0.54	0.55	0.57	0.63	0.64	0.66	0.76	0.95	0.96	0.98	1
LOC	BT-5.38	0.33	0.34	0.34	0.37	0.39	0.4	0.41	0.42	0.47	0.47	0.49	0.56	0.7	0.71	0.73	0.74
PML	PT-6.007	0.3	0.31	0.31	0.33	0.35	0.36	0.37	0.38	0.42	0.43	0.44	0.51	0.64	0.64	0.66	0.67
LOC *	BT-7.51	0.24	0.24	0.25	0.27	0.28	0.29	0.29	0.3	0.34	0.34	0.35	0.4	0.51	0.51	0.52	0.53
NCR *	BT-8	0.23	0.24	0.24	0.26	0.27	0.28	0.28	0.29	0.33	0.33	0.34	0.39	0.49	0.49	0.5	0.51
PML	PT-8.710	0.21	0.21	0.21	0.23	0.24	0.25	0.25	0.26	0.29	0.3	0.3	0.35	0.44	0.44	0.45	0.46

* Body tube sizes marked with asterisks are available from more than one manufacturer.

Scaling Your Model

Once you have decided the size of your model, determine the exact scale. Suppose you were to build a BT-50 D-Region Tomahawk. Calculate the scale of the model by dividing a model dimension by the corresponding prototype dimension. Since .976" ÷ 9.0" = 0.108, you'll build a 0.108 scale model. It is common practice to express scale as a fraction. To find the scale denominator, you can divide the prototype dimension by the model dimension (9.0 ÷ 0.976 = 9.22). You would then express the scale as 1/9.22. If you are building a multi-diameter model, repeat this for each major diameter, and find an average scale.

When I build scale models, I draw out a crude diagram with scaled dimensions for each major model part. A Xerox of a source drawing is a good starting point for such a diagram (see next page). Each model dimension is simply the corresponding prototype dimension multiplied by the scale factor. For instance, to find the length of the body tube of the D-Region Tomahawk model, first find the prototype length by subtracting the station (STA) numbers at the top and bottom of the tubular section of the rocket: 193.085" - 29.25" = 163.835". Then multiply the prototype dimension by the scale factor, giving us: 163.835" x 0.108 =17.77" (I usually just think of it as dividing by the scale denominator: 163.835" ÷ 9.22 =17.77"). An 18" factory-cut length of BT-50 will do nicely for a fun scale or *Sport Scale* model. If you will enter the model in the measured *Scale* event, you may want to cut the tube to the exact length.

Angles remain the same on the model as on the prototype.

A few minutes of calculating will give you a crude, number-cluttered plan. This plan is the place to work out questions such as, "what tube goes inside which adapter ring?" Only fin patterns need to be carefully laid out on paper. It is often convenient to use an enlarging/reducing Xerox machine to make fin patterns. To determine the photocopy enlargement, divide the scale factor of the model by the scale factor of your source drawing. For the D-Region Tomahawk, that's 1/9.22 ÷ 1/25 = 25 ÷ 9.22 = 2.71. That's 271%, more than most self-serve copiers will do. So you will need multiple generations to boost the drawing up to size. Check the measurements of the final copy to insure it is correct, as the copy enlargements may not be exact. When doing multiple generations of copies, rotate each copy 90° from the previous copy to minimize distortion.

If the prototype drawing is dimensioned in inches, a decimal English ruler helps in laying out patterns and measuring parts. Ordinary fractional inch rulers are difficult to use in scale modeling because calculators don't display fractions. Decimal English scales are available at good art and drafting supply stores (triangular engineer's scales are excellent. Don't confuse them with similar architect's scales, which use fractions). Use a metric ruler when you are working with metric prototype dimensions. Avoid metric/English conversions. Every extra calculation could introduce an error.

You must also select the correct thicknesses of fin stock. Calculating from prototype dimensions gives you a decimal English or metric thickness, but wood is sold in fractional inch thicknesses in the US. Table 3 should help you select the best sheet stock. This table will also be of use in selecting wood or plastic strips.

Scaling From Undimensioned Sources

Often you will wish to model details or even whole rockets for which you do not have dimensions. Undimensioned drawings and photographs are useful sources of information, but you must take special care. Some drawings are crude, stylized illustrations that have been eyeballed from other drawings or photographs. Such drawings give a sense of the size or shape of a vehicle, rather than precise information. Photographs are subject to perspective and foreshortening effects that cause the scale to vary from place to place. Fortunately, most launch photos are taken from a considerable distance, so perspective effects are small and foreshortening can be accounted for.

The first step in working from such pictures is to establish a scaling factor. It may be wise to try two scales, horizontal and vertical. This corrects for foreshortening in photos and copying distortions in drawings.

Fortunately, overall length and maximum diameter are easy to look up for most rockets. Try the early March market supplement issue of *Aviation Week and Space Technology* from a year when the rocket was in operation. From this you can determine an overall length and diameter for your model. To find the picture scaling factors, measure diameter and length from the photo. For the vertical factor, divide the model length by the length on the picture. For the horizontal factor, divide the model diameter by the photo diameter.

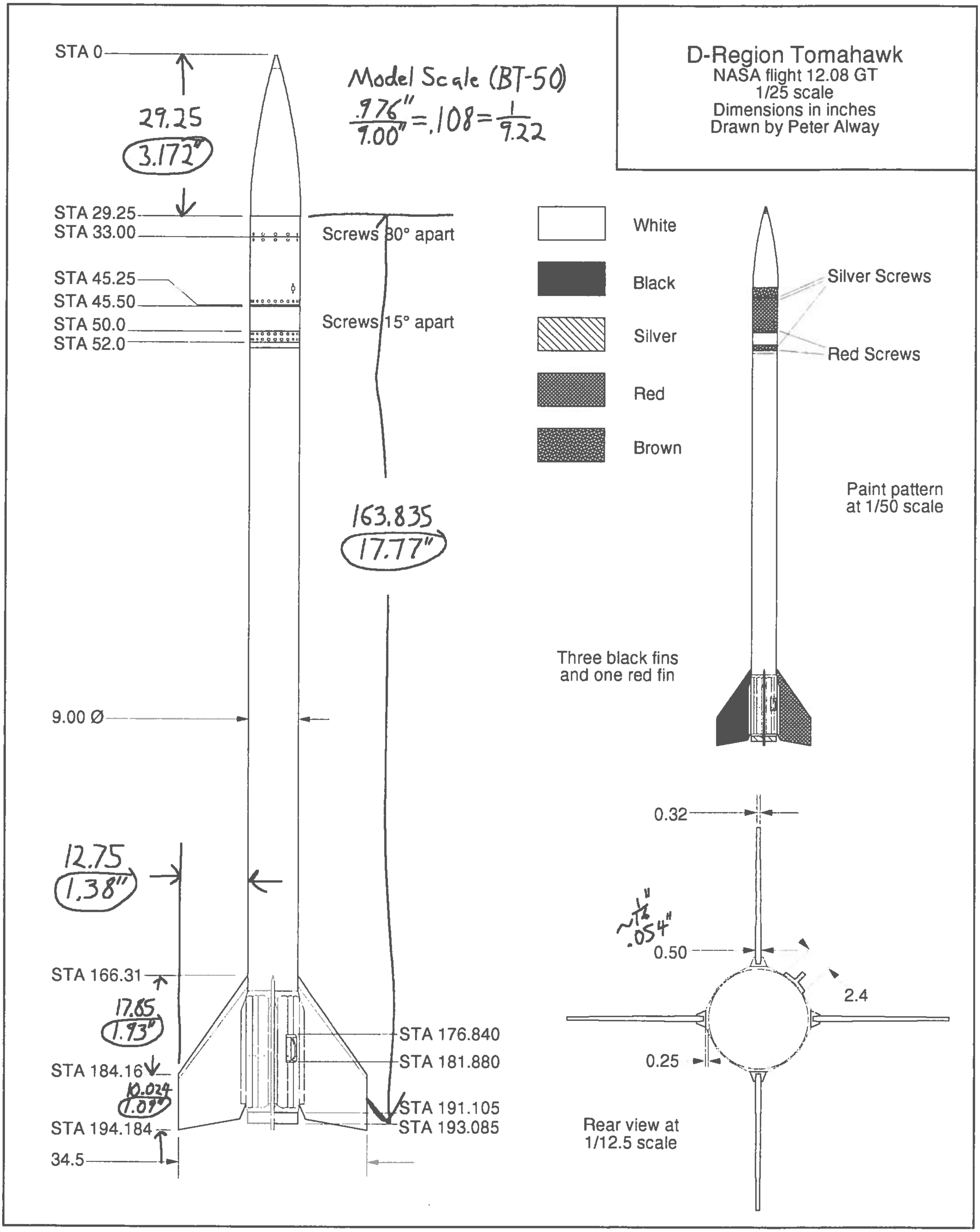
Now you can measure the details directly from the illustration, multiply by the appropriate scaling factor, and have the correct model dimension of the detail.

Table 3: Fraction-Decimal-Metric conversions

Fractional inches	Decimal inches	Millimeters
1/32	0.031	0.8
1/16	0.063	1.6
3/32	0.094	2.4
1/8	0.125	3.2
3/16	0.188	4.8
1/4	0.250	6.4
3/8	0.375	9.5
1/2	0.500	12.7

Scale Calculations on a Source Drawing:

Use a photocopy of a scale drawing to work out the dimensions of a model. The insides of this model are entirely conventional, but for a more complex model, you would also sketch internal components on this diagram.



Designing a Stable Model

Designing an accurate model is just half your job. As a model rocketeer, it is your responsibility to build a safe and stable model. While many sounding rockets and missiles build naturally into stable models, many others do not. Aerodynamic stability determines if your model will fly straight up or fly cartwheels about the pad, possibly puncturing an innocent bystander.

There are two critical points on your model that determine stability. One is the center of gravity (or center of mass), abbreviated CG. The CG is the natural pivot point of your model in free flight. You can determine its location on the completed model by hanging the model by a string tied around the body. When the string is at the center of gravity, the model will hang horizontally. Always locate the center of gravity with a fresh engine of the largest possible impulse in place. You can move the CG by adding, subtracting, or moving weight.

The second point, the center of pressure (CP), is a bit more subtle. When your model is in motion, but not pointing exactly forward, the air flowing over the model can be thought of as pushing at one point. This imaginary point is the center of pressure. You can move the CP by adding, subtracting, or moving fin area. Fins at the rear of the model move the CP back; fins at the front move the CP forward.

The CP *must* be behind the CG if your model is to fly safely. The CP should be at least one body diameter behind the CG. With the CP safely behind the CG, a model that is disturbed from straight motion will promptly return to straight flight. If the CP is forward of the CG, the backwards force of air on the model will be centered forward of the pivot point. The model will promptly turn around and start a pinwheel flight. At best your model will be seriously damaged. At worst, the model will become stable as the engine loses weight, and the model will resume flight in a random direction. If you or an observer happens to be standing in that direction, serious injury could result.

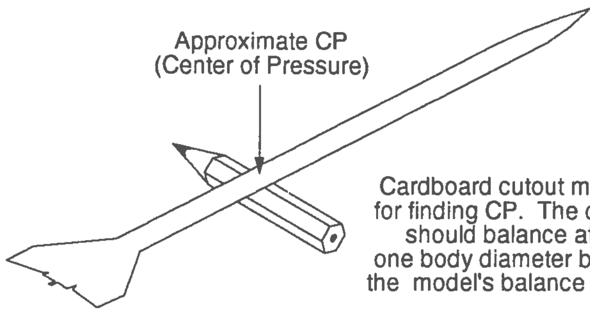
Remember: CG in front of CP. In practice, this means: weight at the front of the model is good; weight at the rear is bad. Fins at the rear of the model are good; fins at the front are bad.

You can estimate the location of the CP of your model by cutting out a profile plan of your model and balancing the cardboard cutout. This method is conservative for models with fins. If your model balances one body diameter forward of the paper cutout balance point, the model is stable. If the model is unstable, add weight to the nose, add fin area to the rear (enlarge the scale fins or add clear plastic fins), or remove fin area from the nose (shrink forward scale fins or move them back).

If you are modeling a finless prototype you will need to add clear plastic fins for stability. Study designs of commercial flying model kits to get an idea of the area needed.

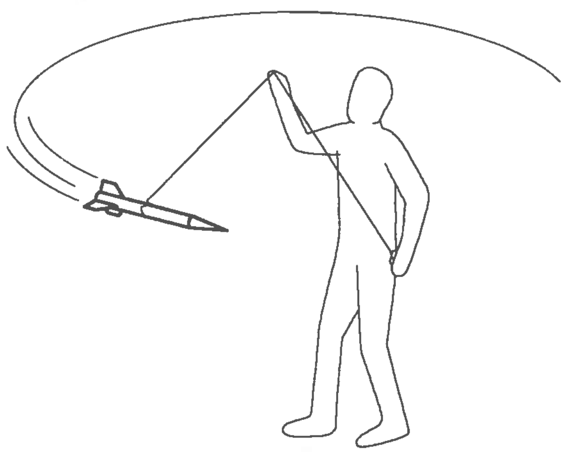
Some special shapes, particularly of conical vehicles such as the Soviet N-1 or American Sprint, may be made stable without fins. There are two methods for checking the stability of such vehicles. The first is a rather involved center of pressure calculation. The *Handbook of Model Rocketry* (6th edition) by G. Harry Stine gives the equations and a BASIC program for this calculation in appendices II and IV.

The second approach is to use the poor man's wind tunnel: the swing (or string) stability test. Tie a string around the completed model at the center of gravity with a fresh engine in place. Then swing the model around your head. If the model naturally points forward, you're in luck—the model is stable. If the model wanders or points backwards, don't despair. If you can start it going forward, and it keeps its nose firmly locked forward once in motion, your model is stable. If you can't keep it pointed forward, add weight to the nose or add fin area to the rear. The swing test only works for models up to about a half or a third of the length of your string. For larger models, you may have to build a smaller version to string test. Then be sure the large model balances at the same point as the smaller model.



Cardboard cutout method for finding CP. The cutout should balance at least one body diameter behind the model's balance point.

"String" or "Swing" stability test. If your model will fly forward with the full weight of an unused engine in place, it is stable.



Construction Techniques

The construction techniques suggested here are not the state of the art high technology, but they have been good enough to consistently win trophies at the regional and national levels. With nothing more than a little patience and some common tools, you can build a model that will collect as many blue ribbons as your grandmother's apple pie recipe. Or, if you aren't into competition, you can build a model that will give you a good feeling whenever you look at it.

Scale models are built in the same manner as other model rockets, from lightweight wood, paper, and plastic parts. However, scale models do have their own peculiar problems. These include the need for non-standard nose cones, tail cones and transitions; the construction of odd detail parts; and the requirement for a superior finish.

There is one thing to keep in mind about craftsmanship. A good craftsman does not rely on manual dexterity to make things well. A skilled craftsman thinks of a way to do something that does not require skill. You can't hand-carve a perfectly circular nose cone, so turn one. You can't brush paint with perfectly straight edges, so mask the model with tape. If a part looks impossible to make correctly, think about another way of making it. A steady hand is a nice thing, but most of craftsmanship is making the most of an unsteady hand.

Turning Wood Parts

Only rarely do commercial nose cones and adapters come in exactly the right size and shape for an accurate scale model. This need not be a roadblock, as you may already have the tools you need for turning balsa wood parts even if you don't have a lathe. If you are serious about scale modeling, turning your own balsa cones is a must.

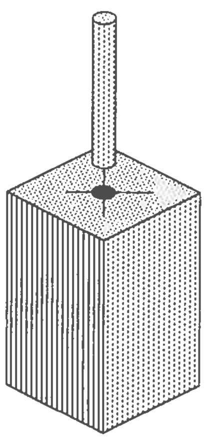
There are few steps in the construction of a model that are more satisfying than turning your own nose cones and adapters. Fortunately, you can adapt a range of equipment for this purpose. A wood lathe is ideal, of course, but a drill press, a hobby lathe, or even a simple power drill will do the trick. Safety glasses are essential, and depending on your setup, you may need a dust mask. You will also need your brain. You may be using a tool for purposes it was not intended for. Neither this book nor the drill manual will cover all aspects of safety. So you will have to think about safety for your own setup. Think carefully about what may come in contact with the turning wood and machinery: tools, your hand, your clothes, your hair... Think carefully about where things will go flying when something gets caught or flies apart.

If you are working with anything harder than balsa, look into taking a woodworking course at a local community college or public school/adult education program. Many of these courses are unstructured and allow you to work on your own projects.

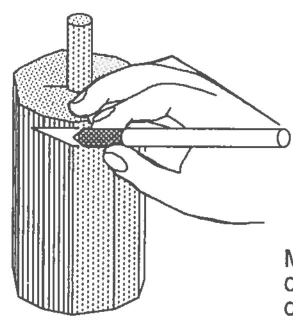
If you own a wood lathe, follow the operator's manual. If you are working with a drill or drill press, here are a few tricks:

First, you need a sturdy and rigid connection between a balsa block and your drill. Begin by drilling a hole in one end of a block of balsa. This hole should be the size of the largest dowel you can fit in the drill chuck. The hole should be as deep as possible without running into the future

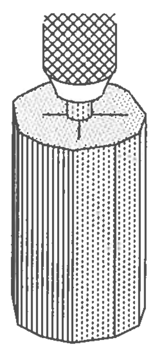
Turning Wood on a Drill Press



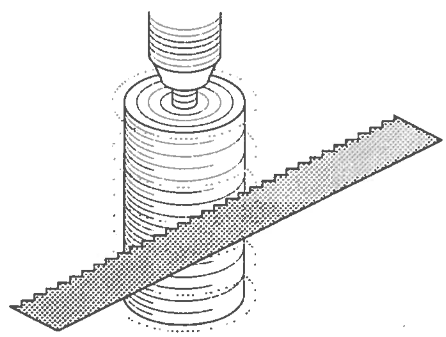
Begin by drilling a hole in one end of a balsa block and gluing in a dowel with white or aliphatic glue (such as Tite-Bond).



Trim the wood block to a rough cylinder.



Mount the block in the drill chuck. A vertical drill press arrangement is shown here, but a horizontally clamped power drill will work fine.



Turn on the motor, and if the block is well balanced, begin to work the wood into a cylinder. A small saw blade, such as that on a Swiss Army knife, is a crude but effective tool.

surface of the nose cone. Next glue a dowel into the hole. The dowel should go all the way to the bottom of the hole. Cut the dowel to a length such that when you insert it into the drill chuck as far as it will go, there will be a 1/4" to 1/2" gap between the chuck and the wood block. Allow the glue to dry thoroughly (overnight) before proceeding.

If you don't have a drill press, clamp the power drill rigidly to your work bench. A solid, sturdy attachment is critical.

Set your drill for its slowest speed. Insert the dowel protruding from the wood block into the drill chuck and tighten. Give the balsa block a few turns by hand. If it isn't turning about its center, trim the block to balance. Give the drill motor a pulse of power for an instant while holding a pen or pencil to the end of the block. This will leave a circle showing you the axis of the block. Use this mark to guide balance trimming.

Every drill has its limits. If your wood block will not turn smoothly no matter how well balanced it is, it may simply be too big for your drill. You may be able to replace the part with a paper shroud, or a combination of turned parts, body tube, and paper shroud. Or you may have to abandon the project. Obviously you should not save wood turning for last if you haven't made a similar part before.

There are two important principles to follow while turning a balsa part. The first is to go slow. The second is to hold cutting tools rigidly. Both are necessary for good results and for safety.

"Going slow" refers to the rate you advance the tool cutting into the wood. If you try to cut too far too fast, the cutting tool can catch on the wood. The results can be a chunk of wood being ripped from the part; the dowel changing its orientation in the drill bit, introducing a wobble; damage to the drill bearings; or the tool being thrown at you or at a finished area of the part. Take it slow. Move the tool along the length of a part at about one centimeter per second. On each pass, cut no more than a millimeter into the wood.

Hold the cutting tool tightly. Hold the tool rigidly to a fixed position. It is easy to fall into the trap of applying a constant pressure instead. If you do, your tool will start to work faster on the softer portions of the wood and more slowly on the harder portions. The result is a lopsided cone. It is easier to hold the tool fixed if you can rest it against something rigid. Use the work support on a drill press or a piece of wood clamped to your workbench if you are using a power drill. A solid grip is also necessary for safety. Should the tool catch on the balsa part, you will want a good grip on it so it won't go flying.

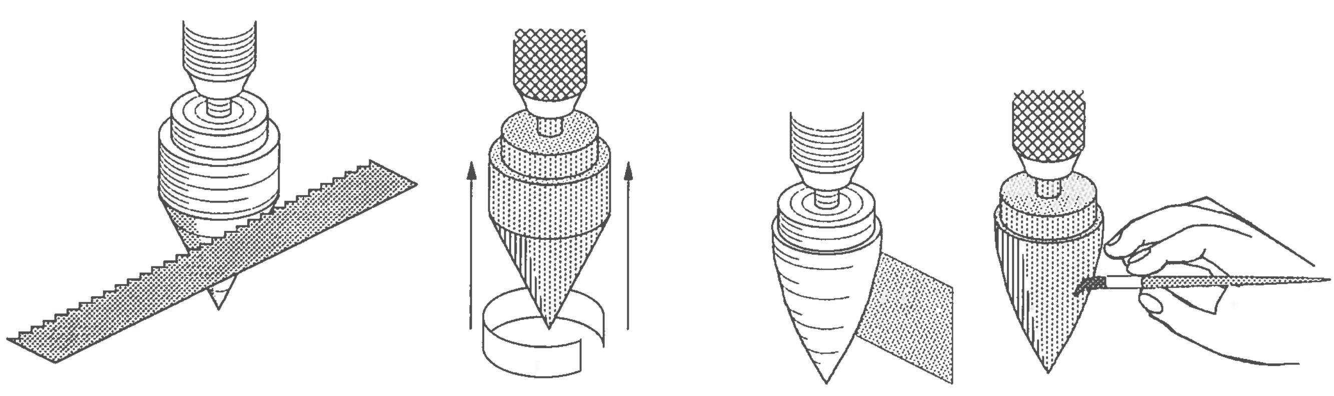
Proper lathes use thick, chisel-like tools to cut into the wood. Fortunately, balsa is softer than most wood, so we can get away with more primitive tools. I have found that the saw blade on a Swiss Army knife is quite useful in the early steps of balsa turning, first rounding up the block, and then getting the wood down to within 1/8" of its ultimate size. Next, use small files, including jeweler's files, to get to within a millimeter. I use very fine finishing sandpaper, down to #400 grit for the final surface.

There are a few tricks to measuring sizes as you work down the wood. The first is to use a ring of the body tube you are trying to fit the balsa part to. Slit the ring so you can fit it over the front of the nose cone. Use this ring to check the fit of the shoulder of the balsa part. If the ring doesn't quite close around the shoulder, then note the size of the gap. You will need to trim the radius by about 1/6 of this distance. Once the shoulders are turned, work on the exposed surfaces.

Vernier calipers are very useful for measuring progress. Use a catalog to determine the shoulder diameters, and your scale calculations for other diameters. An alternative improvised "caliper" can be made from cardboard. Cut out a C-shaped incomplete ring whose inside dimension corresponds to the desired dimension. A cardboard side-view template can also be useful.

Once the part is cut to shape and fine-sanded, it is easier to seal the balsa grain while the part is on the drill

Turning Wood on a Drill Press



Once the wood is a symmetrical cylinder, you can rough in the shape.

Slip a slit ring of body tube over the end of the part to check shoulder size.

Use files, emery board, and fine sandpaper to finish off the part.

Apply sanding sealer and sand it down while the part is still mounted.

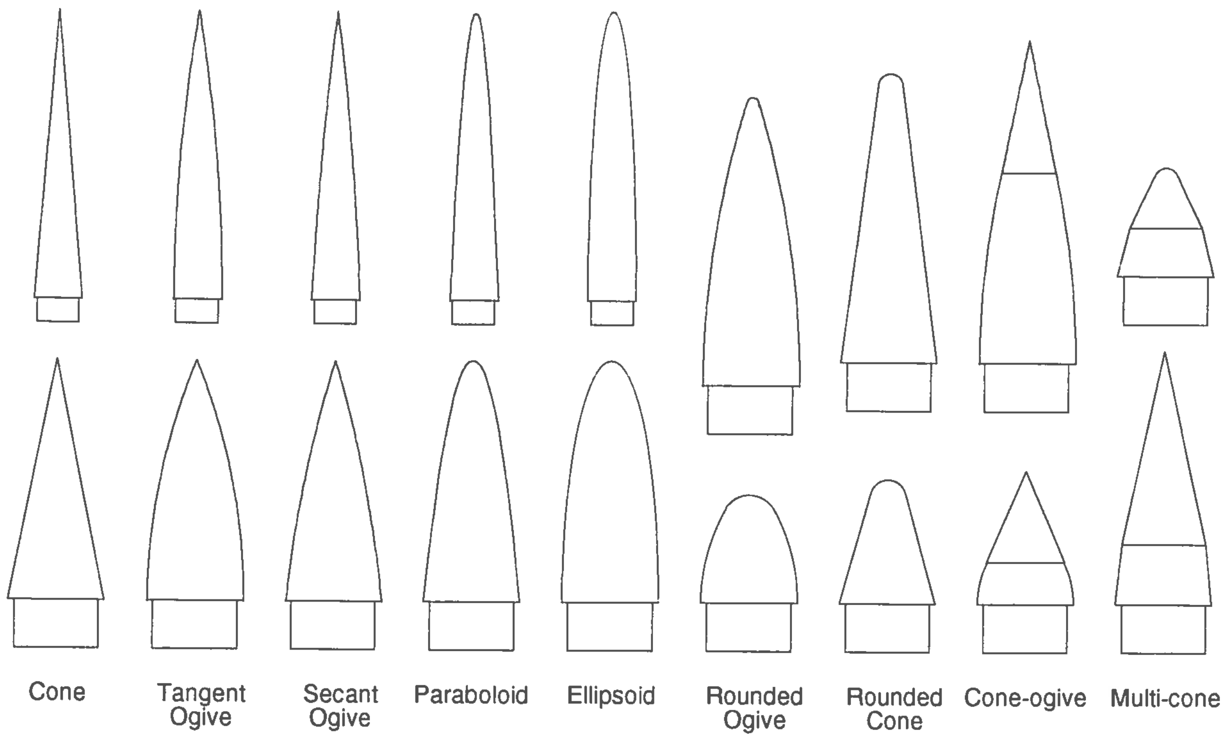
chuck. Do not remove the part before you are completely finished, as you will lose the exact alignment no matter how carefully you reattach the dowel to the chuck. Apply sanding sealer or glue to the part, allow to dry, and then sand with very fine finishing sandpaper. Repeat until the part is perfectly smooth.

Wood-turning is also useful for many detail parts. Often you can turn down a simple bit of dowel mounted in a drill chuck. This is a handy way of making escape rockets, small nozzles, and other bits and pieces.

Custom Wood Turning

Balsa Machining Service offers custom-turned transitions as well as conical and ogive nose cones for modelers without the equipment for wood turning. BMS will produce tangent ogive and conical nose cones up to 3.937" in diameter and 10" long.

This 1/24 scale Thor-Able features a hand-turned nose cone and upper transition. The long lower transition section is a paper shroud.



Some Common Nose Cone Shapes:

The cone, tangent ogive, and secant ogive are common sounding rocket nose shapes. Cones and tangent ogives are available for model rockets in a number of sizes and aspect ratios. Paraboloids and ellipsoids are common model nose cones but are infrequently used on full-size rockets, which usually exceed the speed of sound. Many sounding rocket ogives have a slightly rounded tip, as do most blow-molded model nose cones. The air-launched Pegasus has a blunt rounded ogive quite similar to Estes's Big Bertha cone. Rounded cones are common on satellite launchers. Modelers can turn this shape from wood, round off existing cones, or build up the shape with a paper cone and a balsa tip. The cone-ogive shape was used by the Viking sounding rocket and Corporal missile. This shape can be achieved either by hand turning or by adding a paper cone to the tip of an existing ogive cone. Multi-cone ogives can be hand turned, built up from paper cones, or even trimmed down from balsa cones.

Paper Transitions

Often, conical sections must be hollow, or they are larger than you can turn with the tools at hand. In such cases, you can make paper transitions. In principle, paper transitions are very simple. You just cut them out, glue a tab, and it's done. When you are scratchbuilding, however, they present some special problems. First, you must calculate and lay out the correct shape on paper. Secondly, you must support both ends of the paper to have a rigid part that is humanly possible to glue into place.

You will need three numbers to calculate the dimensions for a tapered shroud. These are: shroud height H, small diameter D_1, and large diameter D_2. From these, you can calculate the inner and outer radii R_1 and R_2 to lay out on the shroud.

$$R_1 = \sqrt{(D_1/2)^2 + (HD_1/(D_2-D_1))^2}$$

$$R_2 = \sqrt{(D_2/2)^2 + (HD_2/(D_2-D_1))^2}$$

Finally, calculate the angle θ to lay out for the shroud:

$$\theta = 180° \times D_2/R_2$$

Don't forget to add a glue tab! The overlap of the tab can be eliminated if you glue a separate glue tab to the inside of the shroud. Lay out the shroud on card stock or heavy paper, available at most print shops. In general, you will want the strength of thicker stock for large shrouds, and the flexibility of thinner stock for small shrouds that are more tightly curved.

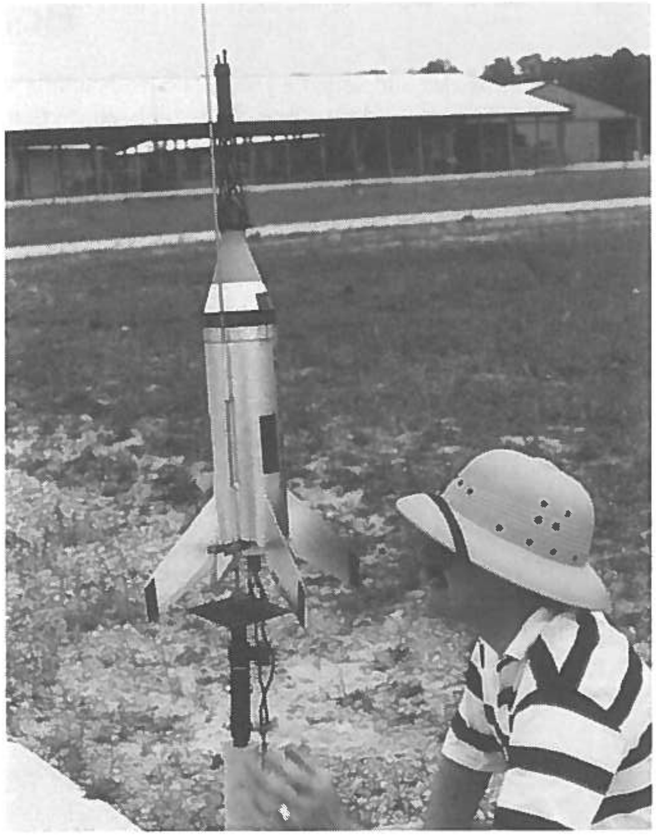
Support at the small end of a conical shroud is usually simple. The narrow end rests against a body tube that runs the length of the shroud. The lower end requires some special provisions. If the cone just butts against the end of the body tube, there is nothing to hold the shroud circular while the glue sets. The solution is to provide a structural member, such as a stage coupler or wound paper adapter ring that fits inside the shroud. This may be the shoulder of a nose cone section, or it can also be glued in place to the larger tube.

After cutting out a shroud, it often helps to put some curl into the paper before gluing it. Rub the paper against a dowel or other cylinder to avoid creasing the paper.

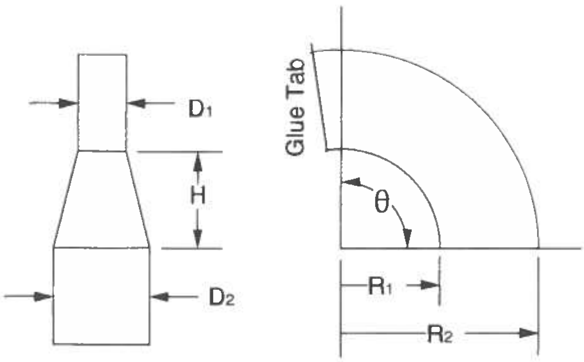
Water-based glues such as Elmer's or Titebond can warp or wrinkle thin paper. Glues such as Duco cement or Testors wood glue are ideal for gluing thin paper. Hold the seam over a mandrel such as a dowel or small body tube while the glue dries to give the seam some curvature.

You can also make shrouds of thin styrene sheeting, glued with cyanoacrylate glue ("super glue").

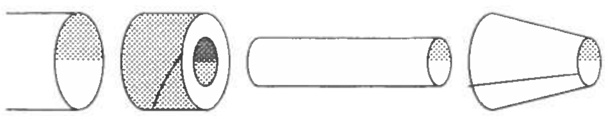
Estes sells a paper adapter kit that includes adapter rings and paper shrouds. The instructions in this kit give useful tips for building up paper shrouds. The kit is available separately and as part of the Designer's Special kit.



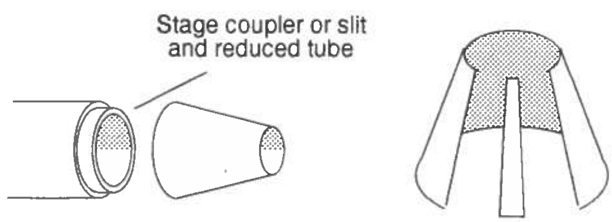
Tom Secrist made the capsule for this Little Joe from a series of paper transitions. (Fred Williams photo)



The dimensions required to lay out a paper shroud



Assembly of paper adapter section



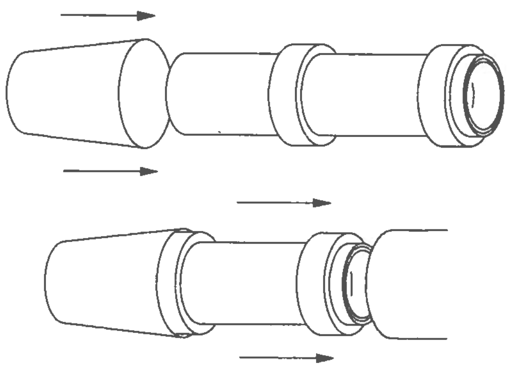
Alternative support for large end of shroud: An inside tab produces a less conspicuous seam than an overlap tab

Boattails

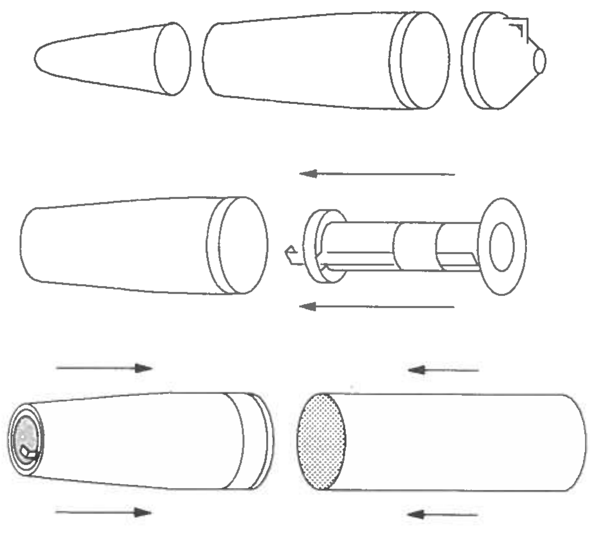
Many missiles and sounding rockets have boattails at the aft end. These tapers at the rear of the tube reduce drag for both prototype and model rockets. Often (for instance on the Standard Aerobee or the Arcas), these can be modeled with paper shroud. However, some prototype boattails (such as that of the V-2) are rounded, rather than conical shapes. In some cases, these can be modeled with sawed-off plastic nose cones. This sort of construction requires careful selection of adhesives. Use tube plastic cement for plastic-wood and plastic-paper joints. Use tube or liquid cement for plastic-plastic joints. Use wood glue for wood and paper joints. If that's too complicated, just use epoxy or super glue for the whole thing!

If there are no plastic cones of the right shape, you can turn a wood tail cone. Turn the outside as you would a flat-tipped nose cone. Before removing the part from the lathe or drill, turn a circular groove into each end. These should be the diameter of the engine mount tube. Remove the part from the chuck, and use the turned grooves as guides for drilling out a cavity for the engine tube.

Paper boattail

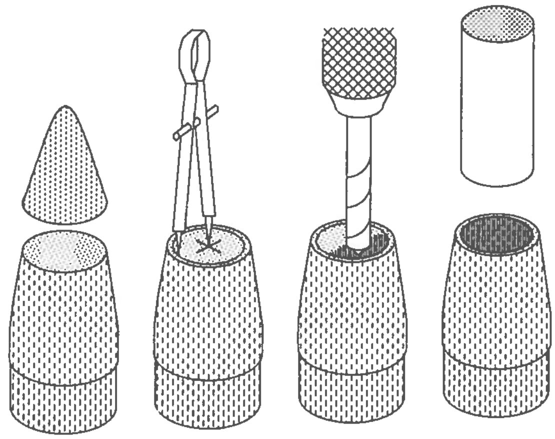


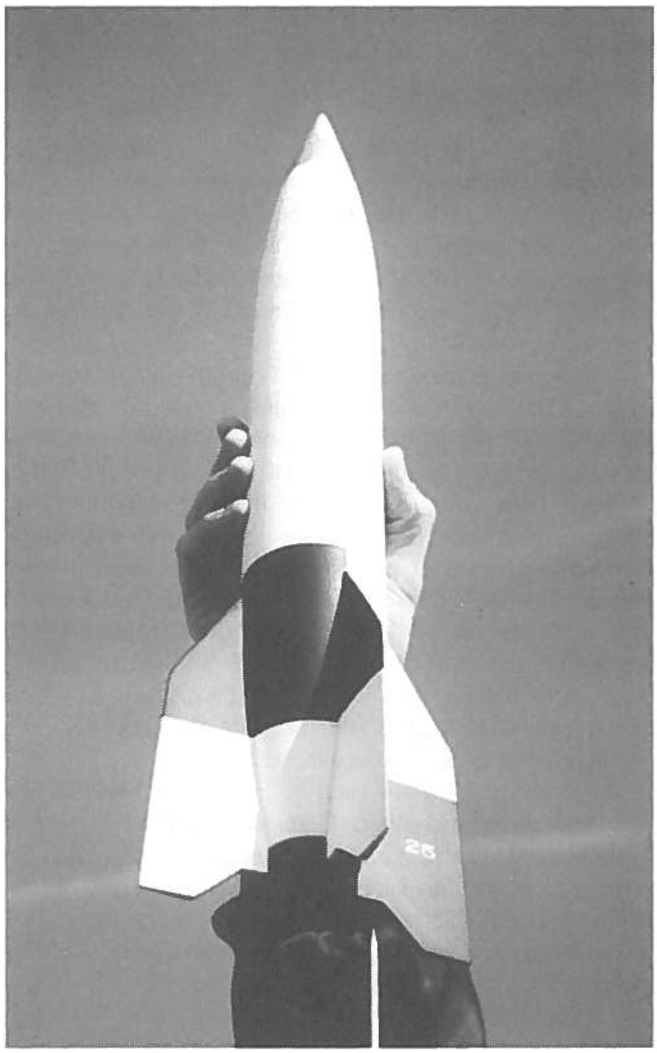
Boattail using plastic nose cone.



Balsa Boattail:

Cut off tip of balsa nose cone, mark circle with outside diameter of engine tube (both ends of cone), drill out opening for engine tube, glue engine tube in place.





Mark Chrumka made his 1/25 scale V-2's boattail by sawing off an Estes PNC-80K nose cone.

Body Tubes

Cutting Body Tubes

Straight, clean body tube cuts are the mark of a good scale model. My favorite method for cutting tubes is described in the *Model Rocket Manual* included in Estes Industries' catalogs in the late 1960's and early 1970's (and again in 1994).

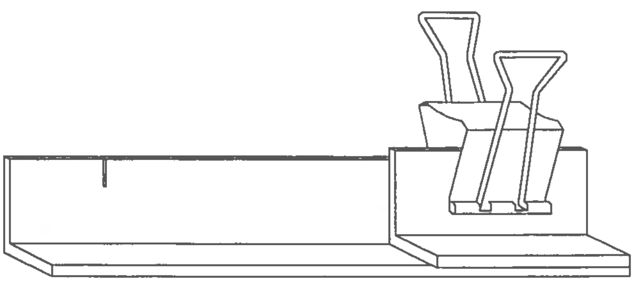
Mark the length of tubing desired. Tear a strip from a sheet of paper. Wrap it tightly around the tube a couple times to insure the factory-cut edge is truly perpendicular to the tube. Tape the paper strip to hold its alignment (if you have a piece of tubing that slips over the tube you are cutting, use it instead of paper). Draw along the factory-cut edge with a pencil (you can use a pen if that part of the tube will be painted a dark color).

Give the tube some internal support while you cut. A stage coupler or expended engine under the cut works well.

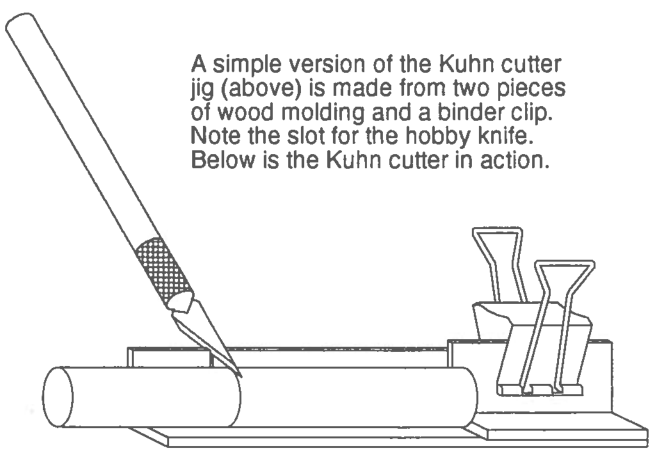
Cut with light, even pressure while rotating the tube. It will take three or four turns to cut through the tube.

To sand the cut, slide the internal support (stage coupler or engine) flush with the cut end of the tube. Lay sandpaper on a smooth tabletop and hold the tube vertically. Sand the whole cut with a circular motion. Rotate the tube periodically to insure even sanding around the cut.

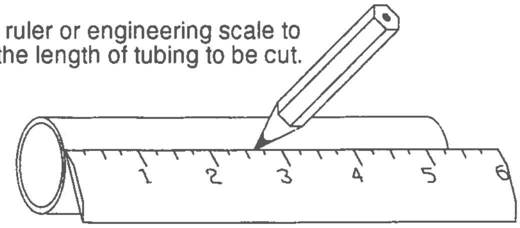
The Kuhn cutter (named for its inventor, modeler Howard Kuhn) is a useful jig for cutting tubes. It can be made from wood molding, or metal angle iron, and allows the modeler to cut a tube without marking it. Estes Industries sells a plastic tube marking and cutting tool that works in a similar manner.

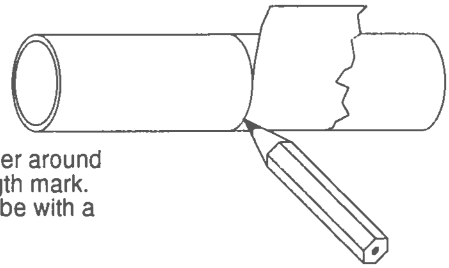


A simple version of the Kuhn cutter jig (above) is made from two pieces of wood molding and a binder clip. Note the slot for the hobby knife. Below is the Kuhn cutter in action.

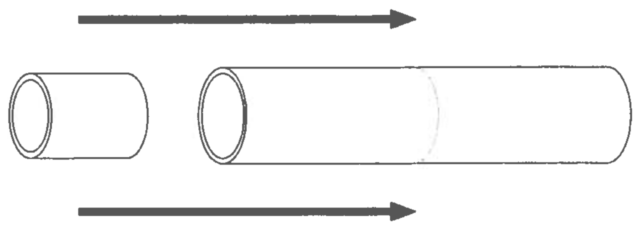


Use a ruler or engineering scale to mark the length of tubing to be cut.



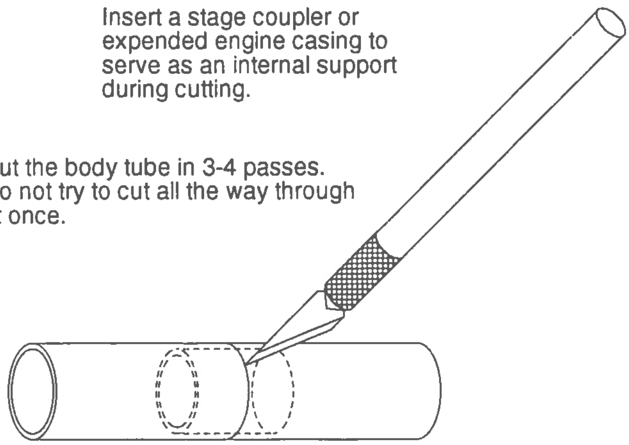


Wrap a strip of paper around the tube at the length mark. Mark around the tube with a pencil.

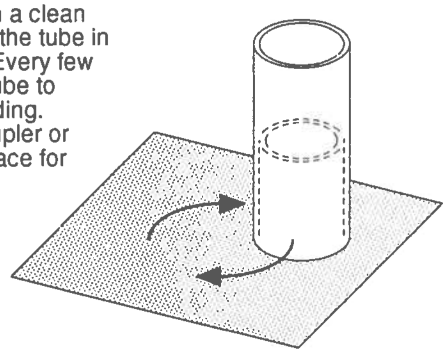


Insert a stage coupler or expended engine casing to serve as an internal support during cutting.

Cut the body tube in 3-4 passes. Do not try to cut all the way through at once.



Sand the cut end. Place #320 sandpaper on a clean tabletop and move the tube in a circular motion. Every few circles, rotate the tube to insure uniform sanding. Keep the stage coupler or engine casing in place for support.



Tube Clustering

Some rockets, such as the Saturn I and IB, feature clusters of tubes nested in a larger tube or grouped around a core. To fabricate such an assembly, you will first need to choose tubes that will fit, and then you must determine the size of an inner core tube.

If you wish to cluster a number of small tubes within a larger tube, select the row from Table 4 corresponding to the number of tubes to be clustered. The number in the second column is the ratio of the outer tube's inside diameter to the clustered tubes' outside diameter. Divide the outer tube's diameter by the diameter ratio to find the maximum diameter that you can cluster inside. For example, if you were to build a BT-80 Saturn IB, you would need to cluster 8 tubes within the 2.56" inside diameter of that tube. Dividing (2.56 / 3.613 = 0.709), you would find the largest tube diameter that would fit. And you would conclude that BT-20 at 0.736" doesn't quite make it. If you are looking for an easier scale to build to, you could try searching for a diameter ratio near 3.613 in Table 2, using the procedure described in the section on selecting a scale. Ideally you would simply scale up from known dimensions, but if you do not know all the diameters, or you need to know how oversized the clustered tubes can be and still fit, Table 4 is useful.

If you are building a model with more than four clustered tubes you will need a core to support them. If you cannot find a core tube of just the right diameter, don't despair! This core will not be visible on the completed model, and so it need not be a perfect cylinder. If the model is small, you can use an undersized core tube and glue two or three spiral wound paper adapter rings along its length. These can be peeled down to exactly the right diameter before assembly. For instance, a 1/130 scale Saturn I built with a cluster of eight BT-5's can use a BT-20 core with 20-50 rings. The "Outside Fit" ratio for eight tubes is 1.613. Multiplying by the diameter of BT-5: 0.541" x 1.613 = 0.873". This is the required outside diameter of the core. It is a simple matter to peel the 20-50 rings down to 7/8". The next step is to glue the BT-5's together in pairs. Set them to dry on a flat surface and they will be parallel. Finally, glue the pairs to the core tube. For larger tubes, where wound paper rings aren't available, you can wrap paper strips around the core for the same effect.

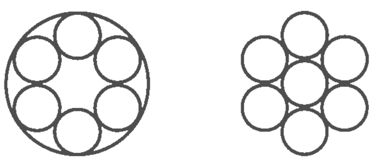
If you are clustering more than eight tubes, use the following equation for the tube diameter ratio needed to nest N body tubes inside a single, larger tube:

$$\text{Diameter ratio} = (1 \div (\sin(180° \div N))) + 1$$

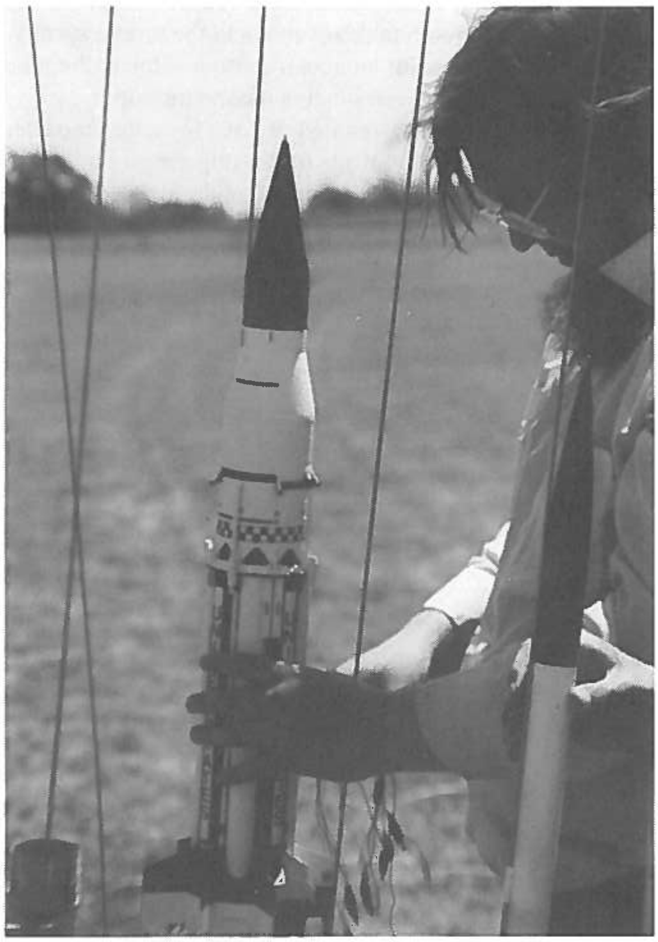
The third column of Table 4 is for the case of multiple tubes clustered around a core. The figures indicate the ratio of the core tube to surrounding tubes. If there are more than 8 tubes, use this equation for finding the diameter ratio for N tubes arranged around a core tube:

$$\text{Diameter ratio} = (1 \div (\sin(180° \div N))) - 1$$

Table 4: Tube Clustering Ratios



Number of tubes	Inside fit tube ratio (Outer Tube ID ÷ Cluster Tube OD)	Outside fit tube ratio (Core OD ÷ Cluster Tube OD)
1	1.000	-----
2	2.000	-----
3	2.155	0.155
4	2.414	0.414
5	2.701	0.701
6	3.000	1.000
7	3.305	1.305
8	3.613	1.613

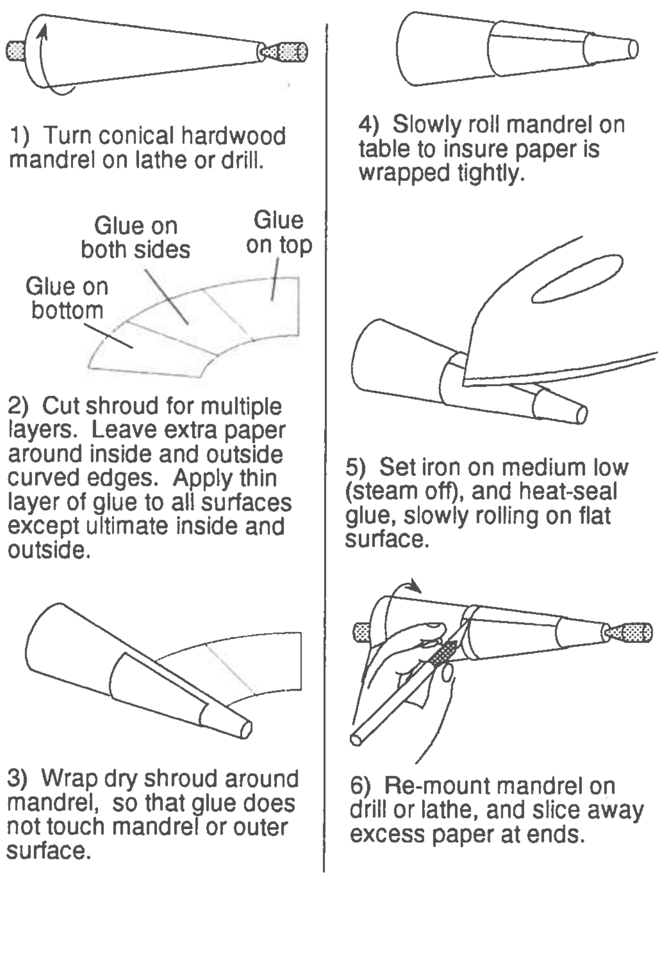


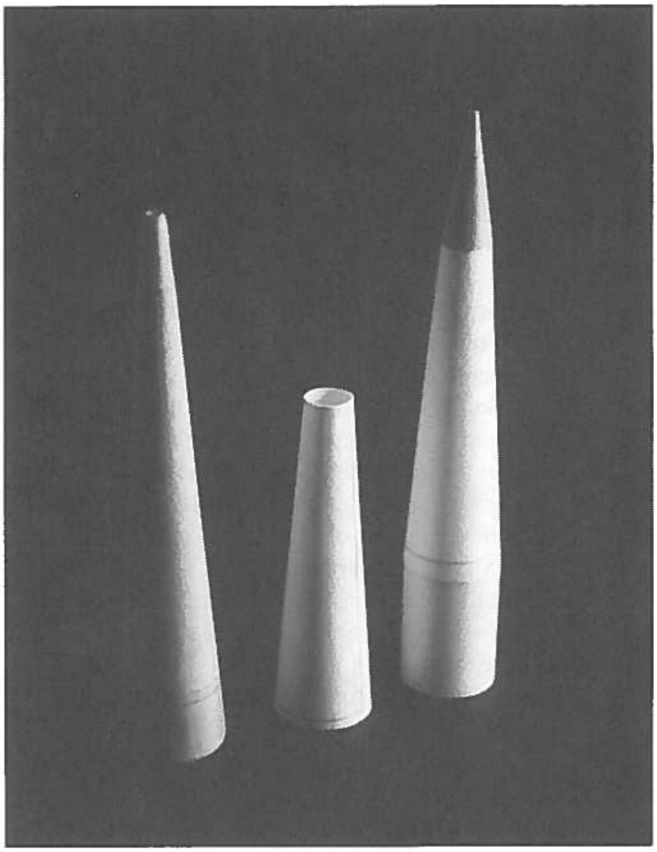
The clustered tubes of this Saturn I make it an appealing model. The eight BT-50's were slit and expanded to match the 1/69 scale of the other tubes. (Mark O'Brien photo)

Rolling Tubes and Long Tapers

Sometimes you must resort to rolling your own tubes. In 1986, modeler Randall Redd suggested a relatively painless approach as a NARAM R&D report. Coat paper with white glue, let it dry, wrap it around a cylindrical mandrel, such as a wood dowel, and seal the glue with an iron set on medium low. If you didn't smear glue on the innermost and outermost surfaces of the tube, you can slip the completed tube off the mandrel. This method can be adapted for long conical pieces, such as Vostok boosters or Trailblazer nose fairings. For a tapered section, you will need to turn a conical mandrel on a lathe from a wood dowel. Cut out an oversized tapered shroud piece that will wrap around the mandrel at least twice. Smear white glue over all but the ultimate outermost and innermost surfaces. Roll up the shroud on the mandrel, and iron it to fuse the glue. Mount up the mandrel again with the shroud in place to trim the ends of the cone.

Parallel-Wound Conical Shroud for Vostok Booster and Other Gentle Tapers





Paper cone (center) was wrapped around the hardwood mandrel (left) and heat sealed. A hand-turned nose cone and a segment of body tube complete the Vostok booster (right).

Diameter Adjustment

Usually, a model can be built with a collection of "close enough" tubes. However, on occasion, tube sizes are just slightly off from what is required. This is common with clustered tube designs where a few percent difference will determine if a set of tubes fits inside a larger tube. In other models, a very slight diameter difference is required between two parts. A few percent error here can be disconcerting to look at.

To shrink a commercial tube, slit it down its length, and then re-glue the edges with a slight overlap. Or make two slices to get the desired circumference. Glue the removed strip of tubing to the inside of the tube. If the model has clustered tubes, point the seam inward. For such tubes you can even glue paper down the outside of the seam. A few bits of Scotch tape can hold the sliced edges together while the glue dries. If the model does not have clustered tubes, locate the seam under a conduit, fin, or other detail.

Many sounding rockets have fins attached to tubing slightly larger in diameter than the main rocket diameter. There are a number of tubes available whose diameters are so close that one tube will fit over another. If you can't find a close match, glue a layer of slit tubing over the main tube. Glue a fin over the slit to cover it.

Fins

Shaping Fins

Most model rocket fins are cut from balsa wood and trimmed and sanded to the desired shape. Balsa is a wonderful material, being extremely lightweight and strong enough to withstand rocket flight at speeds exceeding 300 mph. But balsa has the problem of a very open grain and a soft surface. It takes a lot of time and effort to fill wood grain, and the softness of balsa makes it difficult to form the sharp-edged facets of many scale rocket fins. Basswood, available in good hobby shops, is free of these problems. You can sand and seal a smooth surface on basswood in half the time it takes for balsa, and sharp edged fins are easy to make. For thicker fins, softer balsa is easier to shape; effort saved removing a volume of wood may make up for the extra effort in surface preparation. Model aircraft plywood is more difficult to seal than basswood, and it is difficult to shape its cross-section. Save it for parts that need its bi-directional strength.

Begin by making a fin pattern. It may be convenient to reduce or enlarge a source drawing with a photocopier, or you may need to lay out a pattern to scale with a ruler. Lay out the pattern on graph paper to insure appropriate lines are perpendicular or parallel. As a *Sport Scale* judge at two national meets, I have found out-of-true fin outlines to be the most conspicuous construction flaws on many models.

If the root edge is irregular to conform to a boattail or transition, be sure the fin conforms to your model rather than to a perfect scaled down prototype. Cut out the pattern, and trace the outline onto the wood. You might want to make the pattern oversize on all edges by about a quarter of the wood thickness, in case you have trouble cutting perpendicular to the wood surface. It is conventional practice to run the grain along the leading edge of the fin. The important idea is that every point on the fin should be connected to the body tube by a line along the wood grain.

Cut basswood or balsa with a hobby knife with a fresh blade. Don't try to cut through the wood in a single pass. Once the fins are cut out, hold them together in a stack and sand the edges on a table top. Check your progress against fin pattern (cut exactly to size). Be sure your parallels are parallel and your perpendiculars are perpendicular. Be careful not to round the corners unless they are rounded on the prototype. Use an emery board to shape root edges to match boattails.

Once the outline is correct, work on the cross-section (if you know it and wish to model it—it is not required for *Sport Scale* competition). To sand a scale cross-section into a fin, first trim the fin with a hobby knife. Then lay sandpaper on a flat, clean, hard table, and sand away. If the fin is faceted, mark the facet edges with a light colored marker. Don't press at all when you mark. Be careful to sand the facets only, as the edges can easily be ruined by a careless stroke across the sandpaper.

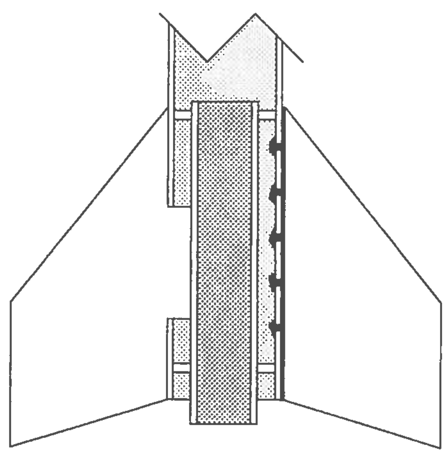
Attaching Fins

The joint between the fin and body tube is one of the most highly stressed points on a model rocket during launch and landing. Most model rockets have fin fillets (lines of glue spread along the fin roots) to reinforce this joint, but fillets detract from the accuracy of most scale models. So a good bond is especially important.

Always begin by marking alignment lines on the body tube. Aliphatic carpenter's wood glue (yellow glue such as Titebond) is excellent for bonding solid wood fins to body tubes. Before gluing the fins to the tube, rough up the body tube surface where the fin will be glued. I prefer to scribe a fine cross-hatching along a fin alignment mark with a hobby knife. Then I sand this down with #320 sandpaper. This allows glue to penetrate through the shiny glassine finish. Next smear a small amount of glue into the fin root and the roughened body tube. Force glue into the porous surfaces, and wipe as much of the glue as you can away with your finger. The glue will dry within a few seconds. Next lay down a paper-thin film of glue on the fin root. It should remain wet long enough for you to apply the fin to the body. Attach the fin, and check alignment. In seconds, the joint will hold the fin on, and you can proceed to the next fin.

For additional strength, use through-the-wall fins. Cut out your fins with a tab on the root edge that fits into a corresponding slot in the body tube. If you are attaching built-up or clad fins, the tab can be thinner than the full fin thickness, so no gaps will be visible.

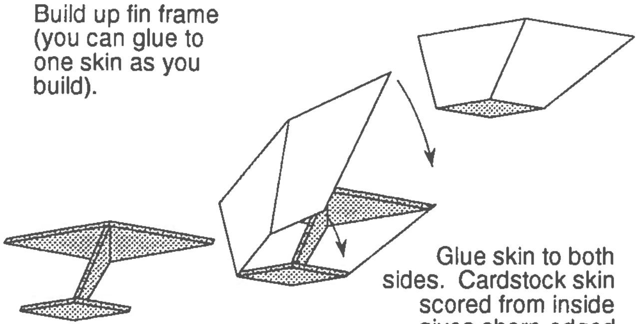
Epoxy is the favored adhesive for large, high-impulse models. One trick for epoxy joints is the epoxy rivet. Before gluing the fin to the body, drill holes through the tube and fill them with epoxy. Then epoxy the fin in place. Use slow-curing epoxy, rather than the 5- or 10-minute stuff.



Extra-Strength Fin Attachement:
Through-the-wall (left) and epoxy rivets (right)

Built-Up Fins

Built-up fins are made of a covered framework. They are a favored way of modeling faceted fins. Construct a framework from balsa, basswood, plywood, or plastic. You can glue this frame directly to half the fin skin as you build it. Cover the frame with paper, cardstock, sheet styrene, or waferglass scored along the facet edges.



Clear Plastic Fins

It is a polite fiction in model rocketry that clear plastic fins are invisible to the eye. Certainly well constructed clear fins can be hard to spot in photographs, and they are the only practical way to represent finless prototypes.

The easiest way to build clear fins is to use a prefabricated clear plastic fin unit. Until very recently, Estes Industries produced such a unit for their BT-60 tube. You may still be able to find these units in older kits, including the "Beta Launch Vehicle," Gemini-Titan II, Titan II, and MX Missile. Older stock "Bail-Out" kits also have these units. The 2-part units include a lock ring glued to the base of the model and a fin unit/engine retainer that attaches to the ring for flight. This design works best on subjects whose rocket nozzles don't project far below the rear of the tube. The various Atlas vehicles and the British Black Arrow come to mind.

Another clear fin unit manufactured by Estes comes with the non-flying "Phantom" kit. This unit fits BT-50 tubing and is an integral part of the body. The fins protrude out the side. By masking the clear fins and painting the cylindrical body portion, a reasonable effect is possible, especially if the fin root is hidden by strap-on boosters. It is a good choice for a Delta booster.

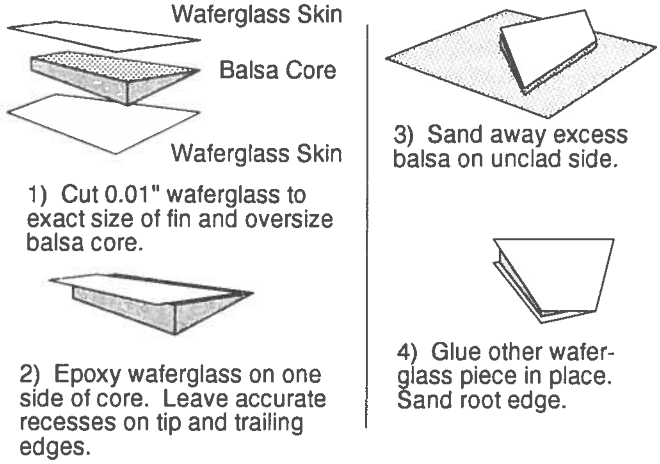
Usually you will have to cut fins from clear plastic, such as Evergreen or Plastruct sheets sold in hobby shops. To avoid unsightly glue joints, make your fins with tabs that can be inserted into the model. Ideally the tabs should fit into inconspicuous slots in the rear of the model. With a little creativity, you can make your fins look like an attractive display stand on the ground.

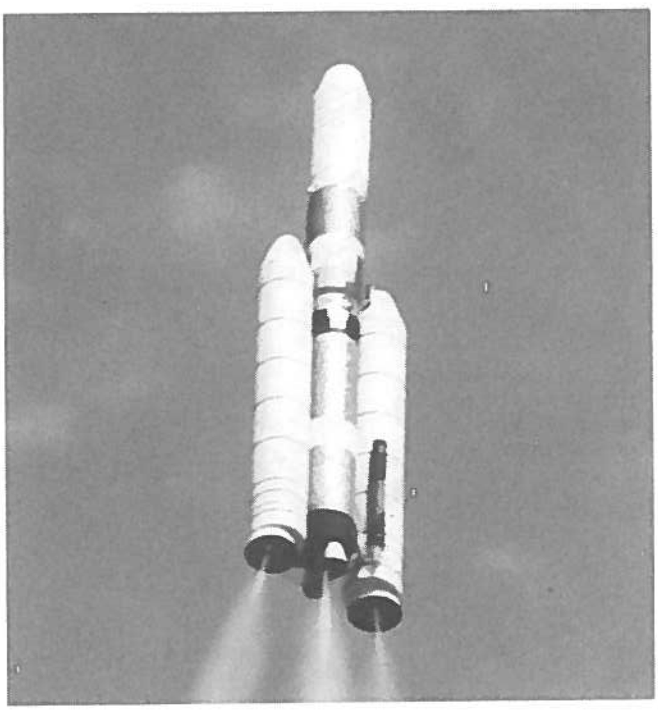
The clear, box-style fins on Marc McReynolds's Titan IIIC are nearly invisible in this photo by the modeler.

Clad Fins

If you really hate sanding and sealing balsa or basswood fins, try waferglass-clad fins. Waferglass is a thin fiberglass sheet available from Apogee Components. This works especially well on prototypes like the Aerobee 350 and Astrobee 1500, whose recessed fin tips require the fin's skin to extend beyond the core. Make the core of the fin from balsa, slightly oversized. Glue one 0.010" waferglass fin surface in place with the correct recess at the tip and trailing edge. Sand the uncovered balsa surface to the correct wedge shape, stopping when you get down to the waferglass on the leading edge. It is easy to sand away the excess balsa, because the waferglass is much harder. Then glue a second piece of waferglass to the sanded side, completing the fin. Finally, sand away excess balsa at the fin root. The waferglass accurately simulates the thin sheet metal skin on the prototype, and is strong enough to support the model.

Waferglass Clad Fins with Recessed Edges:





Detailing

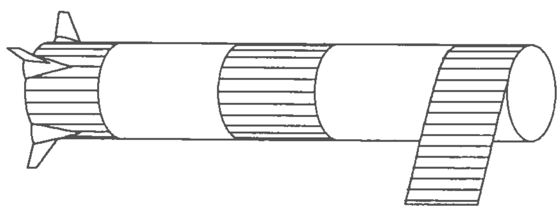
Detailing is an art that can use all sorts of unlikely supplies. Styrene strips, bits of wood dowel turned on a drill, paper, and toothpicks can all find their way into a scale model. Often the question is, "where do I stop?" The amount of possible detail is nearly infinite for a large vehicle, and a perfect model would take decades to complete. One general rule is not to bother with any details smaller than the larger imperfections on the model. There is no point drawing the eye in to admire millimeter-sized details that will be overshadowed by surrounding two-millimeter flaws. This won't impress the judges if it is a contest model. If you are not building for a contest, stop detailing when you get tired of it. Even if you are building for a contest, there are no requirements for fine detailing.

Corrugations

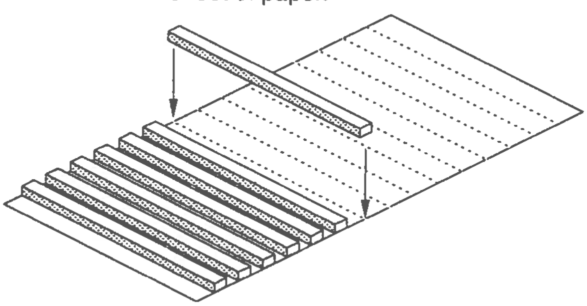
There are several types of details that appear on many rockets. One of the most common is corrugated tube sections. In some cases, this is actually corrugated metal, and in other cases, a smooth surface has stringers attached, running the length of the reinforced section. Both textures can be modeled with the same techniques.

The simplest approach to corrugated segments is the prefabricated wraparound. Model railroaders build corrugated metal structures with a thick stamped aluminum foil, or corrugated sheet plastic. The aluminum material is flexible and comes in different ridge spacings corresponding to different scales. Unfortunately, paint does not adhere to aluminum as well as it does to plastic, so if you mask over this while painting, you run the risk of ripping up patches of paint. The plastic corrugated material is a bit thick, making it hard to bend, and leaving an obvious diameter step.

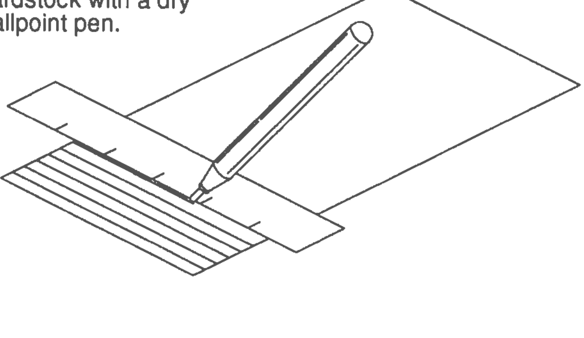
Cardstock or plastic wrap-ons make corrugations simple.



Plastic strips from Evergreen make nice corrugations when glued to a marked sheet of paper.



You can make simpler corrugations by scribing cardstock with a dry ballpoint pen.



You can make your own corrugated wraparounds by scoring card stock with a ballpoint pen. If you have one that's run out of ink, the ink won't show through the paint. This approach is quite satisfactory for fun scale and *Sport Scale* models.

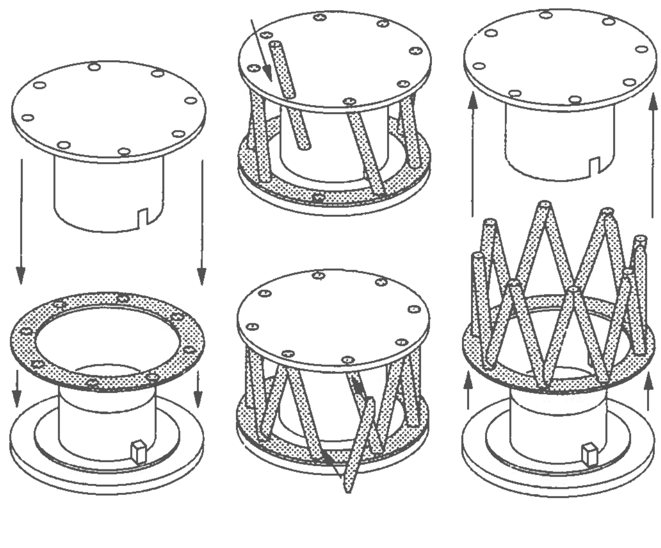
Styrene strips are excellent for simulating corrugations. A well stocked hobby shop should sell a wide range of widths and thicknesses of strip stock. Glue these directly to the body tube, or to a thin sheet of paper or styrene to act as a wraparound. You can photocopy graph paper (the stuff with blue lines is hard to copy—use the green-lined paper) with a reducing/enlarging machine so that the line spacing corresponds to the correct stringer spacing, and then glue the styrene strips to the photocopy.

Use liquid plastic cement for the plastic strips. First position the strip and then brush a drop of liquid along an edge. Capillary action will carry the cement under the strip. Use wood glue to attach paper or cardstock wraparounds to the body tube. Roll the wraparound onto the tube, line it up, and glue one end to the body with a thin layer of wood glue applied to the body tube (water-based glue applied directly to a paper wrap-around can cause wrinkles). Then unroll the wraparound and proceed to glue it the rest of the way.

Framework

Another sort of detail is the open framework often found between stages or supporting escape rockets. There are several approaches to building these structures. The old Estes Mercury-Redstone and Saturn IB kits had the modeler

One of many possible jigs for assembling interstage framework.



lay out wood dowels on a flat surface, and then glue the sections together into the full three-dimensional shape. An alternative approach is to start by gluing major struts into place supporting the escape rocket above the capsule. Then you can add the smaller struts in between. For fun and *Sport Scale* models, the smaller struts need not be structural parts. They can be cut from a single piece of cardstock. The results are convincing from a distance.

A carefully constructed jig can hold critical framework parts in place during gluing.

Conduits

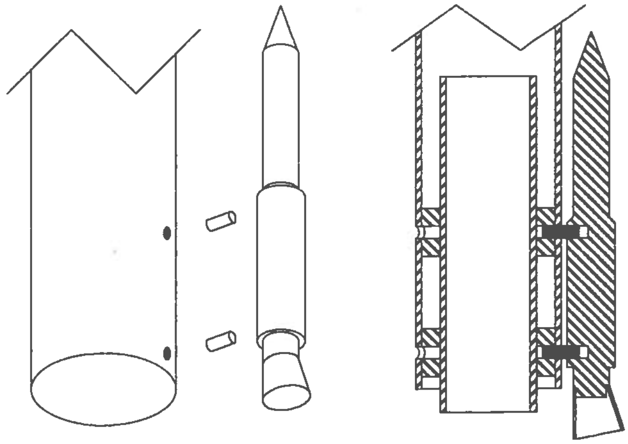
Conduits running along tubes are another common detail. Rectangular strips can be modeled with styrene or hardwood strips. Rounded conduits are a bit more difficult. Basswood half-dowel sections are sometimes sold as dollhouse supplies. Various other cross-sections are sold for dollhouse moldings as well. Your hobby shop may be able to special order some for you. Balsa conduits are easy to make, but filling the grain is time-consuming.

Turned Details

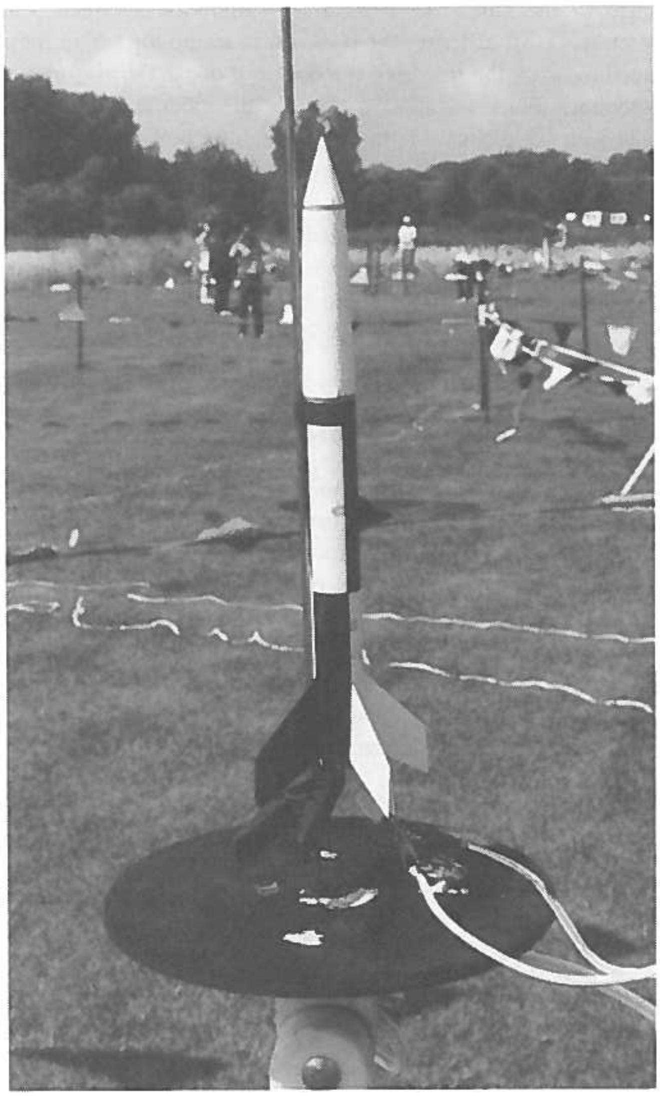
Just as nose cones and transitions can be turned from wood, so can small detail parts. Often a part can be turned simply by inserting a wood dowel into a drill chuck and attacking it with files and sandpaper. Just as with nose cones, it helps to seal the wood grain while the part is still on the drill.

Attachment

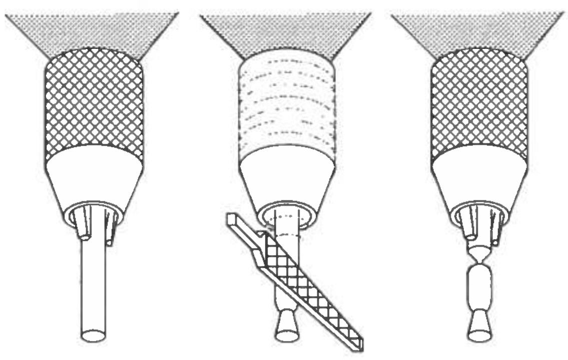
Many details, such as the Recruit boosters on the Astrobee 1500, can be attached to body tubes with pins. This works best if there is a spiral wound adapter ring or other support glued into the body under the hole. Drill 1/16" holes into the tube and into the detail, insert 1/16" brass tubing into the holes. This way you can securely attach the details after painting.



Attachment of details using pins. A Recruit booster turned from wood (with paper shroud nozzle) is shown. Wound paper adapter rings inside body tube give support. Drill holes deeper than needed. Use a sheet of wood or cardboard to maintain correct spacing when gluing.



This tiny 1/42 scale Astrobee 1500 features boosters turned from wood dowels and attached with pins. Nose details are made from folded paper. Fins are waferglass-clad balsa.



To turn a detail part, mount a wood dowel in the chuck of a power drill or drill press, use small files to shape the part, and cut it free with a razor saw.

Vacuum Forming

Vacuum forming (vacuforming) is a good way to make very light, large components. In essence, vacuforming is a way of sucking heat-softened sheet plastic onto a form. You will need an oven and a shop-type vacuum cleaner. You will need to make a frame to hold the plastic sheet and vacuum box. The frame is made from two wood, pressboard, or metal parts that hold the sheet plastic between them. You can clamp them together with clamps or screws. For most uses, a 4" by 4" area of exposed plastic is adequate. Use plastic with an extra 1" around the edges for the frame to grip (6" by 6" sheet). Depending on the size of the part, plastic between 0.02" and 0.04" thick works well. Heat in the oven until it begins to sag (hold the frame off the oven rack with old cans). Remove the frame and place it on the form and vacuum box.

The vacuum box should be big enough to hold the plastic and frame, and deep enough to attach your shop vac hose to the side. 8" x 8" x 2" should be adequate for starters. Drill at least 100 1/16" holes in the top. You may need to brace the inside of the box so it doesn't distort under vacuum. Place the master part on the vacuum box before you heat the plastic. Turn on the vacuum just as the plastic is ready. Quickly take the plastic and frame from the oven and place it on the box and form.

For more details, consult *Do It Yourself Vacuum Forming*, sold by *RC Modeler* magazine. A vacuform kit is available from Vacuum Form of Lake Orion, Michigan. Sizes range from 6" x 9" (4" x 7" effective area) up to 12" x 18" (10" x 16" effective area).

Casting

When a small, hard-to-make shape is to be used repeatedly, you may want to experiment with resin casting. Fabricate a single master part with all seams and wood grain carefully filled. Attach a flat root edge of the part to a flat surface such as a scrap of plastic sheet with two-sided tape. Build a dam or box around the part with plastic sheeting. Brush the part with room-temperature vulcanizing rubber (RTV), then pour RTV over it to submerge it. Once the RTV cures, the part is removed. A mold release may be sprayed into the mold. Then pour a resin, such as Alumalite, into the mold. Work out the bubbles with a toothpick. When the part cures, remove it from the RTV mold. Refer to modeling magazines such as *FineScale Modeler* for details.

Plastic Model Conversion

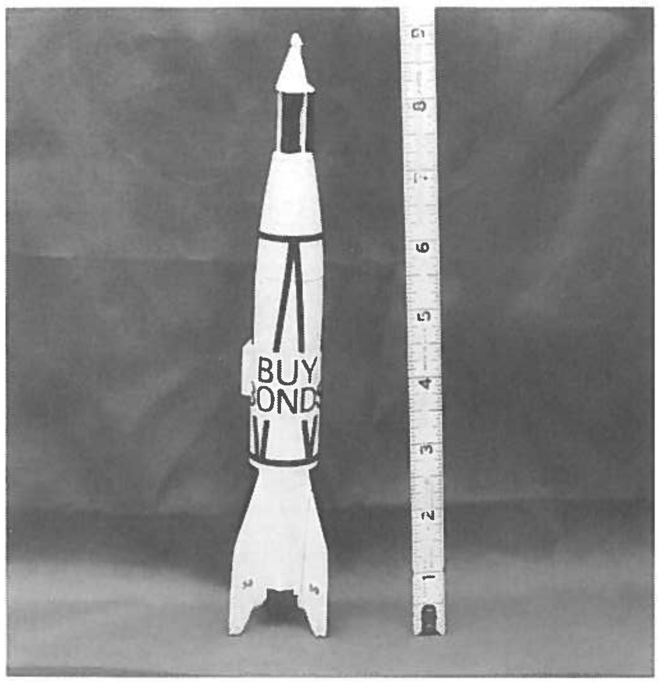
A popular technique for building scale model rockets is to convert a plastic model kit for rocket flight. Not only do modelers convert the few plastic rocket kits to fly, they also convert spacecraft, aircraft, and even science fiction models to fly under rocket power. These are permitted in NAR *Plastic Model Conversion* competition.

Plastic models are also excellent sources of components for traditional wood-and-paper models.

Aside from a number of Space Shuttle kits, most space-related plastic model kits were introduced in the 1950's and 1960's. Some of these are occasionally re-released. As this book goes to press, a 1/144 scale Saturn V, 1/48 scale Apollo Lunar Module, and 1/32 scale Apollo Command-Service Module are available from Monogram. Glencoe produces a series of early speculative designs by Wernher von Braun as well as a 1/48 scale Juno I and 1/6 scale Explorer I satellite. Revell has recently re-issued their 1/24 scale Gemini Capsule. Other Revell re-issues are in the works as this book goes to press. With sufficient engines and appropriate clear plastic fins, any of these kits can be persuaded to fly. The Glencoe Juno I is especially well-suited for flight conversion. Because they are very asymmetrical Space Shuttle kits do not easily lend themselves to flight conversion.

Flying plastic models is especially challenging because plastic model kits are typically several times heavier than a similar model rocket kit. When converting a model to fly, build the engine mount and recovery system into a conventional cardboard model rocket body tube to insulate the plastic from the heat of the engine and its ejection debris. One of the great challenges of plastic conversion is fitting a parachute and shock cord adequate for recovering a heavy model into this small stuffer tube.

Because plastic models are notoriously heavy, always weigh your model to insure it does not exceed the maximum weight recommended by the engine manufacturer.



Bill Dauphin converted this Revell 1/70 scale V-2 to fly, and added a scientific payload. "Buy Bonds" markings are accurate. (Bill Dauphin photo)

Finishing Techniques

The paint on your model may go on last, but it is the first thing anyone sees. In particular, the quality of color divisions (masking) will determine in one step whether your model looks like a work of art or junk. If you find it impossible to do a good masking job, then put your efforts into ways of avoiding masking.

There are many right ways to paint a model rocket, and many wrong ways. These suggestions for finishing scale models are just a few of the right ways. Whatever specific techniques you use, the goals are the same: a smooth surface to paint, a uniform coat of paint, and clean lines between different colors.

Preparing the Surfaces

A good finish on a model starts with sanding and sealing wood surfaces. It is easier to sand and seal fins and details before gluing them in place. Begin by sanding all wood surfaces with #320 grit sandpaper. When you sand a flat surface such as a fin facet, sand on a table top, setting the sandpaper on the table and moving the part. Be sure there is no debris between the sandpaper and the table top.

I have used four materials for sanding sealer. Elmer's glue and Titebond are easy to find, and there are times when they are a superior material. They strengthen balsa fins and make it possible to glue parts to the sealed surface. Sig sanding sealer and Hobby Poxy Fast Fill tend to dry a bit faster and sand more easily.

I usually begin with a coat of Titebond smeared onto the wood with the straight edge of a scrap of wood. Press down while spreading the glue to force it into the wood and to simultaneously remove all but the thinnest possible layer of glue from the surface. Be sure to coat the edges.

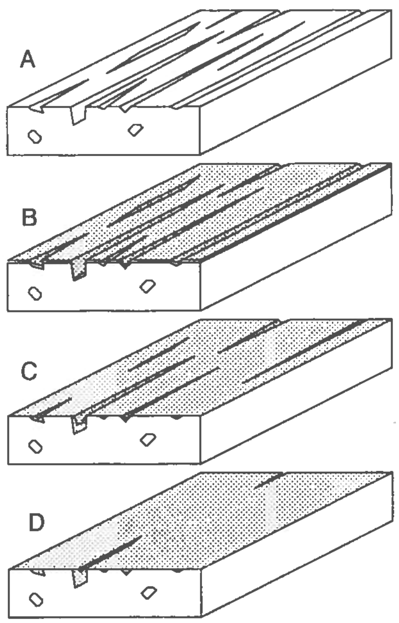
Once the glue is dry, sand it with #320 grit sandpaper. Hold the part up to the light and examine glancing reflections off the glue. You will quickly learn to recognize when the sandpaper has reached almost all of the fin surface, but hasn't reached the wood. If you don't have sanding sealer on hand, you can repeat the process until the wood is smooth. My preference is to apply one or two coats of glue before moving on to sealer.

Both Sig sanding sealer and Hobby Poxy Fast Fill work well for additional coats. The opaque white Fast Fill stands out against the wood and glue during sanding. Both products can be brushed on or spread on, although brushing is preferred. Be sure not to apply sanding sealer where you will be gluing later (root edge of a fin). Sand each coat of sealer down to the level of the previous layer. The contrast between the white Fast Fill and the darker transparent Titebond surface makes it easy to see the progress of sanding. One or two coats works for bass wood, while balsa requires three or four. Sand the final coat with #400 sandpaper. You might even want to use a coat of white spray paint as a final layer of sealer and as a test of the surface.

Nose cones require the same treatment as fins, but hold the sandpaper in your hand. If you are turning your own nose cone, complete sanding and sealing before removing the part from the lathe or drill. Balsa Machining Service sells a tool for finish sanding of pre-manufactured wood cones. The unit attaches to a power drill and can be screwed into the base of the nose cone.

Body tube seams also require filling. I've used Hobby Poxy Fast Fill for this, with reasonable results. Others use Hot Stuff and microballoons, spackling compound, and other filling materials. Use a fine paint brush to fill the spiral seams with your choice of filler. Carefully scrape away the excess. Then touch up the places where you completely scraped the filler. Scrape your touch-up. You may want to proceed with construction at this point. To complete sealing of the tube seams, spray with a couple thin coats of white paint (I use Dutch Boy/Kmart flat white; some modelers prefer Krylon white sandable primer). Look for remaining gaps along the seam, and fill. Lightly sand with #400 grit finishing sandpaper. Spray... sand... spray... sand... Keep this up for three to four cycles, and you will not only fill the spiral seam itself, but also the more subtle spiral contours on the body tube. You'll have to cut away the paint where you want to glue the fins on. The resulting tube is heavy but smooth. If weight is critical, just concentrate on the seams themselves.

You don't always need the same quality of sanding and sealing on all your models. Silver paint will mercilessly amplify every flaw in a surface, while minor surface flaws are lost behind a black and white checkerboard pattern.



Sanding and Sealing Balsa.

A: Open grain (magnified) of balsa must be filled.
B: Layer of glue or sealer.
C: After sanding, only deeper depressions remain.
D: Another cycle of sanding and sealing fills most grain.

A few more cycles will give the balsa a perfect finish.

Basswood may be ready to paint after just one or two cycles.

Painting

Do some careful thinking about when to paint your model. While ordinary "sport" model rockets are almost always painted after completion, scale models often have details and assemblies of contrasting colors that are most easily painted before final assembly. For example, the tank cluster section of a Saturn I or IB is most easily painted before gluing it into the tail shroud and upper stage section. The same holds for the tiny red and white ullage rockets that must be attached to a black and white body tube. When painting before assembly, remember that glue does not stick well to paint, so be sure there's plenty of paint-free area in the joints. If possible, use pins of wood, stiff wire, or brass tubing to hold parts in place. If your fins are too thin to hold this way, glue them on before painting and mask where needed.

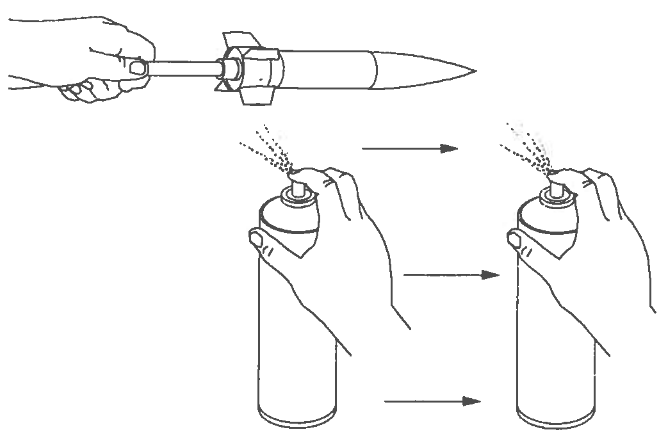
Before painting, you will need a handle for your rocket. Buy a supply of 1/2" wood dowels. You can insert one directly into a mini engine mounts. Shove an expended standard engine casing on the end, and it will fit into a standard mount. Add an expended D on top of that and you can paint D-powered models. Some people recommend rolled-up newspaper paint sticks. Unless you want to model big black scale fingerprints, I'd advise keeping newspapers far from your model. If you are painting the body of a model without the nose cone, protect the inside of the upper end of the body tube with a roll of paper or a wad of paper towel. If you are painting a nose cone alone, protect the shoulder of the nose cone with a scrap of body tube.

Whenever you decide it's time to paint, the first step is to apply a base coat. My favorite base coat is Dutch Boy flat white sold by Kmart. This paint goes on in very smooth, very thin coats. Apply this paint in strokes starting behind the tail of the rocket, and continuing past the end of the nose. Apply a thin coat—thin enough to dry in a few seconds. Turn the model a quarter turn, and spray another strip. By the time you get back to where you started, the paint will be non-glossy and dry enough for another coat. Continue this operation until the paint doesn't dry immediately. This should be after half a dozen rotations. Let the model dry for a few minutes. You may need two or three of these sessions to get an opaque pure white finish.

Testors flat white covers in fewer thick coats. If you use this as a base coat, be careful to avoid thick wet coats that may sag or run. Flat paints (particularly the Dutch Boy spray) dry quickly, and can be painted over by gloss or flat paints in an hour or two. Although decals usually adhere well to flat paints, they often leave unsightly air pockets, as the smooth decal film cannot make perfect contact with the micro-rough surface of flat paints. This is especially apparent over dark colors (most Honest John and other Army missile models end up marred by this problem). But flats have a more "realistic" look to them. Flats also cover surface flaws better, as there is no telltale glint of light off of irregularities.

Gloss paints are not well suited as base coats as they are slow to dry. They typically take several days to a week to cure completely. Flat paints applied over a gloss coat may shrink, leaving large, ugly cracks as the paint dries. A second coat of gloss paint must be applied either within hours or after a complete cure. A second coat of gloss a day later may create a wrinkled finish. In general, you should check for compatibility on scrap material when applying one brand of paint over another. Fresh gloss enamel does, however, hold decals smoothly, seamlessly, and permanently. Once gloss paint dries, it is a hard layer, resistant to yellowing. I prefer gloss paints for kits, which come with water transfer decals, while flats are better for doing multiple layers of masking and work well with individually applied vinyl or dry-transfer letters.

The choice of matte or gloss finish may have little to do with accuracy. The degree of gloss on most prototype vehicles is poorly documented, and often photographs give misleading impressions. In the end, a model may be oversprayed with a matte or gloss varnish (such as Testors Dullcote or Glosscote) to give the desired impression.



Hold the model by a 1/2" dowel while spraying in long strokes.

Masking

Masking seems to be a big trouble spot for many modelers. In my experience as a youth division scale judge at two national meets, I have found that masking is the most important step in making an attractive scale model. Your masking job is the first thing anyone will see when they look at your model. If you have trouble masking, practice on scrap material until you get it right. If you can't get it right, cheat.

The following masking instructions work well with flat paints: Let the base coat dry overnight first. I use Scotch "Magic" tape for edges, and aluminum foil for the interiors of large areas (you can use scraps of plastic bags or wax paper if you'd like, but I can see the foil more easily. Do not use paper, as some paints can soak through). You can substitute frosty "Magic" tape equivalents, but glossy transparent tape seems to adhere a bit too strongly for masking work. Masking tape usually leaves rough edges. Always press the tape edges to insure actual contact with the surface. This is especially crucial for masking tape. If there are corners or curves in the paint pattern, or you need to mask areas narrower than the tape, stick the tape to a clean sheet of plastic and cut it to shape with a hobby knife. If you trim the tape in place, you will score the surface of the undercoat, and chips may come up with the tape later. Also, check your hobby shop for narrow trim tape. There are also liquid masking compounds that can be painted on to protect irregular surfaces.

If I am painting just a small part of a model, I put the model in a plastic bag (beware of holes), and cut openings for the parts to be painted.

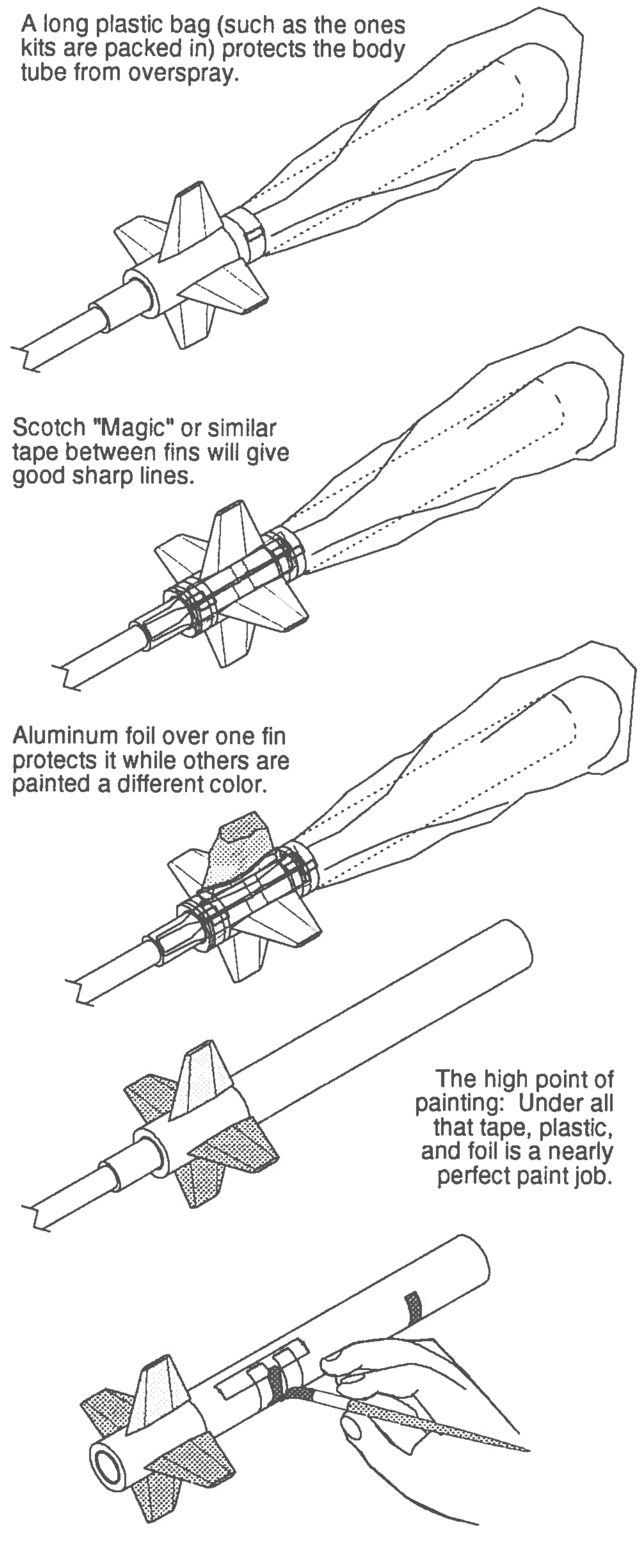
The second coat of paint should go on lightly, in many passes of the spray can, without creating drips that can sneak under your masking job. If you are using multiple colors, use the light colors first, then dark colors to black, then metallic silver, gold, and copper last, as they cover any color easily. Space launch vehicles are usually finished almost entirely in white, black, and silver. I usually use Testors flat black and metallic silver, using Testors chrome or Kmart silver only where an extra-shiny finish is needed, as these paints dry slowly and are easily smudged. For bright non-fluorescent colors, Testors gloss is most satisfying. Fluorescent paints require a white surface under them. Use flat white as an undercoat, as fluorescent paints will react with fresh gloss white, leaving unsightly cracks.

I never have the patience to let an overcoat dry completely before I start ripping off the tape. Once I can touch the tape without getting paint on my fingers, I start peeling the tape. It is possible that the overcoat may tend to chip or peel if it cures completely, but as I've never had the patience to wait that long, I don't know. Use a hobby knife to get a piece started.

Some problems will appear at this time if you are not extremely lucky. Don't Panic! You will notice that the spray from the second coat has managed to sneak around your masking job. Sometimes it is clear that the tape wasn't really down as well as you'd hoped. Let these flaws dry completely. Wiping them up will merely smear them around. Paint thinner will dissolve the undercoat (unless it is a gloss enamel that has set for a week or more). When they are dry, carefully scrape excess paint off with the edge (not the point) of a hobby knife. You will see places where the base coat has pulled up. They should be fairly small, and can be cured with a bit of paint brushed from a bottle. After the paint is thoroughly dry, you can touch up these spots with #600 sandpaper if they stand out. There may be places that you accidentally masked or somehow didn't paint. Again, paint from a bottle or even a magic marker (for a black second coat) can cover your mistakes.

If you can't get a sharp masked edge after all this, you can cheat and avoid masking entirely by applying decals or self-adhesive sheets to the model. Solid color decal material, clear decal material sprayed with the desired color, colored tape, and trim Monocote are all alternatives to masking. These work best on smooth areas without compound curves.

Masking a Model to Paint Fins:



Some small areas can be masked and painted with a brush with good results.

Decals and Markings

Once your model is painted you can apply decals, lettering, and insignia. The water transfer decals provided in most kits adhere best to fresh glossy surfaces. To avoid problems on matte finishes, apply a layer of Testors Glosscote to the area to be covered with decals. A later coat of Testors Dullcote will restore the matte finish.

When scratchbuilding, it is rare that you will be able to dig up correct decals. I have a collection of old decals saved from years of modeling, which helps out some, but usually I'm on my own. One very useful sort of decal is a stripe or solid color. These can be purchased at hobby shops, although I tend to use decals from model rocket kits I've bought for kitbashing. Cut the material to the correct size and shape, and be sure there is no transparent film around any edges. You will surprised when people marvel at the "excellent masking job." Hobsco Solvaset (available through the Walthers model railroad catalog) is the best decal solution I've tried for getting decals to adhere to irregular surfaces. Given time and multiple applications, Solvaset will convince decals to conform to the surface of the deepest corrugations.

Top Flite Monokote trim material is a self-adhesive film that is useful as well. It is thicker than decal material, but more flexible. The extra thickness is a minus, but the flexibility can be useful for straight lines on curved surfaces. Chrome Monokote trim displays different behavior. It is not as flexible, but it is a bit thinner. It gives excellent results on flat, cylindrical, and conical surfaces, but may not work so well on compound curves. You can also use striping tape, but this tends to be very thick and the results look like tape. Check the model airplane and car sections of your hobby shop.

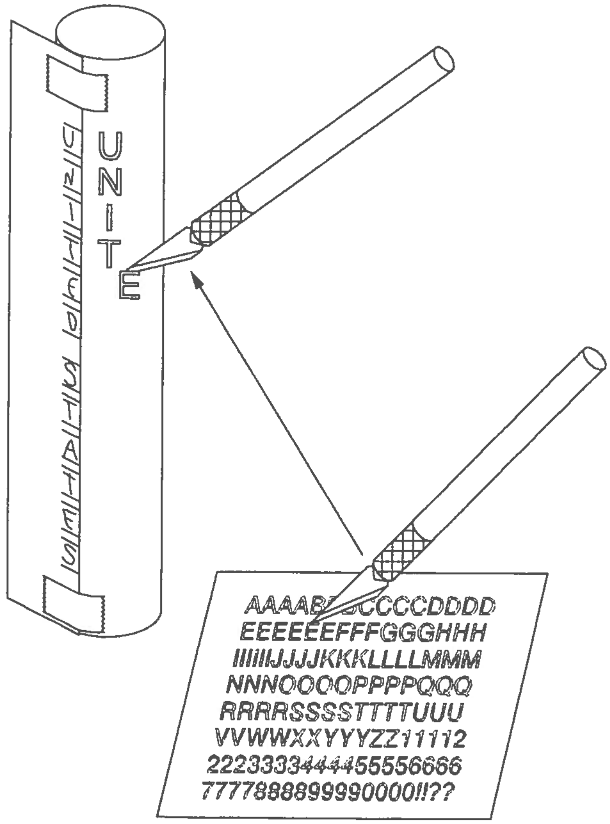
Lettering can be done in a couple of ways. Vinyl stick-on letters are cheap and come in several sizes and colors. You can even paint them or use them in masking. Peel them from the backing and set them on the model with a hobby knife. I find it helps to work out letter spacings on a strip of paper, and then tape the space-guide strip to the model as I apply letters. Vinyl letters are a bit thick for an ideal model, but they are much cheaper and more forgiving than the best choice—dry transfer letters. Dry transfer letters are rubbed onto the surface. Usually they are available in black only, but in a wide variety of shapes and sizes. Your local art supply store can special order colored letters. Dry transfer letters can be expensive; I have spent $10 for a sheet with only enough lettering for the first stage of just one Saturn I. Fortunately, black lettering in the smaller sizes is a lot cheaper. Look for both types of letters in office supply, art supply, and college bookstores.

It is also possible to create you own decals. Office supply stores and mail-order houses sell a number of adhesive label products for office copiers and laser printers. You can create oversize artwork by hand, reduce it at a copy shop, and copy it onto the appropriate opaque or transparent label material. If you have a computer with appropriate graphics software and a laser printer, you can print out decals directly. These stickers require a transparent overcoat to prevent the toner from rubbing off.

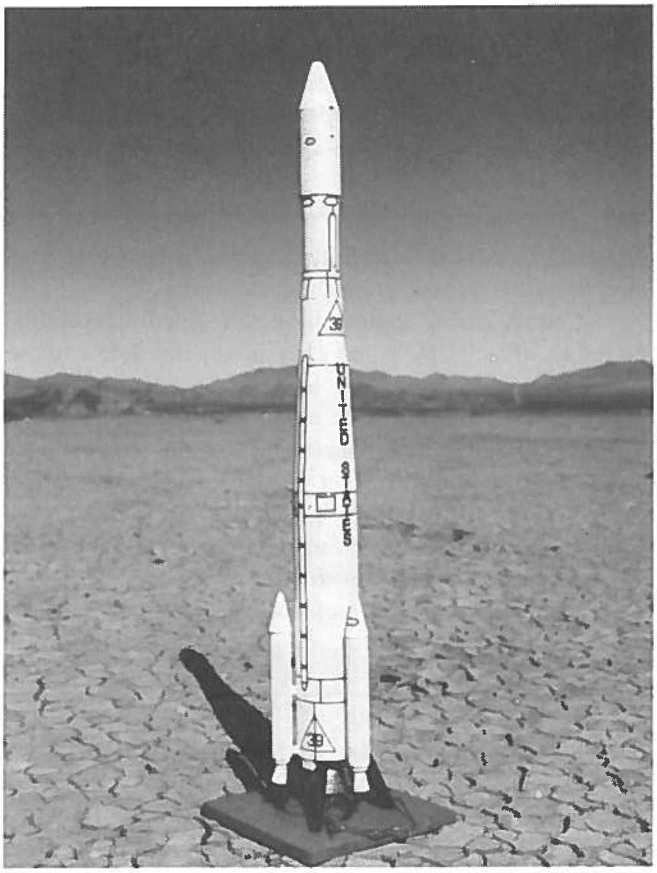
Once the model is complete, you may wish to give it a few light coats of Testors Dullcote or Glosscote. Glosscote and Dullcote both provide some protection of decals, but both varnishes are subject to yellowing with time. Any spray over extra-shiny chrome paint will affect its luster. You may wish to save the chrome for very last. This will also reduce handling of the chrome surface.

If you are entering a model in NAR competition, you are required to place your NAR number or team number on the outside of your model. While some modelers have plastered models with billboard-sized numbers, a discreetly placed NAR or team number produces a much more pleasing result. Favored locations are on the launch lug and on the bottom of the model (beware of exhaust damage to the bottom of your model. Be sure the number is legible before entering NAR competition). If there is stenciling on the prototype that you can't quite make out on your source material, you may want to replace it with your NAR number.

Applying Vinyl Letters:
Use hobby knife to pick letters from sheet. Tape an alignment guide to the model to aid in placement.



Below: Marc McReynolds cut 1/16" strips of Monocote trim for the fine lines on this model of a NASA Delta E. Lettering was computer printout glued to the model. (Marc McReynolds photo)
Right: Tom Pastrick used chrome Monocote trim, model aircraft decals, and hand-cut decals to dress up this beautiful Bomarc model.



Weathering and Imperfections

Experienced plastic modelers love to add all sorts of wear and tear and scale imperfections to model rockets. I am reminded of plastic modeler who won a trophy for a V-1 modeled with all the scuffs, oil stains, black wash, and chipped paint of a veteran fighter aircraft. He forgot that he was modeling a missile before its first and only flight. He was lucky that the judges did, too. Before you get carried away, remember that you are probably modeling your prototype rocket as it appeared before its only flight.

Not all rockets have a pristine appearance at liftoff, however. In some case, rockets carry imperfections from their painting or manufacture. Sounding rockets frequently display cradle marks. These are spots of incomplete coverage where a surplus military rocket was supported during painting. These usually appear as rectangles of base color (typically olive drab), often surrounded by fuzzy areas of incomplete paint coverage. Another "birthmark" is the wrinkled finish of V-2's, left from the shaping of skin panels and their attachment to the rocket's frame.

Some rockets or components are re-flown, and show signs of age. Space Shuttle orbiters show areas of discoloration after numerous reentries. Many sounding rocket payloads are recovered for reflight. Close inspection of the skin sections for one scientific payload revealed bare aluminum sections of different ages. Each had a different shade of silver or anodized gold. Some segments had black anti-glare panels showing varying degrees of degradation from different hypersonic trips through the atmosphere.

Larger rockets using cryogenic fuels often develop frost on the propellant tanks. Sometimes this frost is translucent or uneven.

Be cautious about weathering, flaws, and frost on your models; a cradle mark can look like inadvertent overspray on the modeler's part, and frost-covered lettering can look like a botched cover-up of a mistake. Don't model a prototype flaw unless it is clearly visible in a photograph, at least as visible as your fine details, and more visible than your finish flaws. Model the flaw accurately, as you would model an intentional paint scheme.

Flying Scale Models

The flying techniques for scale are no different from those of other model rockets, except that you've probably put more effort into a scale model. And after all that work, you want to relish the liftoff and be sure the model returns in good shape. Most scale modelers also like to fly in the presence of other appreciative modelers. Since the maiden flight of your work of art just may be its last flight, it's nice to have witnesses. Find a copy of *Sport Rocketry* or contact the National Association of Rocketry to find a launch or group near you (for big models powered by H and larger engines, look for *High Power Rocketry* or contact the Tripoli Rocket Association). Many clubs hold regular "sport" launches as well as contests. Flying with a group makes great economic sense; for every engine you burn, you see several flights, and for every model you lose, you will see several interesting failures. The best benefit is the time spent with fellow modelers who understand the thrill of model rocketry.

Don't forget to use either the string test or calculations for stability before you fly. It's easy to forget about stability after looking at all those photos of the prototype, flying straight as an arrow, with forward fins, tiny fins, or no fins at all. Model rockets are naturally more tail-heavy than the full-size versions, and models don't have inertial guidance and gimballed motors. Be prepared to add lead or clay to the nose. Models of finless prototypes will almost always require clear plastic fins. Remember that scale data just allows you to make an accurate model. It's up to you to make a stable model.

The best scale models tend to be bigger and heavier than most "sport" models. These heavy models lift off slowly, giving the crowd a satisfying dose of smoke and fire. But if the liftoff is too slow, it presents a safety hazard. Be sure to follow the engine manufacturer maximum liftoff weight recommendations. A model must be traveling much faster than the wind speed as it leaves the pad. Avoid flying large models (near the engine lift weight limit) in high winds, as slow launches are susceptible to serious weather cocking. Heavy scale models are best launched from a vertical rod, not tilted into the wind. A vertical liftoff is more impressive and safer than the arcing horizontal trajectory a heavy model will follow after tilted liftoff.

Heavy rockets need large engines, and large model rocket engines require some special care. Large black powder engines are sensitive to heat. When an engine is stored in a closed car in sunlight, it can easily reach temperatures well in excess of 120°F. At such temperatures the propellant expands and forces the casing to enlarge slightly. When the temperature drops again, the propellant contracts, but the casing stays enlarged. The result is a slight gap between the casing and propellant. When the engine is ignited, the flame front soon reaches the gap, and the entire outer surface of the propellant grain ignites. The result is an explosive burn and a catastrophic failure (cato). A cato may just blow out the front, kicking out the recovery system, or the casing may rupture, seriously damaging the model. About 1 in 50 model rockets will suffer a catastrophic failure. If you obey the safety code's requirements for remote launching and model stability, these explosions will injure only your model. Store engines (especially D engines) carefully, away from heat, and don't leave them in a parked car on a hot, sunny day.

Certain rocket engines have developed a reputation for catoes. Estes C5-3's and early production E15's (those with an X in the date code), and FSI E's and F's are not recommended for use in scale models. Together, Estes and FSI (directly and through Quest) produce the vast majority of the reliable model rocket engines that make model rocketry a safe and enjoyable hobby. But the specific types listed above should be saved for sport models without weeks of effort invested in their construction.

Large composite engines, such as those manufactured

Marc McReynolds launched this Little Joe with a cluster of eight engines. (Marc McReynolds photo) by Aerotech, require extra care for ignition. Improper igniter installation can cause chuffing (intermittent wheezes of thrust before full ignition), slow igniton, and even catoes. Be sure you are experienced with these engines before using them on a special model with many hours of work invested in it. Clustering and staging composites is more complicated than with black powder engines. North Coast Rocketry's technical publications (available from North Coast and NARTS) cover techniques for clustering and staging composites.

Clustered scale models are most impressive. But cluster ignition can be touchy. I find that Estes Solar igniters are fine for clusters of Estes or Quest black powder engines. Tamp them in tightly, and be sure that they are in contact with the propellant. Use a car battery for a power supply, and you should get all motors roaring instantaneously. Four engines is the conventional limit for reliable clustering, although clusters of 7 or more have been ignited successfully. Try to design your model and select engines so that if any one fails, the model has sufficient impulse and a short enough delay for a safe flight. Don't cluster a model using a type of igniter that you have never used on a single-engine model.

Multi-staging scale models requires some unusual techniques, as engines must be separated by unusually large gaps. I've staged Aerobee models across 6" air gaps with no special ignition system with 90% reliability. Gap staging, as described in Stine's *Handbook of Model Rocketry,* is reliable if the space between stages is vented to the outside. If your subject has no interstage gap or ports, you can preserve scale appearance by venting gasses out the rear of the booster. Unfortunately, long scale boosters are aerodynamically stable, and will streamline in if not provided with a recovery system.

Some modelers stage with Thermalite fuse. The Thermalite is electrically ignited at launch, and ignites the upper stage after booster burn-out. This technique allows for the normal recovery of both stages. Another technique is to include an electrical flashbulb ignition system at the top of the first stage. When the rocket decelerates after first stage burnout, a mercury switch closes, allowing current from small battery or capacitor to set off a flashbulb, which in turn ignites a Thermalite fuse.

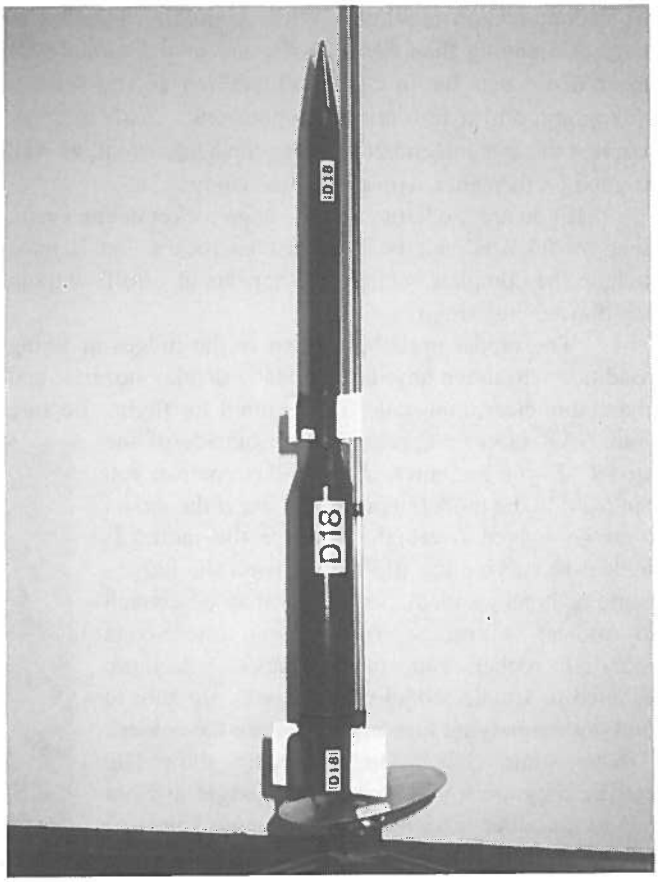
Be cautious about clever staging gimmicks. In the heat of competition, clever staging mechanisms fail with alarming frequency. Even the best contest modelers on a national and international level can suffer as much as a 50% failure rate with their staged scale models. Practice any staging method repeatedly before risking a fine scale model.

Once your model makes a successful trip up, you don't want to see hours of work undone on recovery. Nose cone snap-back is a very common cause of minor damage to model rockets. When it happens to your perfect scale model, it can be heartbreaking. A weighted nose cone makes the damage even worse. If your model is large, use a separate chute for the nose section. If you do, you may want to run a line between booster and nose sections in case one parachute fails to deploy. Some modelers use very long shock cords to prevent snap-back.

A parachute sling arrangement to lower your rocket sideways may help prevent damage on landing. If your model has a heavy nose cone, run an elastic shock cord between the parachute and nose cone. This will reduce stress on your parachute at ejection. For larger models, consider a cloth parachute. Avoid mylar parachutes on large models as they tear easily.

Catching your model may or may not prevent damage. In competition, catching the model will cost "damage points," on the grounds that your model may just be too flimsy to withstand a landing. It is best to be close at hand when the model hits. First, if your model is headed for pavement, you'll want to catch it, and secondly, if there is much wind, you will want to stop the model before it is dragged across the ground.

If there are small children loose on your flying field, be sure to instruct them not to pick up your model, but just to grab the parachute should the wind start to carry your model away. Model rockets are kiddie magnets, and even if your model isn't crushed by converging urchins, you will want to inspect your model at the point of impact. If parts fall off on landing, an uninformed volunteer recovery crew will make it impossible to locate them.



Andrew Miller built a flashbulb ignition system into this model of a French Dragon sounding rocket to ignite the upper stage at first stage burnout. (photo courtesy Andrew and Paul Miller)

Entering NAR *Scale* and *Sport Scale* Competition

The National Association of Rocketry sanctions model rocket contests across the United States. These contests are great places to meet fellow modelers and to sharpen your skills in all aspects of the hobby. Contest events include parachute and streamer duration, rocket-boosted glider events, helicopter recovery duration, egg lofting events, and other performance events. Just getting qualified flights in some events is a challenge in itself. Craftsmanship events are a class of their own, and are rewarded generously within the NAR's scoring system. A visit to an NAR competition will open your eyes to new worlds of model rocketry.

The first rule for entering NAR competition is to read the rules in the NAR "Pink Book." This will help you prepare your model and documentation for judging. This will also help determine if a model is suitable for the event being held at a contest. *Sport Scale* is open to any model that "closely resembles" a given prototype rocket. *Peanut Scale* is a form of *Sport Scale* for small models that are either no more than 2 cm in diameter or no more than 30 cm long (your model can exceed either dimension, but not both). *Giant Scale* is *Sport Scale* limited to models either over 100 cm long or 10 cm in diameter.

The *Scale* event differs from the *Sport Scale* only in the documentation required. While popularly regarded as more challenging than *Sport Scale*, any model suitable for *Sport Scale* can fly in *Scale* competition if you have a photograph and a few critical dimensions. *Scale Altitude* requires the same documentation as the *Scale* event, as well as good performance with a specified engine class.

If you are modeling a multi-stage rocket in any event, your model need not be a multistage rocket, but it must include the complete rocket as it appears at liftoff, without any boosters missing.

The model must be handed to the judges in flying condition. Remove any dummy static display nozzles, and install any clear, non-scale fins required for flight. Be sure your NAR number appears on the outside of the model. If you are entering a one-day contest, you can hand in the model unprotected, but if the model is to be judged overnight, be sure the model is packed to survive the trip to and from the judge's home or hotel room. A plastic bag may be enough to protect a robust four-fins-and-a-nose-cone sounding rocket from paint scrapes. A more detailed or fragile model needs a box. Be sure to find out the judging turn-in time before the contest. While some contest directors may allow late entries, they are a nuisance for the judges and not fair to the other modelers. If you know you can't get to a contest in time, have a friend take the model in ahead of you.

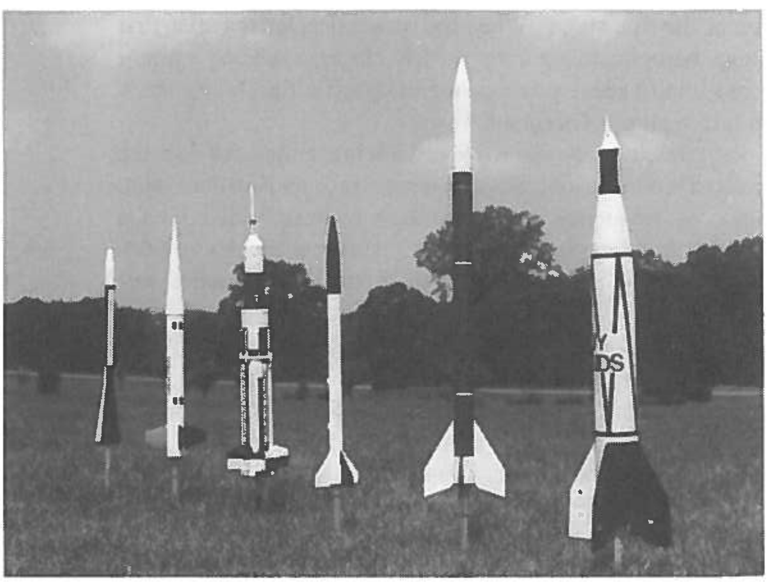
You must prepare a documentation package for your model to be judged against. Refer to the Pink Book to be sure you are including proper documentation. Remember that *Scale* and *Sport Scale* judges are neither mind-readers nor experts on every rocket flown. In many contests, the judge is the nearest NAR member without a scale model to enter. If you are going to amaze a judge with your precise accuracy and fine detail on a difficult subject, you must first give the judge something simple and clear to show what the prototype looked like down to the level of detail you have modeled. This is what a scale substantiation packet is all about. First, it is the standard your model will be judged against. Second, it is a place to explain just how difficult it really was to build your model, and third, it is a place to explain any special flight characteristics of your model that reflect the flight of the prototype.

Do not overburden the poor judges with excess documentation to show what a thorough researcher you are. *Scale* and *Sport Scale* judges want to finish judging as quickly as possible so they can get back to flying in the contest. A tired judge finds irrelevant material annoying.

Some models are complex enough to require a few pages of documentation to show that you did not just dream up certain details. Don't get carried away. Too much detail in the documentation may draw the judge's attention to things you left off the model.

Your model is of a specific round of a rocket, or at least of a specific version of a rocket, so make sure your pictures all correspond to your version. If some sources are not obviously relevant (such as a photo of a different version of a rocket that shows some detail of your model especially well), explain why they are included.

Some scale kits (most notably those from Quest and Aerotech) come with prototype drawings. Neither *Scale* nor *Sport Scale* allow you to document a model entirely with kit materials (unless you are flying *Sport Scale* and use a color

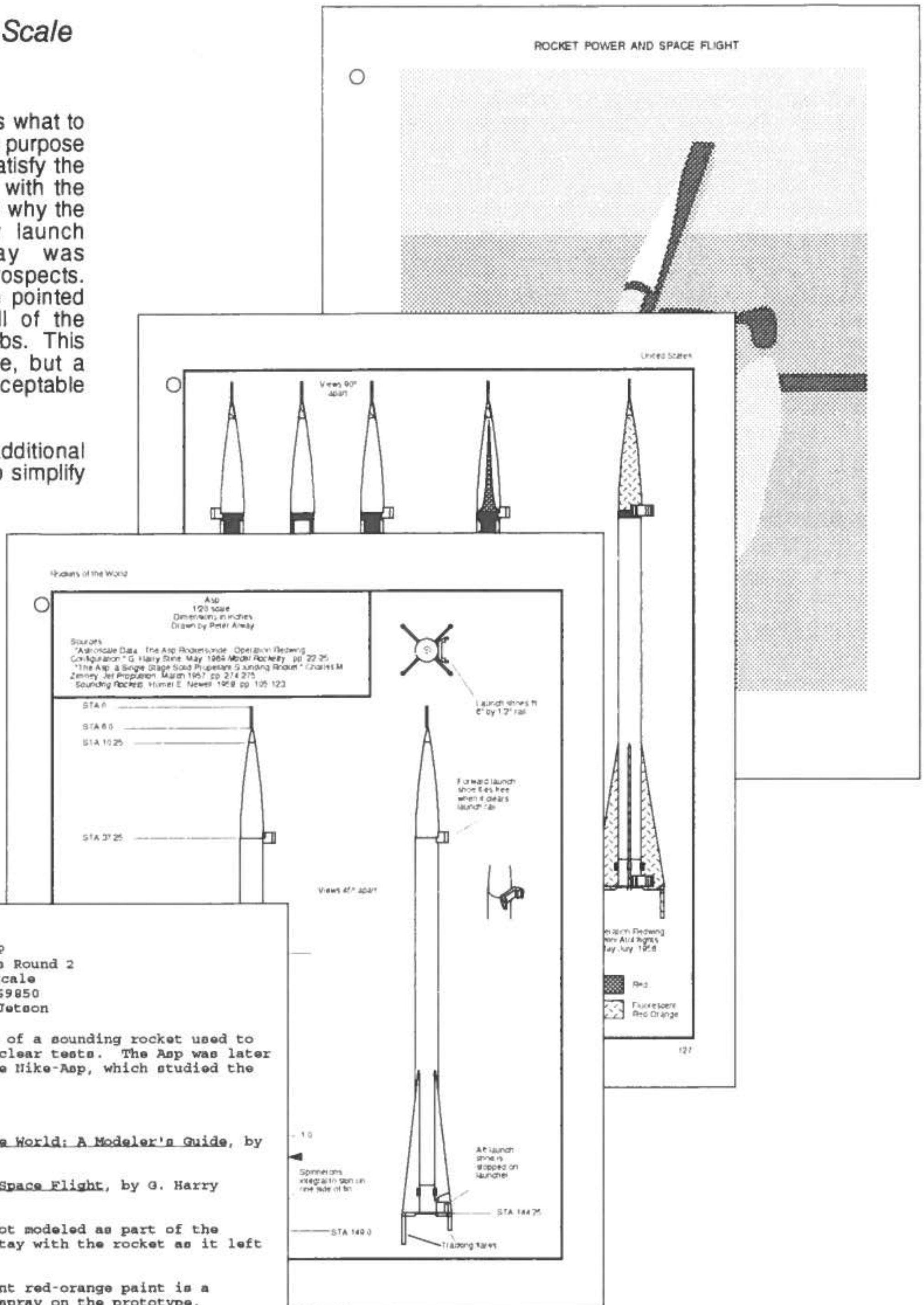


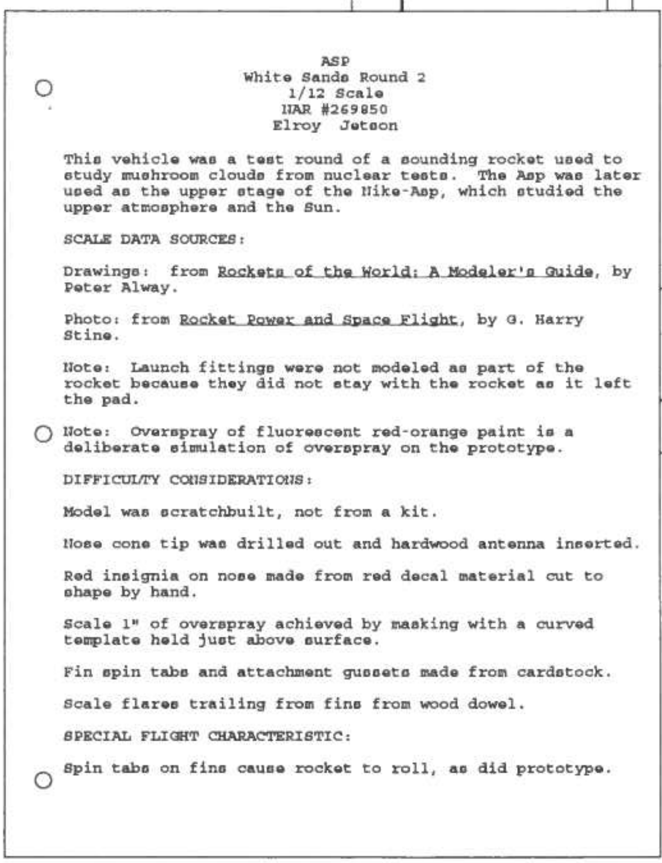
A model rocket contest can bring out a whole range of scale models.

A Well-organized *Sport Scale* Data Packet:

The cover page tells the judges what to look for. Two sentences on the purpose of the rocket are enough to satisfy the curiosity of a judge unfamiliar with the vehicle. Explanations, such as why the modeler chose not to show launch shoes and why overspray was deliberate, improve judging prospects. Difficult construction steps are pointed out, as is the intentional roll of the model induced by scale spin tabs. This modeler typed the cover page, but a carefully handwritten one is acceptable as well.

The modeler may have had additional material, but this was left out to simplify judging.





ASP
White Sands Round 2
1/12 Scale
NAR #269850
Elroy Jetson

This vehicle was a test round of a sounding rocket used to study mushroom clouds from nuclear tests. The Asp was later used as the upper stage of the Nike-Asp, which studied the upper atmosphere and the Sun.

SCALE DATA SOURCES:

Drawings: from Rockets of the World: A Modeler's Guide, by Peter Alway.

Photo: from Rocket Power and Space Flight, by G. Harry Stine.

Note: Launch fittings were not modeled as part of the rocket because they did not stay with the rocket as it left the pad.

Note: Overspray of fluorescent red-orange paint is a deliberate simulation of overspray on the prototype.

DIFFICULTY CONSIDERATIONS:

Model was scratchbuilt, not from a kit.

Nose cone tip was drilled out and hardwood antenna inserted.

Red insignia on nose made from red decal material cut to shape by hand.

Scale 1" of overspray achieved by masking with a curved template held just above surface.

Fin spin tabs and attachment gussets made from cardstock.

Scale flares trailing from fins from wood dowel.

SPECIAL FLIGHT CHARACTERISTIC:

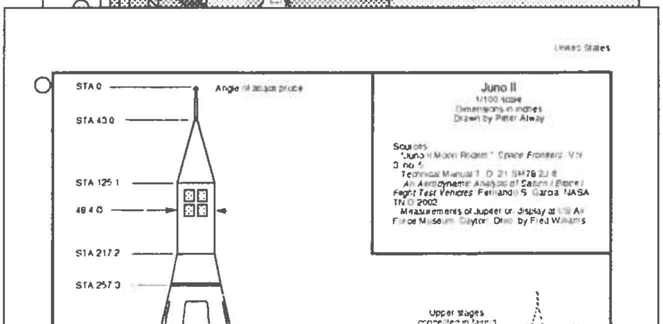
Spin tabs on fins cause rocket to roll, as did prototype.

A Well-organized *Scale* Data Packet:

This *Scale* documentation packet is similar to a *Sport Scale* packet. Two required additions are photographs and a scale dimension table. The modeler includes the dimensions the model *should* have. The measurement spaces are left blank for the judges to fill in.

In addition to the required dimensions, the modeler has included the length of the first stage cylindrical section. If the modeler knows the model's main body tube's length is more accurate than, say the transition section length, including it will improve the model's prospects. The judges must measure five dimensions. They might skip the transition length in favor of the easier to measure tube length.

Note that the modeler defined nose cone length to include the nose probe. Since judging uses percent error, it is easier to make a larger subassembly accurate. By defining a larger dimension for the nose, the scoring prospects are improved. It is also possible to fix fabrication errors (such as a short nose cone) during assembly.



JUNO II
Pioneer 4
1/40.7 Scale
NAR 269851

Scale Factor: 1/40.7 = .0246

Prototype Feature	Prototype Dimension	Calculated Dimension	Measured Dimension	% Error	Score
Overall Length	920.2"	22.61"			
1st Stage Diameter	105"	2.58"			
Upper Stage Shroud Diameter	48.4"	1.18"			
Nose cone length (including probe)	125.1"	3.07"			
Transition Length	128.9"	3.17"			
1st stage cylinder Length	539.2"	13.25"			

JUNO II
Pioneer 4
1/40.7 Scale
NAR #269851
William Robinson

SCALE DATA SOURCES:

Drawings: from Rockets of the World: A Modeler's Guide and SPACE FRONTIERS.

Color photo: from Apollo Expedition to the Moon, NASA SP-350.

B&W photo: from Space Frontiers.

DIFFICULTY CONSIDERATIONS:

Model was scratchbuilt, not from a kit.

Nose cone turned from balsa wood.

Adapter section turned from balsa wood.

Nose cone tip was drilled out and hardwood probe inserted.

Black lettering is individual dry transfer letters.

Black checks from decal material.

Corrugations are plastic strips glued to paper wrap-around.

Tabs on clear fins inserted into slots on base of rocket.

Nozzle turned from basswood, drilled out for engine mount.

prototype photograph from the kit). You must provide additional material to verify that the kit material depicts the prototype, and not just the model.

Don't forget to include a list of difficult or complex assemblies or markings. You get points for difficulty, but you must point out what you did that was difficult. A judge just might assume your beautiful scratchbuilt model was made from a kit with prefabricated components, and judge accordingly. You must also list any parts scavenged from plastic model kits.

If you deliberately model flaws, such as oil stains, dents, etc., make explicit mention of them in your scale documentation. Otherwise, they will look like mistakes to the judges, and later protestations will sound a lot like excuses for poor craftsmanship. The cover page is also a good place to mention special flight characteristics, if you want "mission points."

In some cases, flight characteristics or color information are described in text only. In those cases, a page of text with the relevant passages highlighted is appropriate. If you must include a photocopy of a text source, highlight the facts that are essential in judging your model.

Some people include historical summaries with their models. These are often ignored by judges, but a couple sentences explaining the purpose of an obscure prototype can be enlightening.

Documenting *Sport Scale* Models

If you are entering *Sport Scale*, one illustration indicating the color and general appearance of the prototype is adequate. It can be as little as a color photograph clipped from a magazine or marked with a post-it note in a book (color photocopies from your local print shop are good, too). A color-keyed drawing such as one in this book or *Rockets of the World* will do as well. A modest amount of additional data can be helpful. Two photos and a nice profile drawing should be enough for almost any vehicle.

If you really need more than a couple of items in your data packet, include a cover page to guide the judge.

Documenting *Scale* Models

Scale requires more documentation than *Sport Scale*. You must have a photo and documentation of dimensions. Usually, you will only need a page or two of drawings and a photo or two, plus a page of your own paperwork. It is helpful if everything is written on or mounted on 8 1/2" x 11" sheets in a looseleaf binder. Top-loading page protectors and "magnetic" photo-album pages are perfect.

Begin with a cover page listing your NAR number, name of the prototype, scale, and the sources in your packet. Next you will need a table (or drawing) of prototype and model dimensions. Check the Pink Book to be sure you've got everything. Include the scale factor at the top of the page. Take basic prototype dimensions directly from the data included in your packet. Then use the scale factor to calculate the correct model dimension from each prototype dimension. It's up to the judges to measure your model and see how close you came.

There are tricks to making your model score as well as possible. The required dimensions are overall length, nose cone length, principal diameters, transition lengths, and length and width of fins. You can also specify other dimensions. Measure your model before it is judged. See how your actual dimensions compare to your calculated dimensions. If your model is consistently off in one direction (too large or too small), change the scale factor accordingly. If you set out to build a 1/24 scale model, and parts of it came out between 1/25 scale and 1/24.5 scale, call it a 1/24.75 scale model. If you can pick a scale for which all the critical dimensions are within 1%, the model is as good as perfect. When you have a choice of how to measure a component, select to your advantage. Fin chord might be measured at the tip or the root. If one is a few percent off, specify the other in your table. Similarly, "nose cone length" is ambiguous for many manned spacecraft. You may choose to include an escape tower in the length or not, depending on which length is more accurate.

Follow the table of dimensions with a single overall drawing. Follow it with any necessary detailed material. Start the photos with the clearest one possible, and then follow it with any others required for details or "other side" colors. Extra photographs of the round you are modeling, especially in color, are a plus. Be sure your photos are of reasonable quality. A good first generation photocopy won't offend most judges, but unintelligible multi-generation copies may disqualify you.

You may wish to tie all your research together in a single drawing of your own. Be sure that the information on the drawing can be easily traced back to the sources in your packet. If you publish your drawing in *Sport Rocketry* or your local club newsletter, you can use it as scale substantiation in its own right. It's a sneaky trick, but if it increases the amount of scale data published, it's worth suggesting it.

Flying a Contest Model

Usually *Scale* and *Sport Scale* models are flown after static judging. Some individuals may have to fly before judging (typically if they can only fly the first day of a 2-day contest). This brings on the risk of having a model judged in damaged condition.

Contest models must be designed to withstand recovery intact. NAR competition uses a system of damage points to insure your model is really flightworthy. You cannot catch your model in a contest without forfeiting all damage points, but if you stand by at the landing site, you can grab the parachute before it drags your model along the ground.

Now that you know the tricks of the trade, it's time for you to *build* something! Pick something you can't resist, and start building. Remember: perfect models only exist in a modeler's imagination, so just make it!

Model Plans and Scale Data

These plans assume some experience in model rocket construction. Details of engine mounting and recovery systems have been left out. Before attempting these models, build a couple of simple flying model rocket kits such as the Estes Alpha or Big Bertha, or Quest Astra. These will give you a good feel for how a model rocket works.

All the plans show an Estes-type paper shock cord mount. You may wish to use a sturdier shock cord mount, such as a Quest-type mount, in which an elastic shock cord is tied to a Kevlar string, which, in turn, is tied to the engine mount.

Each plan is followed by scale data—a dimensioned and color-keyed drawing of the real thing. The data will suggest improvements you might want to make in the plans (the plans in this book are as accurate as possible for easy construction). Many of the vehicles can be easily modeled at different scales, as well. If you enter your model in an NAR *Sport Scale* competition, present the judges with a copy of the data page as a standard to judge your model against.

These plans are presented in order of difficulty, beginning with the simplest models, and concluding with the most challenging. Scale data on two rockets without plans (Terrier-Sandhawk and Saturn V) is included to aid in documenting two popular Estes Kits.

Asp

The Asp (pp. 41-42) was a single-stage research rocket created in 1955 to investigate the mushroom clouds of nuclear explosions. The plans depict a test flight flown from White Sands, New Mexico, in December of 1955 as a test of the vehicle. In later years, the Asp was adapted to a much larger Nike booster to become the 2-stage Nike-Asp. The Nike-Asp discovered the localized emissions of X-rays by the Sun's corona.

D-Region Tomahawk

Thiokol created the Tomahawk sounding rocket (p. 43) for the Sandia National Laboratory in the early 1960's. NASA tested the D-Region version on February 5, 1968. The D-region is a layer of the Earth's ionosphere. At very high levels of the atmosphere, solar radiation knocks electrons free of atoms in the air. The electrons and the ions (atoms that are positively charged because of missing electrons) in the ionosphere may reflect or absorb radio waves, interfering with or aiding radio communications. The D-Region Tomahawk reached an altitude of 74 miles. The Tomahawk rocket is an upper stage for various NASA multistage sounding rockets, such as the Nike-Tomahawk.

Black Brant VB

Canada's Black Brant sounding rockets date back to the Propulsion Test Vehicle of 1958. The test vehicle proved to be a useful research rocket, renamed the Black Brant. The first Black Brant VB flew from Fort Churchill, Manitoba (a gathering spot for polar bears on Hudson Bay) in 1965. This plan (pp. 44, 46) depicts the first Black Brant VB to carry a scientific payload, a German barium cloud experiment that created an artificial aurora. NASA flies Black Brant V's in combination with other rocket stages.

Black Brant VI

Canada's Bristol Aerospace created the tiny Black Brant VI (pp. 45-46) as a meteorological rocket for the US Army. It served in other research work as well.

V-2

In the years prior to World War II, the German Army began developing a rocket that would replace the big guns banned from Germany after WWI. The Army hired Wernher von Braun and others to create a giant guided missile, known as the A-4 or V-2 (pp. 47-50). Eventually the V-2 would be used for the deadly but strategically ineffective bombardment of London and Amsterdam. In the closing days of WWII, Americans and Soviets scrambled to capture missiles, their creators, and the production facilities.

Parts for about 100 V-2's made it to the United States for assembly at White Sands, New Mexico. The US Army flew them to gain experience in missile operations. The army invited scientists from around the country to devise experimental payloads for the rockets. V-2 flights to 100 miles opened up the space sciences for Americans. V-2 payloads measured the properties of the atmosphere, solar radiation, and cosmic rays. American, Soviet, and French space boosters all can trace their ancestry to the V-2.

GIRD 09

At the end of the 19th century, Konstantin Eduardovitch Tsiolkovky, a Russian schoolteacher, worked out the fundamental mathematics of rocket propulsion and interplanetary travel. Tsiolkovsky was exclusively a theorist; he did not perform rocket experiments on his own. That was left for the next generation of space pioneers at the Gas Dynamics Laboratory (GDL) and Group for the Study of Reactive Motion (GIRD). By 1933, under the leadership of aeronautical engineer Sergei Pavlovich Korolev, GIRD members built the GIRD 09 (pp. 51, 53), the Soviet Union's first liquid fueled rocket.

GIRD 09's fuel was jelled petroleum, placed in the combustion chamber. Liquid oxygen was forced into the combustion chamber by the pressure from its own evaporation. GIRD 09 took off at 7:00 PM, August 17, 1933. It reached an altitude of 400 meters (1,300 ft) and fell back to Earth 18 seconds after launch. The GIRD 09 was the first in al ong line of rocket developments that let to Sputnik, the Earth's first artificial satellite.

Sparrow-Arcas

Only 7 feet tall, the Arcas was developed in the late 1950's to monitor winds, temperatures, and pressures as high as 30 miles up. Combined with the motor from a

Sparrow Air-to-air missile, the Arcas could fly higher than 80 miles. Sparrow-Arcas (pp. 52-53) rockets performed vapor release experiments for ionospheric study.

Aerobee 150A

The Aerobee 150A (pp. 54-58) was part of a series of liquid propellant sounding rockets, dating back to the Standard Aerobee, first flown in 1947. The Aerobee 150A shown here flew an astronomical mission studying the ultraviolet light of extremely hot stars.

Astrobee 500

The Astrobee 500 (pp. 59-61) was a 3-stage solid propellant rocket produced by Aerojet General (makers of the Aerobee series) for the Air Force. On its first flight, it was to carry explosive flares to be observed from the ground as part of a surveying experiment. But the rocket failed, and never came into general use.

Juno II

After World War II, Wernher von Braun and his fellow V-2 developers came to the United States, and formed the nucleus of the Army Ballistic Missile Agency (ABMA). This group created the Redstone missile, which was later adapted into the Juno I, which launched America's first satellite, and the Mercury-Redstone, which carried the first US astronauts. A second missile was the Jupiter. After the success of the Juno I, the ABMA added a collection of upper stages to the Jupiter missile to create the Juno II.

The first two Juno II's carried Pioneer moon probes. Neither made it to the moon, but the first discovered the outer Van Allen radiation belt, and the second went into orbit around the sun. The Juno II (pp. 62-63) also orbited satellites for NASA.

Mercury-Atlas

The Atlas was America's first Intercontinental Ballistic Missile (ICBM). The missile incorporated balloon construction and a one-and-a-half stage flight profile. The skin of the missile was so thin that it required the pressure of the propellants to hold it upright. Because staging was not perfected in 1955 when the project began, all engines had to ignite at launch. To gain the benefits of staging, two of three engines were dropped during flight.

NASA chose the Atlas as the booster for the first US manned orbital program, project Mercury. In 1962, a Mercury-Atlas (pp. 64-66) carried astronaut John Glenn into orbit. Three more astronauts followed. The Atlas (now with a hydrogen-powered Centaur upper stage) still serves as an important space booster.

Saturn I Block 2

The largest rocket devised by Wernher von Braun's Army Ballistic Missile Agency was the Saturn—a cluster of Redstone and Jupiter missile tanks topped by high energy hydrogen-propelled stages. NASA took over the project by the time the first of the series flew. The Saturn I Block 2, (pp. 67-73), was a 2-stage unmanned rocket capable of placing nearly 20 tons into orbit. The Saturn IB followed,

Continued on p. 53

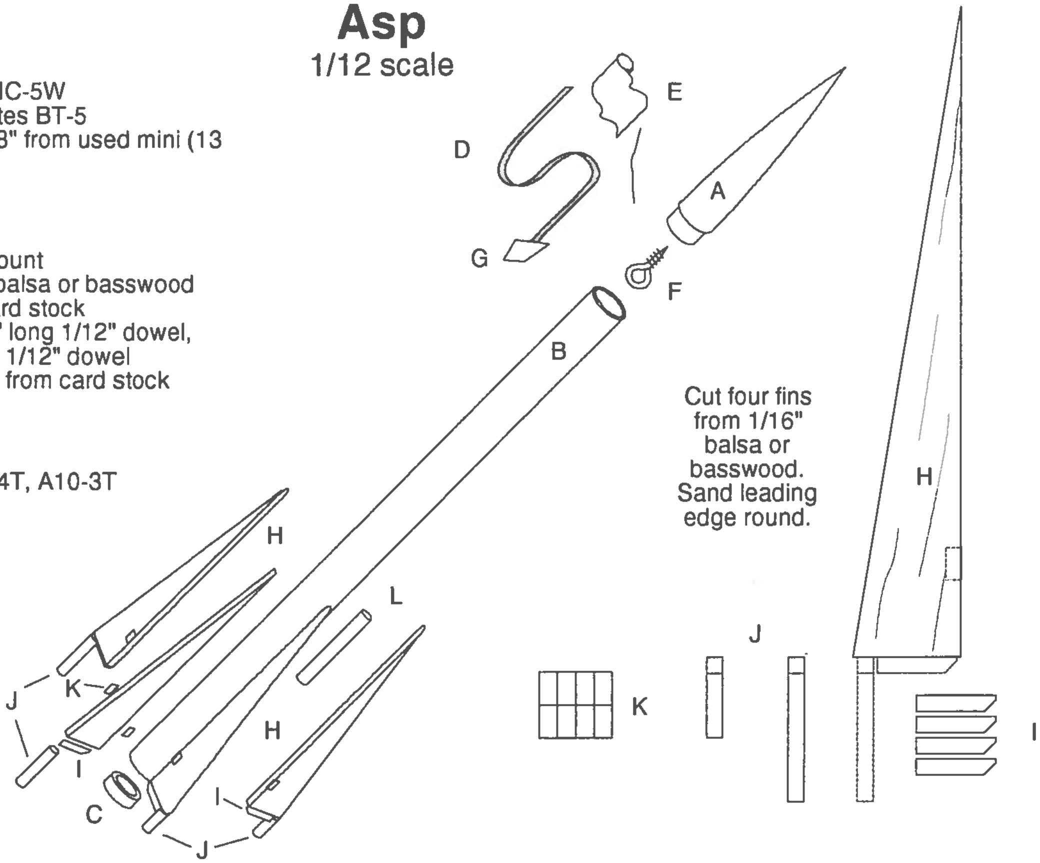
Asp

1/12 scale

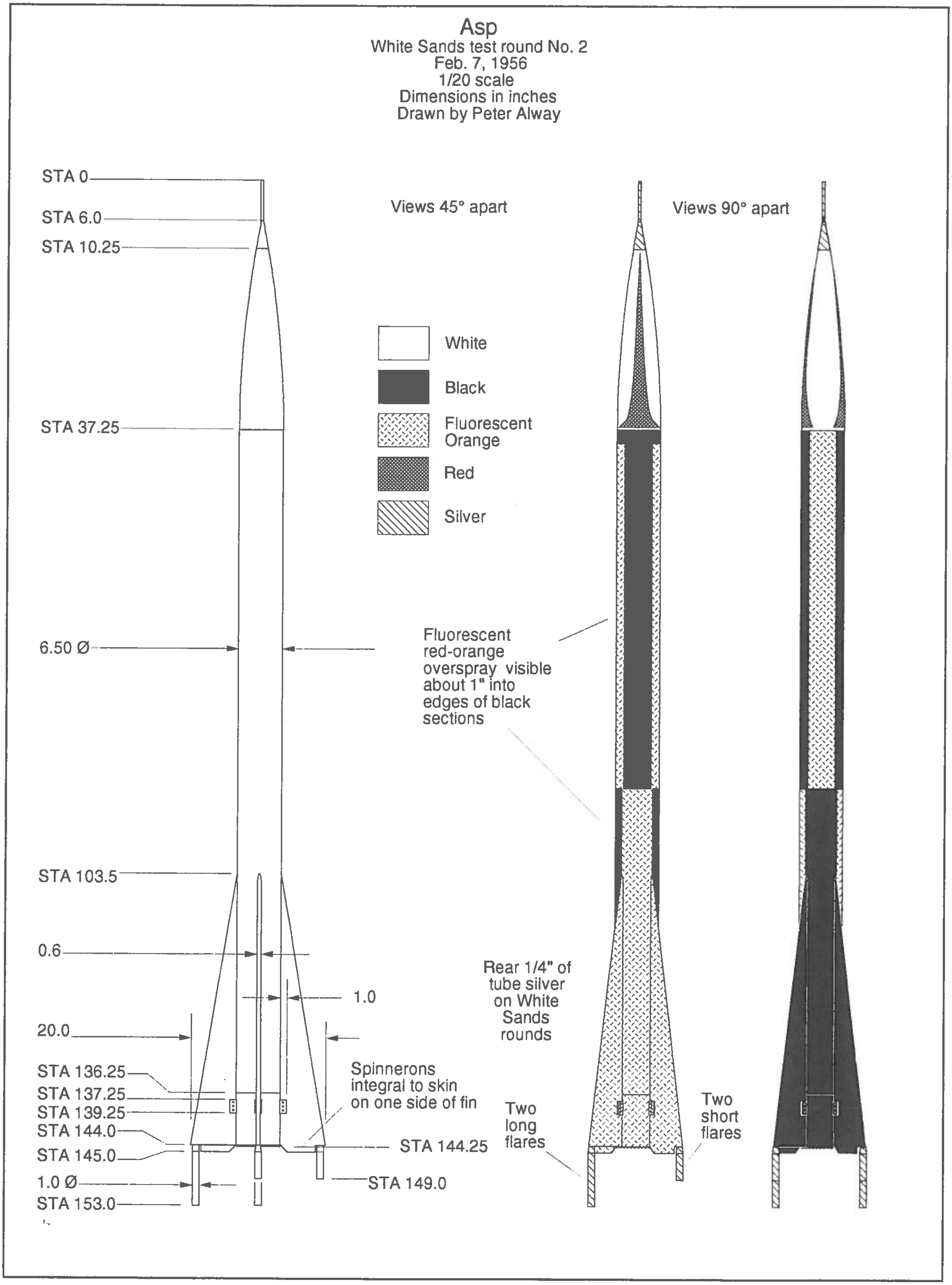
Parts List:

A) Nose Cone, Estes BNC-5W
B) Body Tube, 8 7/8" Estes BT-5
C) Engine Block, Cut 1/8" from used mini (13 mm) engine
D) 12" shock cord
E) Streamer
F) Screw Eye
G) Paper Shock Cord Mount
H) Fins (4x), from 1/16" balsa or basswood
I) Spin tabs (4x), from card stock
J) Flares, Long (2x) 3/4" long 1/12" dowel, and Short (2x) 7/16" long 1/12" dowel
K) Fin attachments (8X), from card stock
L) Launch lug

Recommended Engines:
1/2A3-2T, 1/2A3-4T, A3-4T, A10-3T



Copy this page onto card stock. Cut the spin tabs and fin attachments directly from the copy.


Asp
White Sands test round No. 2
Feb. 7, 1956
1/20 scale
Dimensions in inches
Drawn by Peter Alway
STA 0
STA 6.0
STA 10.25
STA 37.25
6.50 Ø
STA 103.5
0.6
1.0
20.0
STA 136.25
STA 137.25
STA 139.25
STA 144.0
STA 145.0
1.0 Ø
STA 153.0
STA 144.25
STA 149.0
Spinnerons integral to skin on one side of fin
Views 45° apart
Views 90° apart
White
Black
Fluorescent Orange
Red
Silver
Fluorescent red-orange overspray visible about 1" into edges of black sections
Rear 1/4" of tube silver on White Sands rounds
Two long flares
Two short flares

D-Region Tomahawk

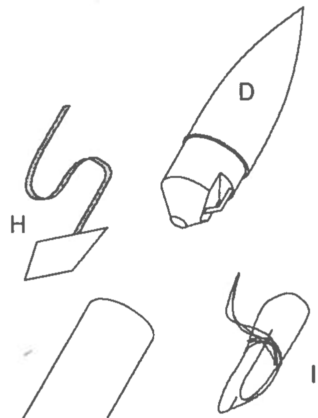
1/9.22 scale

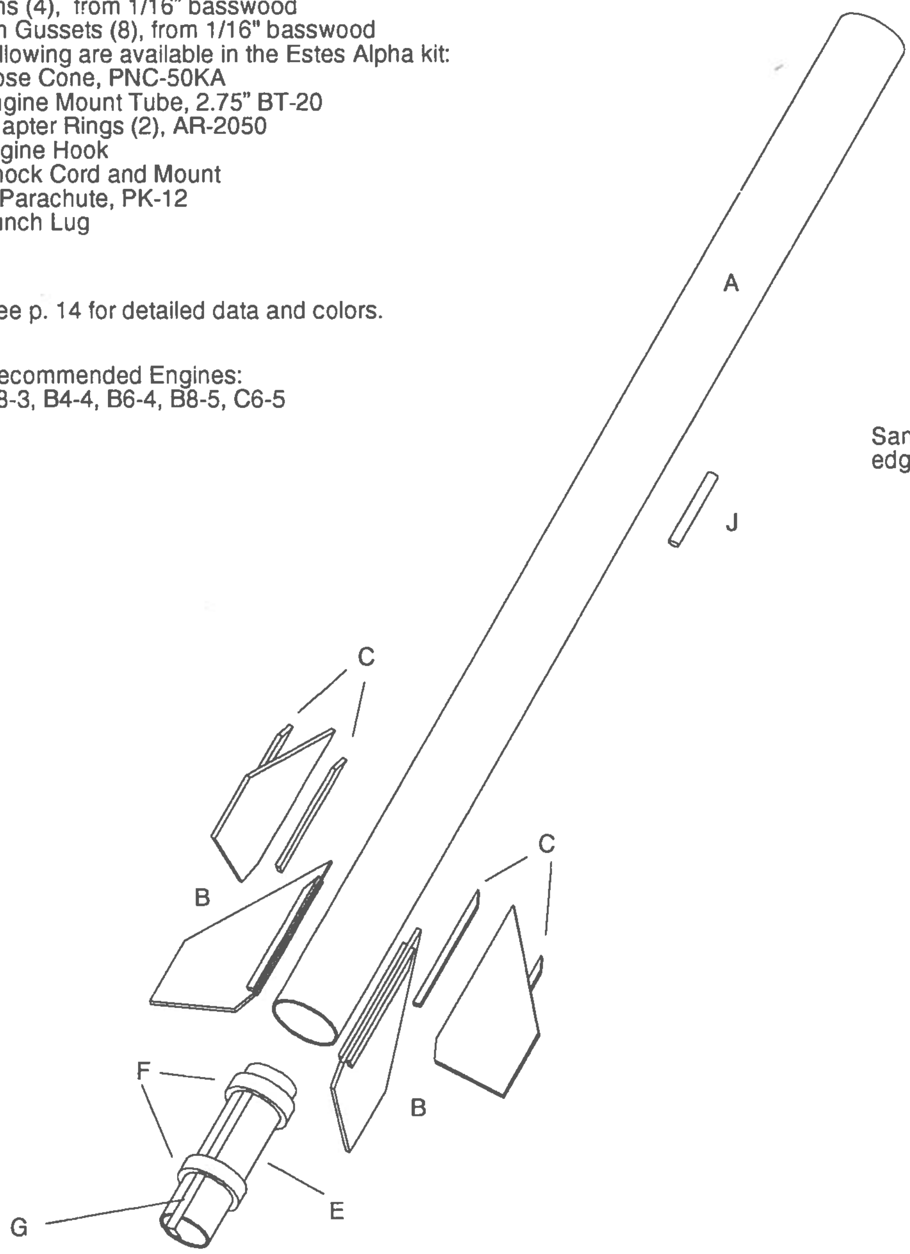
Parts List:

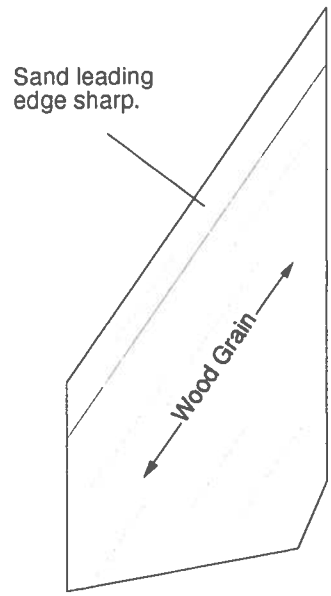
A) Body Tube, 18" Estes BT-50
B) Fins (4), from 1/16" basswood
C) Fin Gussets (8), from 1/16" basswood
The following are available in the Estes Alpha kit:
D) Nose Cone, PNC-50KA
E) Engine Mount Tube, 2.75" BT-20
F) Adapter Rings (2), AR-2050
G) Engine Hook
H) Shock Cord and Mount
I) 12" Parachute, PK-12
J) Launch Lug

See p. 14 for detailed data and colors.

Recommended Engines:
A8-3, B4-4, B6-4, B8-5, C6-5







Fin Pattern (B):
Make four from
1/16" basswood.

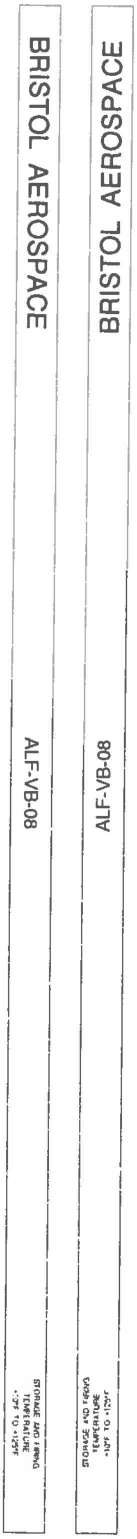
Gusset Pattern (C):
Make eight from
1/16" basswood.

Black Brant VB

1/23.4 scale

Nose marking

Body markings

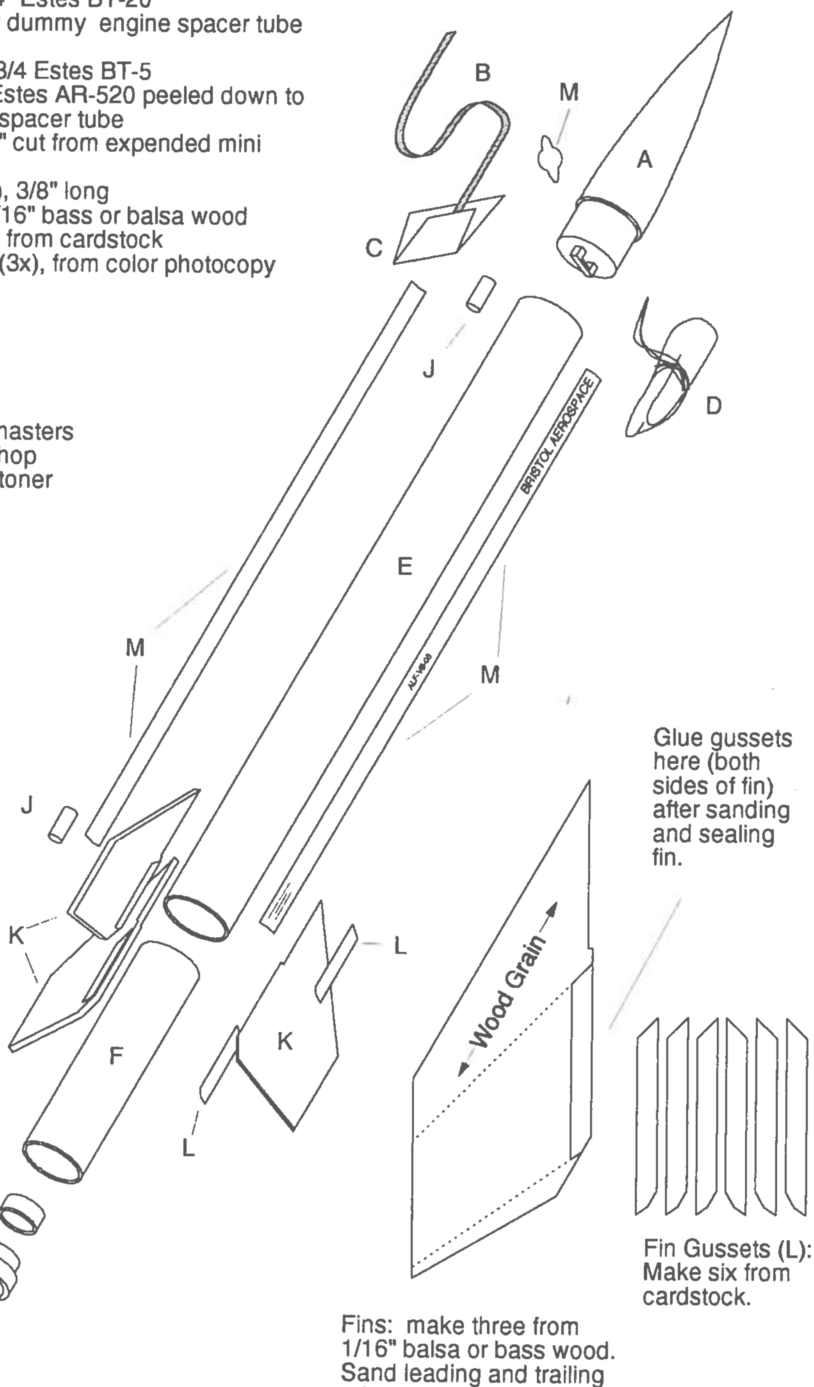


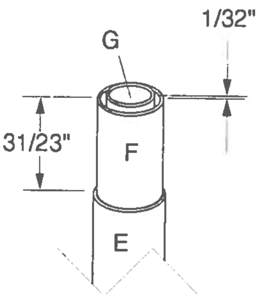
Parts List:

A) Nose Cone PNC-20 (available in most Estes BT-20 kits, not sold separately)
B) Shock Cord
C) Shock Cord Mount
D) 12" Parachute (or streamer)
E) Body Tube, 8 1/4" Estes BT-20
F) Tail Tube, yellow dummy engine spacer tube from an Estes kit
G) Engine Tube, 1 3/4 Estes BT-5
H) Adapter Rings, Estes AR-520 peeled down to fit in dummy engine spacer tube
I) Engine Block, 1/4" cut from expended mini engine casing
J) Launch Lugs (2x), 3/8" long
K) Fins (3x), from 1/16" bass or balsa wood
L) Fin Gussets (6x), from cardstock
M) Paper Markings (3x), from color photocopy

Recommended Engines:
1/2A3-2T, A3-4T, A10-3T

Paper Markings masters (M): Have print shop photocopy in red toner with color copier.





Lower ends of tubes

Glue gussets here (both sides of fin) after sanding and sealing fin.

Fins: make three from 1/16" balsa or bass wood. Sand leading and trailing edges to knife edge.

Fin Gussets (L): Make six from cardstock.

Black Brant VI

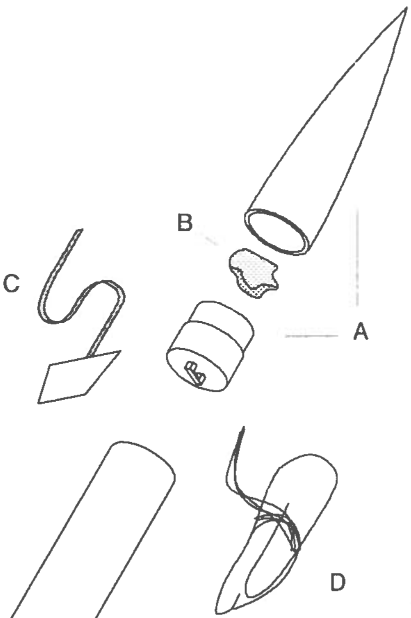
1/5 scale

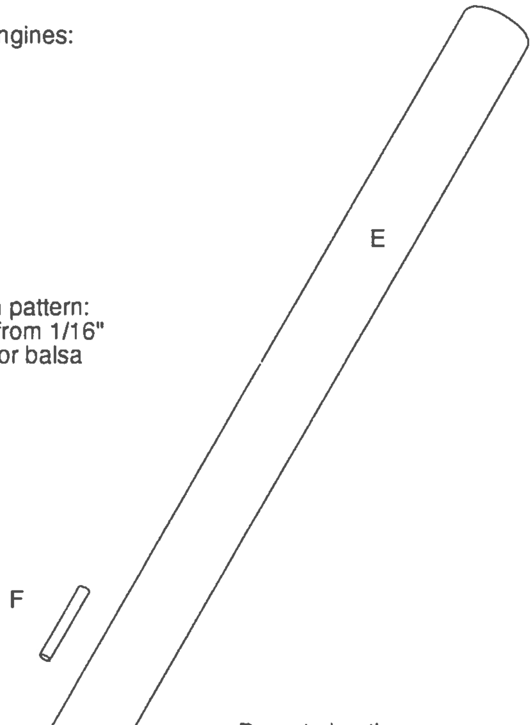
Full-size markings

Parts List:

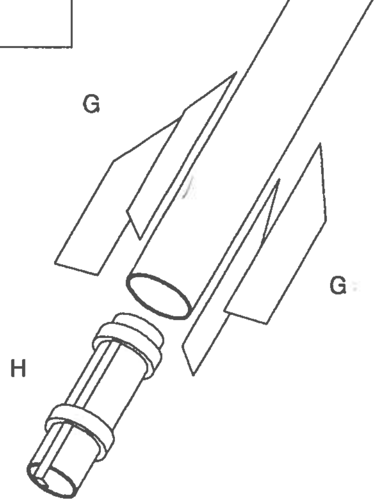
A) Nose Cone, 2-piece Estes PNC-50 cone available as kit part.
B) Nose Weight, clay or lead
C) 18" Shock Cord and Mount
D) 12" Parachute
E) Body Tube, 18" Estes BT-50
F) Launch Lug
G) Fins (4), from 1/16" basswood
H) Engine Mount, Estes EH-2050

Recommended Engines:
B4-2, B6-2, C6-5

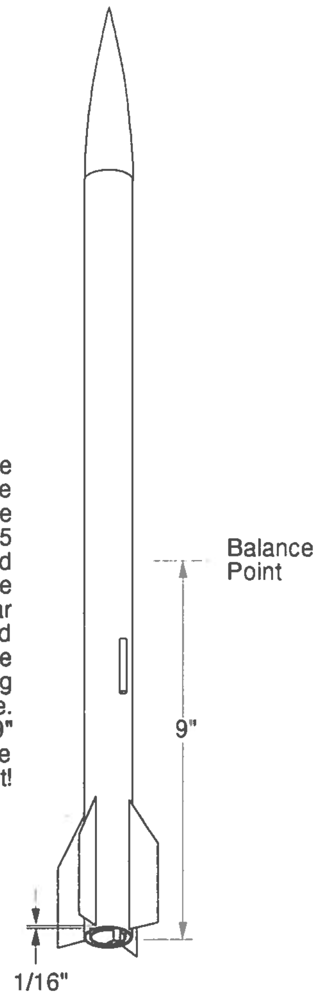




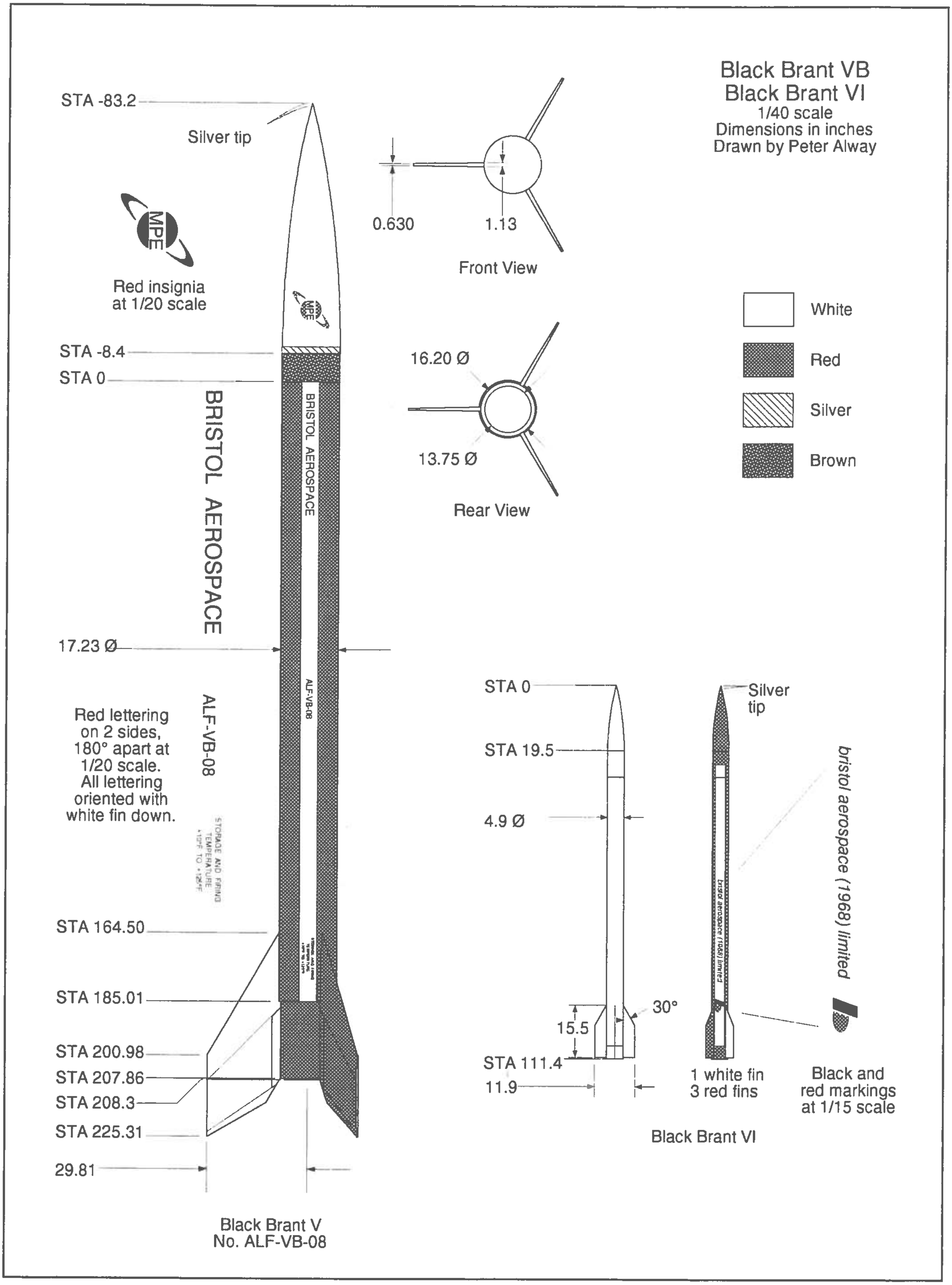
Full-size fin pattern: Make four from 1/16" basswood or balsa



Do not glue the nose cone together until the rest of the model is assembled. When the model is complete, insert a C6-5 into the engine mount, and add clay to the nose cone until the model balances 9" from the rear of the body tube. If using lead nose weight, epoxy or super-glue the lead into place before gluing the base onto the nose cone. Model must balance *at least* 9" from the rear of the tube for safe flight!



Glue fins 1/16" from rear of body tube



Black Brant VB
Black Brant VI
1/40 scale
Dimensions in inches
Drawn by Peter Alway
STA -83.2
Silver tip
MPE
Red insignia at 1/20 scale
STA -8.4
STA 0
BRISTOL AEROSPACE
17.23 Ø
ALF-VB-08
Red lettering on 2 sides, 180° apart at 1/20 scale. All lettering oriented with white fin down.
STA 164.50
STA 185.01
STA 200.98
STA 207.86
STA 208.3
STA 225.31
29.81
Black Brant V
No. ALF-VB-08
0.630
1.13
Front View
16.20 Ø
13.75 Ø
Rear View
White
Red
Silver
Brown
STA 0
STA 19.5
4.9 Ø
15.5
30°
STA 111.4
11.9
Silver tip
bristol aerospace (1968) limited
1 white fin
3 red fins
Black and red markings at 1/15 scale
Black Brant VI

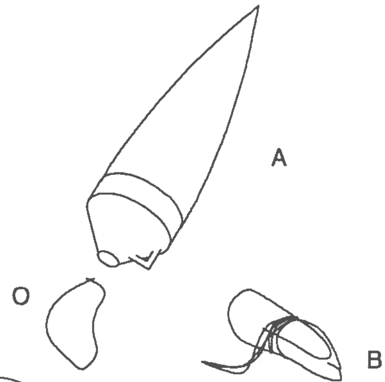
V-2

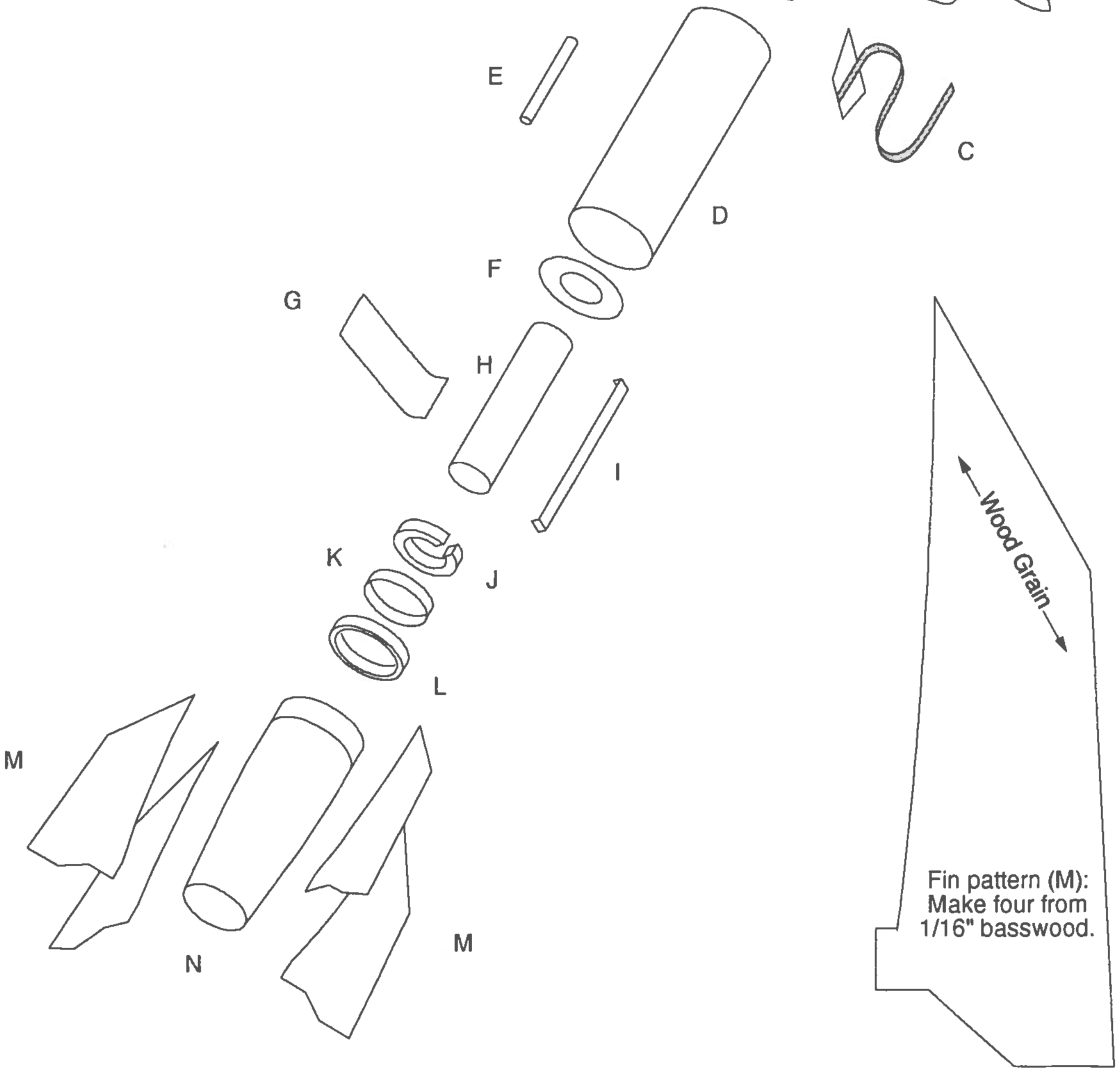
1/40 scale

Parts list:

A) Nose Cone, from Estes Bail Out kit
B) Parachute (12" or 18")
C) 18" Shock Cord and Mount
D) Body Tube, 4 1/4" Estes BT-60
E) Launch Lug
F) Front Adapter Ring, Estes RA-2060
G) Engine Hook Wrap, masking tape or paper
H) Engine Tube, 4 3/8" Estes BT-20
I) Engine Hook
J) Rear Inner Adapter Ring, Estes AR-2050, slit for engine hook
K) Rear Adapter Shim, 1/4" Estes BT-50
L) Rear Outer Adapter Ring, Estes AR-5055
M) Fins (4x), from 1/16" basswood
N) Tail Cone, Estes PNC-60AH nose cone cut to 3 7/8"
O) Nose Weight, clay

Recommended Engines:
B4-2, B6-2, C6-5



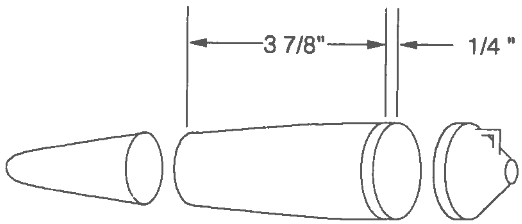


V-2

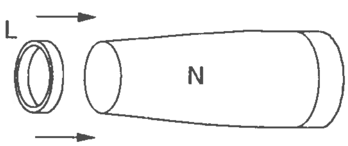
1/40 scale

The nose cone used in this plan isn't available separately, so you'll have to scavenge it from the Estes Bail Out kit.

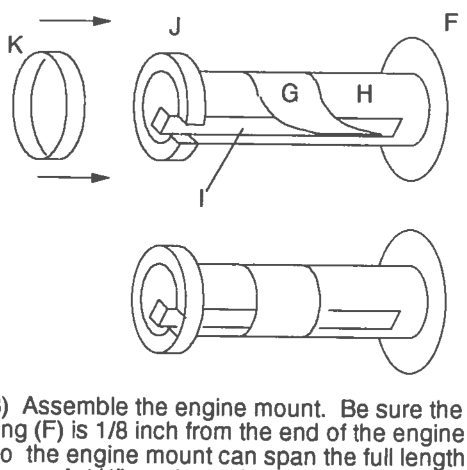
The tail section of this model is a little complicated, so here are some construction details. Use epoxy or super glue with epoxy fillets when gluing wood and paper parts to the plastic tail cone.



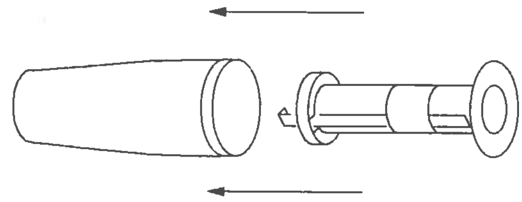
1) Cut the ends off the PNC-60AH cone (N) as shown here.



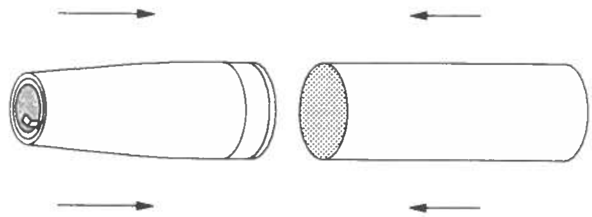
2) Peel down the AR-50-55 ring (L) until it fits into the rear of the tail cone, and glue it into place.



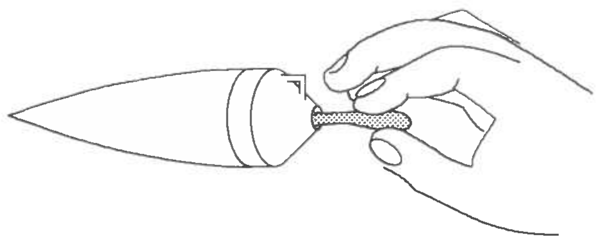
3) Assemble the engine mount. Be sure the RA-2060 ring (F) is 1/8 inch from the end of the engine tube (H) so the engine mount can span the full length of the tail cone. A 1/4" section of BT-50 (K) over the AR-2050 ring (J) insures a good fit at the rear of the engine mount. Wrap tape or glue paper (G) around the engine tube to hold the engine hook (I) in place.



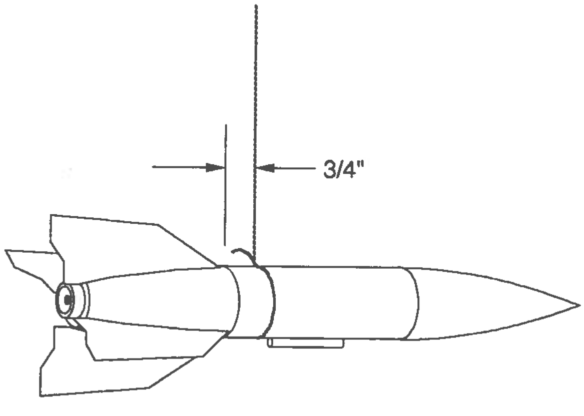
4) Smear glue on the rear adapter ring of the engine mount, and insert it through the tail cone, and into the AR-5055 ring. Smear epoxy into the rear of the BT-60 body tube, and insert the tail section into the tube, being careful not to push the engine mount out of the tail cone in the process.

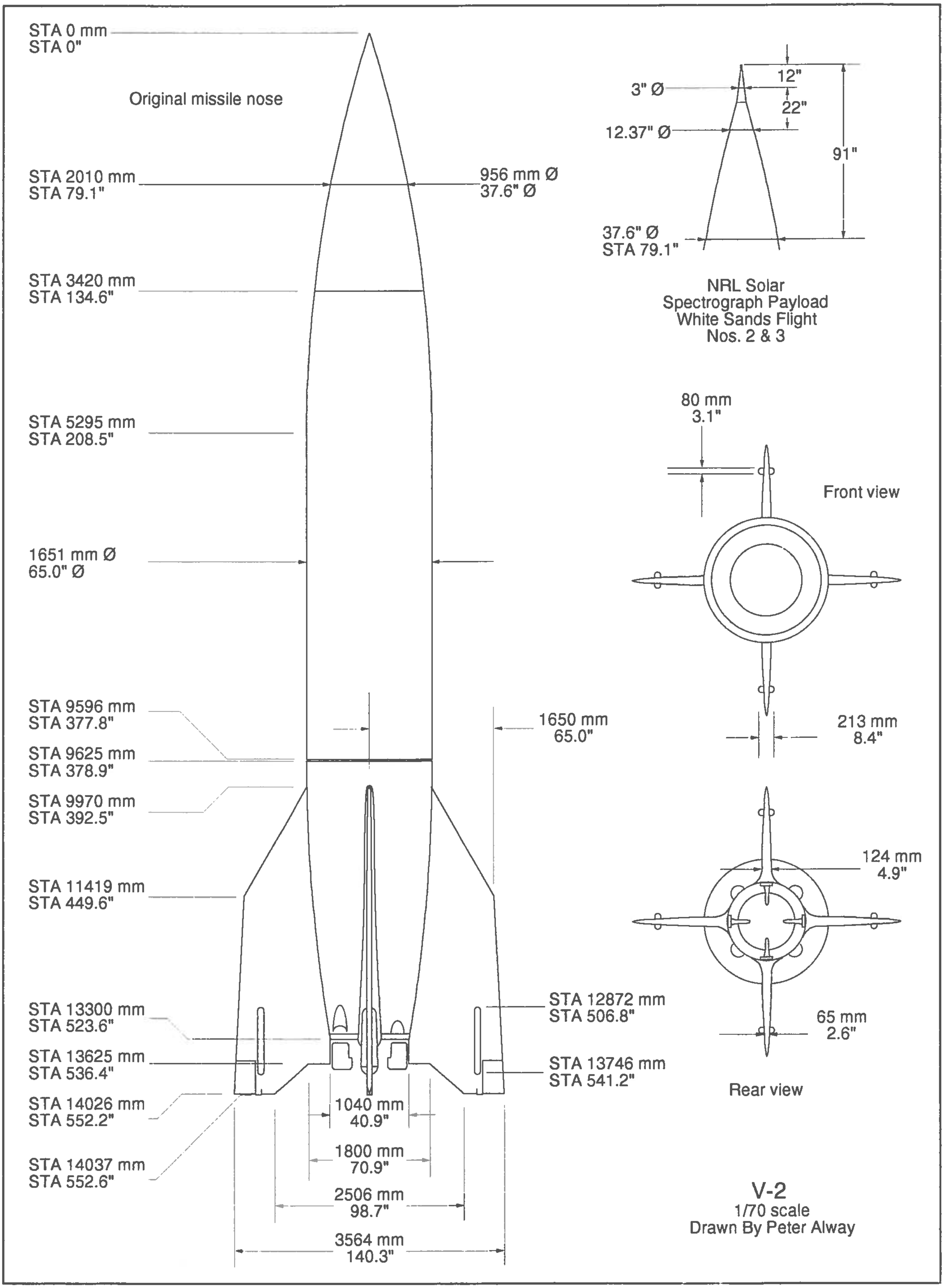


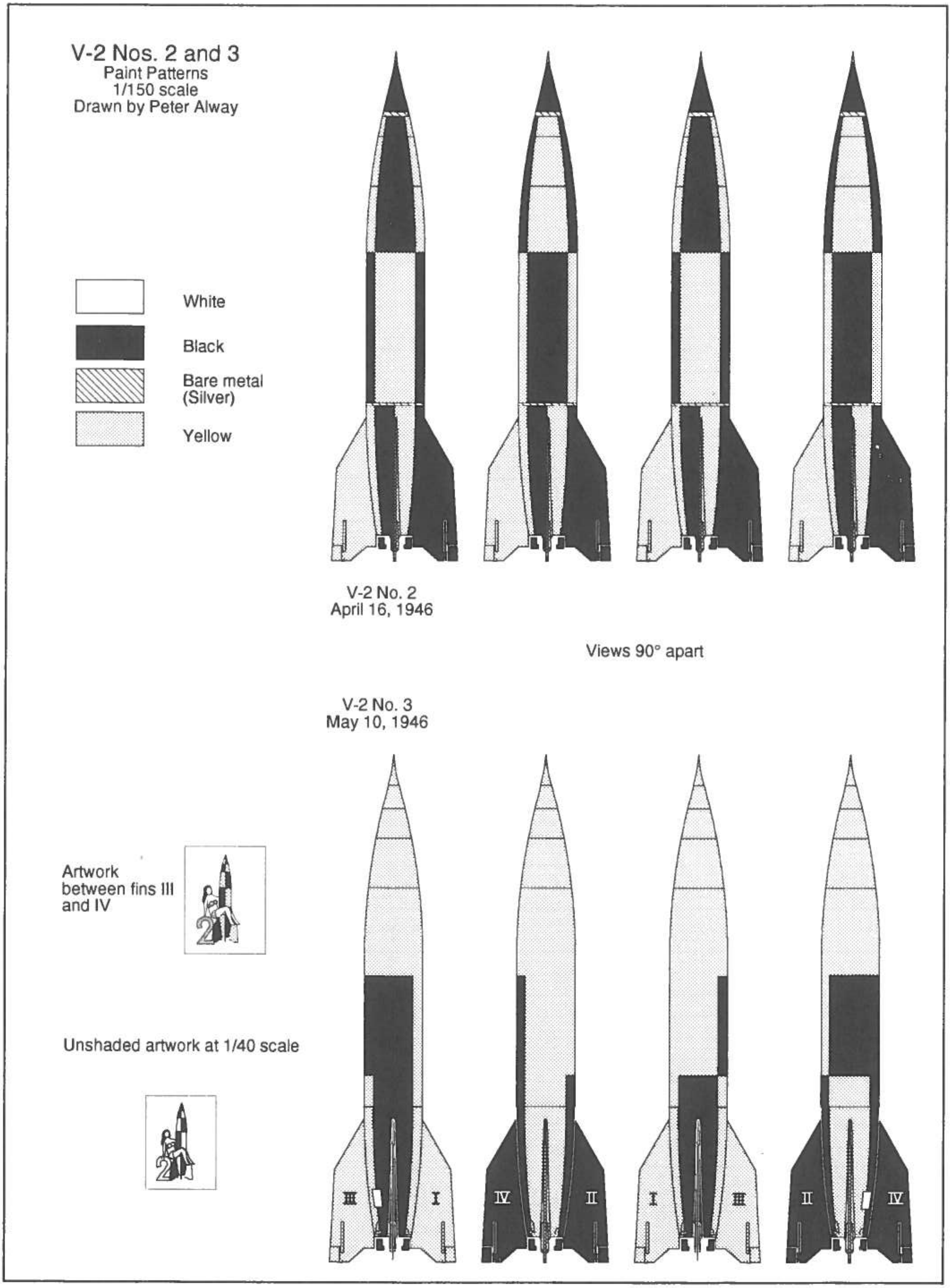
5) Refer to the exploded drawing to complete the rest of the model.



6) When the model is complete, load a C6-5 into the engine mount. Add clay to the nose cone to bring the model's balance point 3/4" in front of the tail-cone / body tube joint.




STA 0 mm
STA 0"
Original missile nose
STA 2010 mm
STA 79.1"
956 mm Ø
37.6" Ø
STA 3420 mm
STA 134.6"
STA 5295 mm
STA 208.5"
1651 mm Ø
65.0" Ø
STA 9596 mm
STA 377.8"
STA 9625 mm
STA 378.9"
STA 9970 mm
STA 392.5"
1650 mm
65.0"
STA 11419 mm
STA 449.6"
STA 13300 mm
STA 523.6"
STA 13625 mm
STA 536.4"
STA 14026 mm
STA 552.2"
STA 14037 mm
STA 552.6"
STA 12872 mm
STA 506.8"
STA 13746 mm
STA 541.2"
1040 mm
40.9"
1800 mm
70.9"
2506 mm
98.7"
3564 mm
140.3"
3" Ø
12"
22"
12.37" Ø
91"
37.6" Ø
STA 79.1"
NRL Solar
Spectrograph Payload
White Sands Flight
Nos. 2 & 3
80 mm
3.1"
Front view
213 mm
8.4"
124 mm
4.9"
65 mm
2.6"
Rear view
V-2
1/70 scale
Drawn By Peter Alway


V-2 Nos. 2 and 3
Paint Patterns
1/150 scale
Drawn by Peter Alway
White
Black
Bare metal (Silver)
Yellow
V-2 No. 2
April 16, 1946
Views 90° apart
V-2 No. 3
May 10, 1946
Artwork between fins III and IV
Unshaded artwork at 1/40 scale
III
I
IV
II
I
III
II
IV

GIRD 09

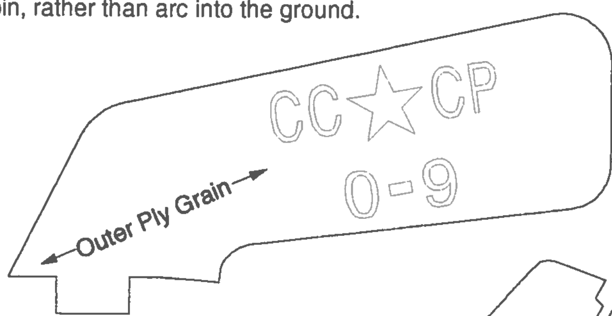
1/6.8 scale

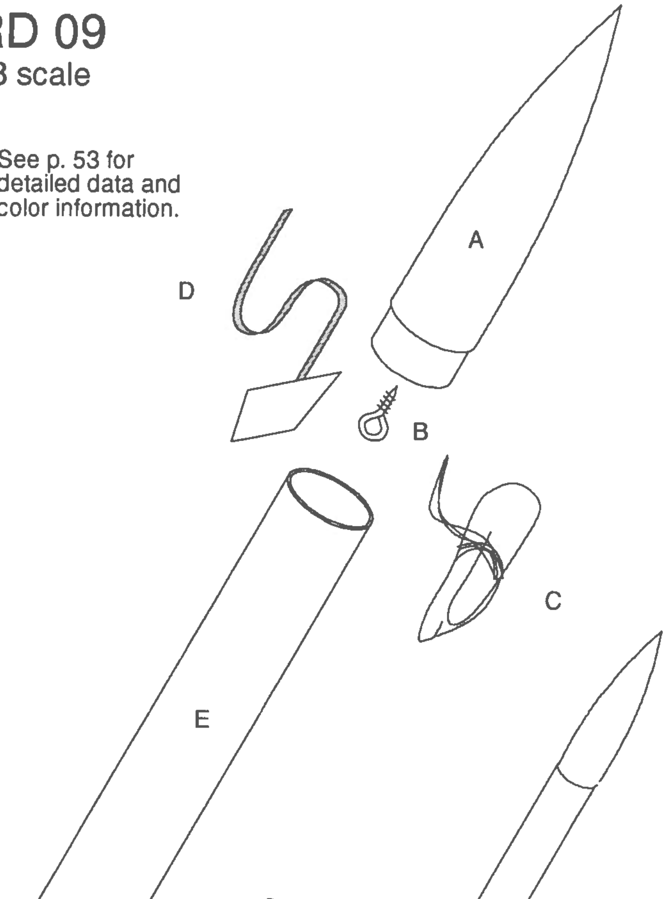
Parts List:

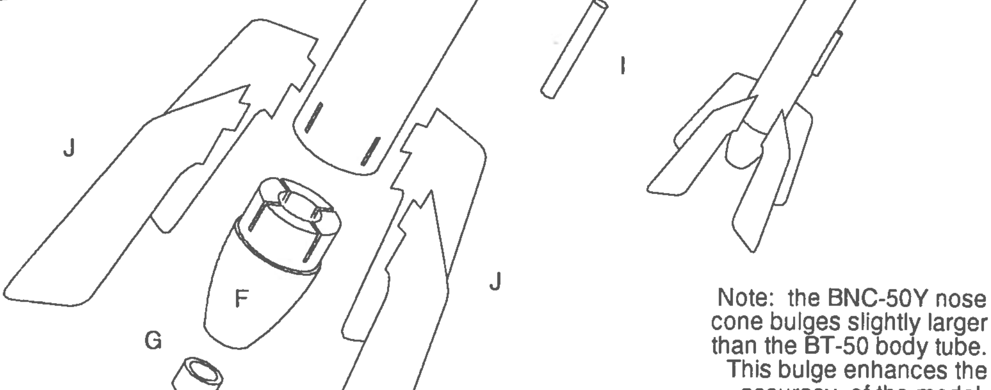
A) Nose Cone, Estes BNC-50Y
B) Screw eye
C) Parachute (12")
D) Shock Cord and Mount
E) Body Tube, 7 1/2" Estes BT-50
F) Tail Cone, from drilled out Estes BNC-50J nose cone
G) Engine Block, 1/4" sawed off expended mini (13 mm) engine
H) Engine Tube, 1 3/4" Estes BT-5
I) Launch Lug
J) Fins (4x), from 1/32" plywood

See p. 53 for detailed data and color information.

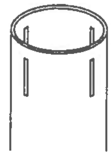
Fins (J):
Make four from 1/32" plywood (single-layer wood cannot be oriented to prevent breakage). Trace fin pattern four times face up on the same side of the wood, in the same orientation, so any warpage will be the same for each fin, causing the model to spin, rather than arc into the ground.





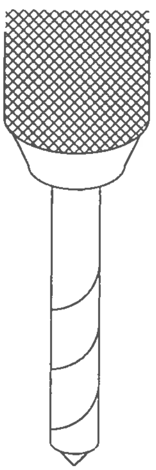


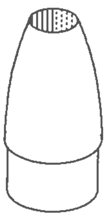
Note: the BNC-50Y nose cone bulges slightly larger than the BT-50 body tube. This bulge enhances the accuracy of the model.



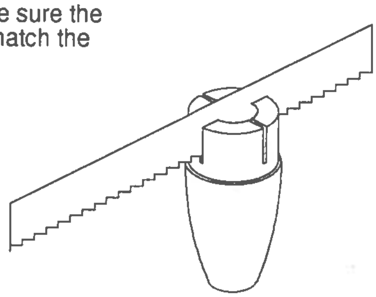
Cut four 1/32" x 3/8" slots, 1/8" from the base of the body tube (E). Be sure the body tube slots match the tail cone slots.

Recommended Engines:
1/2A3-2T, A3-4T, A10-3T





Tail Cone (F) fabrication:
Drill out hole through BNC-50J (left). A 1/2" drill bit is excellent, but smaller bits, a Dremel Moto-Tool, or even wood carving tools will do. Test fit and allignment of hole with BT-5. Use a razor saw to cut two sets of perpendicular slots 3/8" into the shoulder of the cone to accept the fin tabs.



Sparrow-HV Arcas

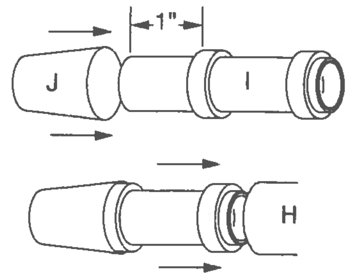
1/8.25 scale

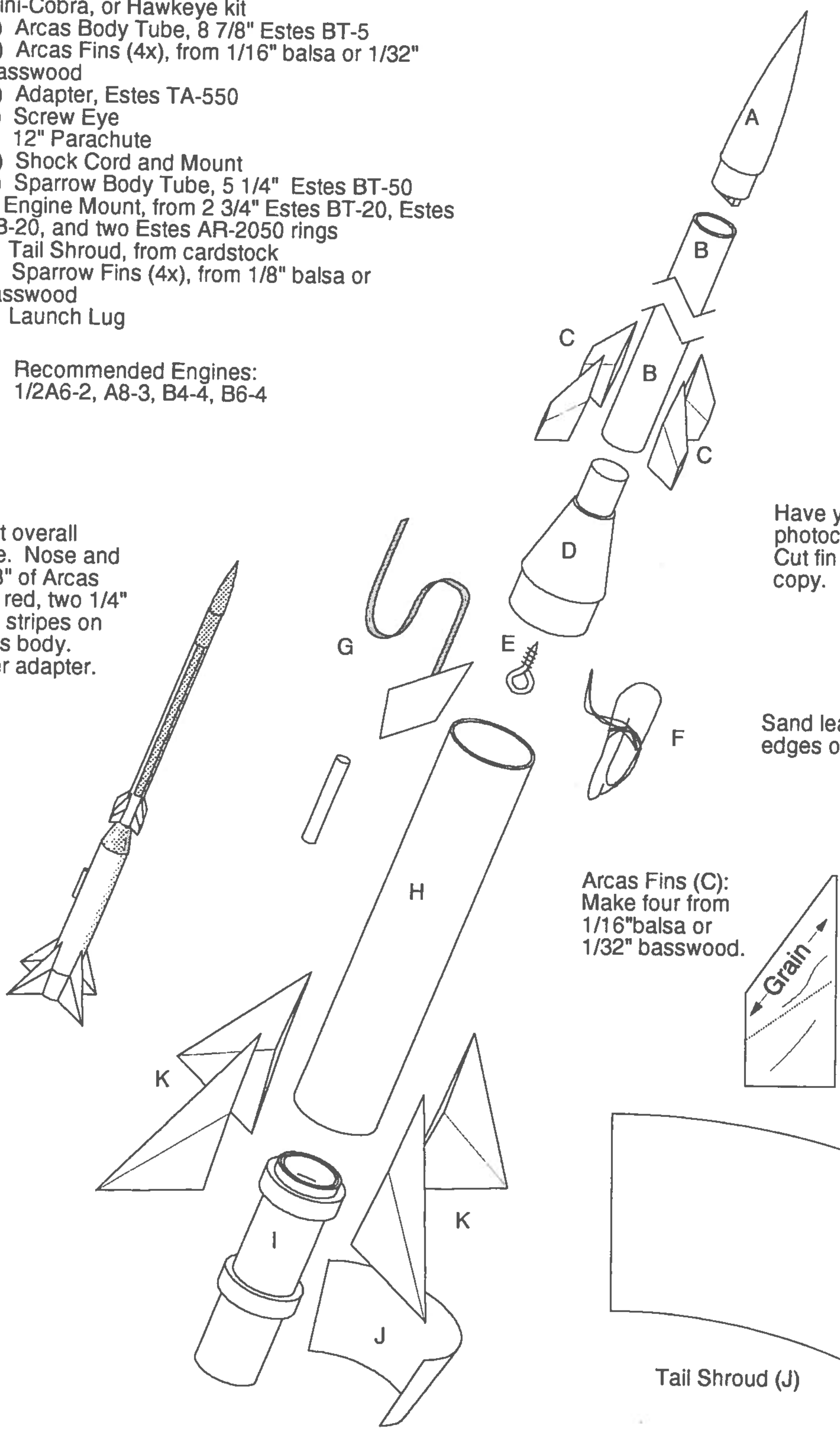
Parts List:

A) Nose Cone, from Estes Gnome, Sparrow, Mini-Cobra, or Hawkeye kit
B) Arcas Body Tube, 8 7/8" Estes BT-5
C) Arcas Fins (4x), from 1/16" balsa or 1/32" Basswood
D) Adapter, Estes TA-550
E) Screw Eye
F) 12" Parachute
G) Shock Cord and Mount
H) Sparrow Body Tube, 5 1/4" Estes BT-50
I) Engine Mount, from 2 3/4" Estes BT-20, Estes EB-20, and two Estes AR-2050 rings
J) Tail Shroud, from cardstock
K) Sparrow Fins (4x), from 1/8" balsa or basswood
L) Launch Lug

Recommended Engines:
1/2A6-2, A8-3, B4-4, B6-4

Glue one ring of engine mount 1" from rear of tube. Then glue tail shroud (J) to engine mount. Finally, glue engine mount into Sparrow body tube.





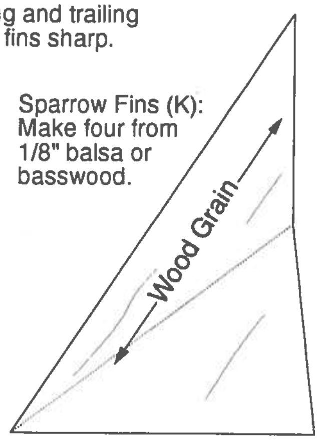
Have your neigborhood copy shop photocopy this plan onto card stock. Cut fin patterns and shroud from copy.

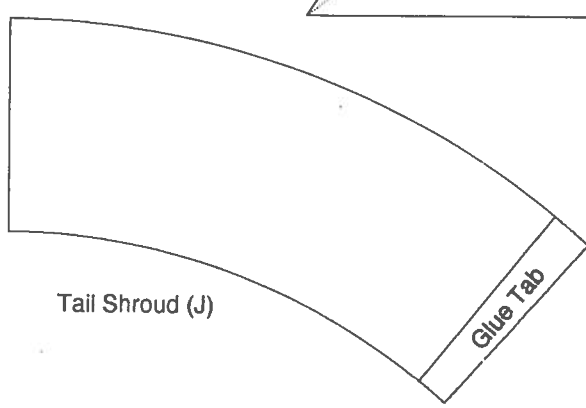
Paint overall white. Nose and 1 3/8" of Arcas tube red, two 1/4" wide stripes on Arcas body. Silver adapter.

Sand leading and trailing edges of all fins sharp.

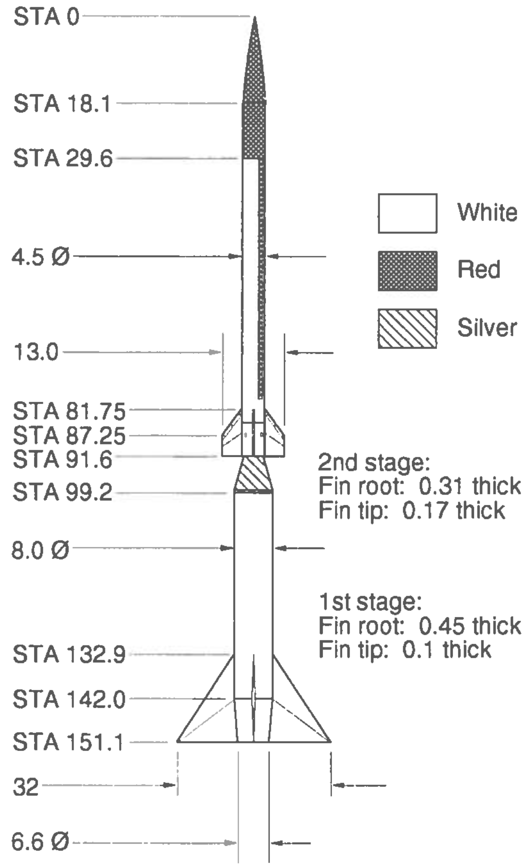
Arcas Fins (C): Make four from 1/16"balsa or 1/32" basswood.

Sparrow Fins (K): Make four from 1/8" balsa or basswood.

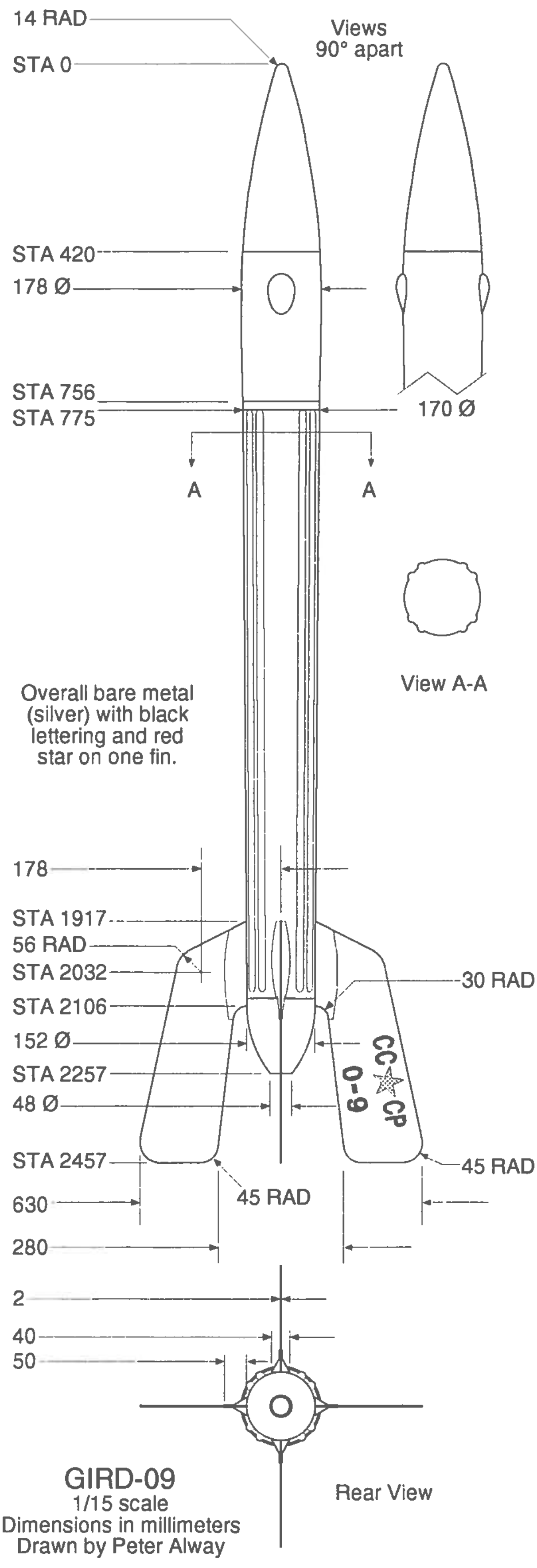




Tail Shroud (J)



Sparrow-HV Arcas
1/40 scale
Dimensions in inches
Drawn by Peter Alway



GIRD-09
1/15 scale
Dimensions in millimeters
Drawn by Peter Alway

carrying the first manned Apollo spacecraft into orbit in preparation for a manned Moon landing. Later Saturn IB's carried Skylab crews and the US half of Soviet-American Apollo-Soyuz Test Project.

Vostok

The Vostok booster (pp. 75-79) is one of a family of Soviet-Russian rockets that dates back to the original Sapwood intercontinental ballistic missile of 1957. As soon as the Sapwood had flown, Soviet Chief Designer Sergei Korolev adapted it to launch the world's first artificial satellite, Sputnik 1. With an additional upper stage, the Sapwood became the Vostok booster, which sent the first probes to the Moon. The manned Vostok spacecraft followed. On April 12, 1961, Yuri Gagarin rode Vostok 1 into Earth orbit, becoming the first human to fly in space. The Vostok still carries satellites into orbit. The Soyuz and Molniya boosters use more powerful upper stages to launch larger payloads, including the current manned Soyuz craft.

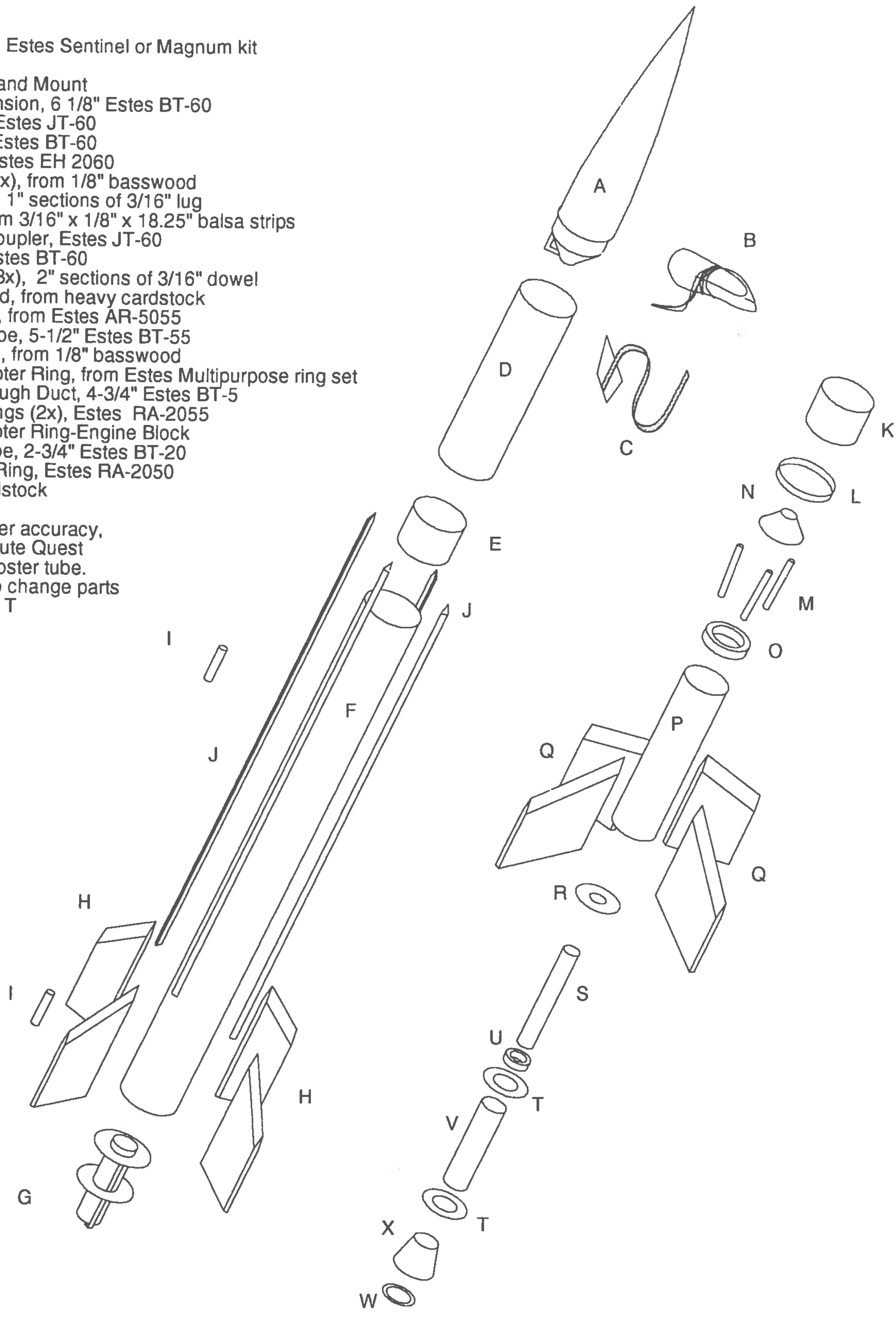
Aerobee 150A

1/9.16 scale

Parts List:

A) Nose Cone, from Estes Sentinel or Magnum kit
B) 18" Parachute
C) 18" Shock Cord and Mount
D) Body Tube Extension, 6 1/8" Estes BT-60
E) Stage Coupler, Estes JT-60
F) Body Tube, 18" Estes BT-60
G) Engine Mount, Estes EH 2060
H) Sustainer Fins (4x), from 1/8" basswood
I) Launch Lugs (2x), 1" sections of 3/16" lug
J) Conduits (4x), from 3/16" x 1/8" x 18.25" balsa strips
K) Booster Stage Coupler, Estes JT-60
L) Tube ring, 1/4" Estes BT-60
M) Booster Struts (3x), 2" sections of 3/16" dowel
N) Booster Front End, from heavy cardstock
O) Reinforcing Ring, from Estes AR-5055
P) Booster Body Tube, 5-1/2" Estes BT-55
Q) Booster Fins (4x), from 1/8" basswood
R) BT-5/BT-55 Adapter Ring, from Estes Multipurpose ring set
S) Booster Blowthrough Duct, 4-3/4" Estes BT-5
T) Engine Mount Rings (2x), Estes RA-2055
U) BT-5/BT-20 Adapter Ring-Engine Block
V) Engine mount tube, 2-3/4" Estes BT-20
W) Nozzle Support Ring, Estes RA-2050
X) Nozzle, from cardstock

Note: for greater accuracy, you can substitute Quest T-35 for the booster tube. you will need to change parts N, O, P, R, and T accordingly.



Aerobee 150A

1/9.16 scale

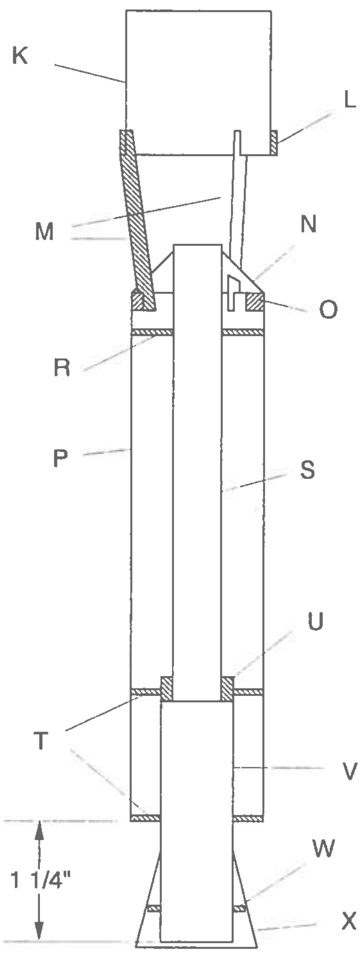
This model uses a simple staging trick that you can use for various Aerobee versions, as well as the Wac Corporal or Iris sounding rocket. A similar plan for the Aerobee-Hi appeared in the June, 1989 *American Spacemodeling*. G. Harry Stine suggested a vented staging system for widely separated engines in the fifth edition of his *Handbook of Model Rocketry*. This model takes "venting" to an extreme, with its open air interstage. This system has been shown to be over 90% reliable in Aerobee-Hi models.

The sustainer stage of the Aerobee 150A follows familiar construction techniques, with the exception of the engine mount. The rear adapter ring of the mount should be 1 1/4" forward of the rear of the engine tube, to leave clearance for the stage coupler. Don't install the engine mount until you have glued the booster tube ring (L) in place on the stage coupler (K). Then use the stage coupler to press the engine mount in the correct distance.

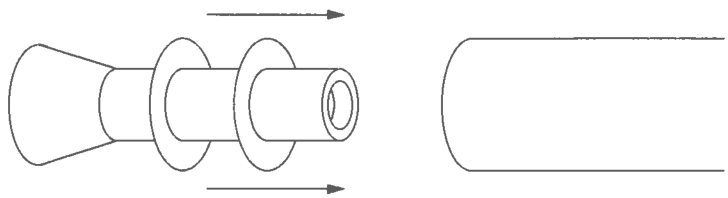
Booster assembly is a bit tricky, as parts must be assembled in the correct order to avoid "painting yourself into a corner." You may wish to modify the plan to incorporate through-the-wall fin construction in the first stage, as the tumbling booster can hit hard.

The nose cone for this model is not available separately, so you'll have to kitbash from an Estes Sentinel or Magnum.

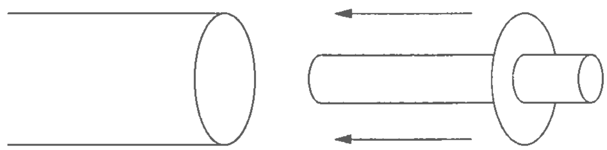
Cross-section of the booster shows the arrangement of concentric tubes and rings.



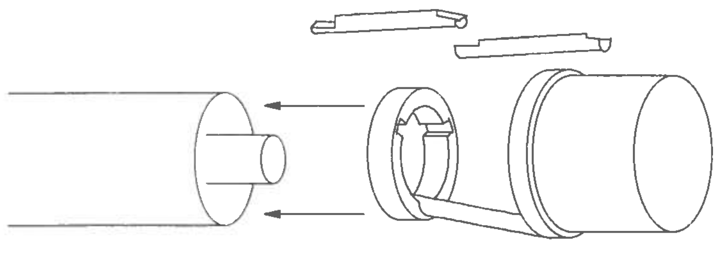
Install the booster engine mount first.



Next glue in the booster blowthrough vent. An expended engine in the engine mount will keep you from pushing the tube in too far.



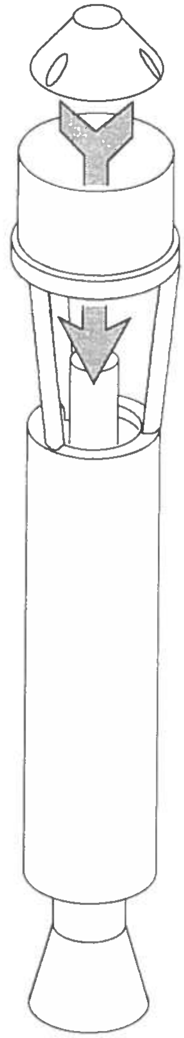
Assemble the interstage section, and glue it in place. As the glue on the AR-5055 support ring dries, you can do last-minute alignment of the booster and sustainer.

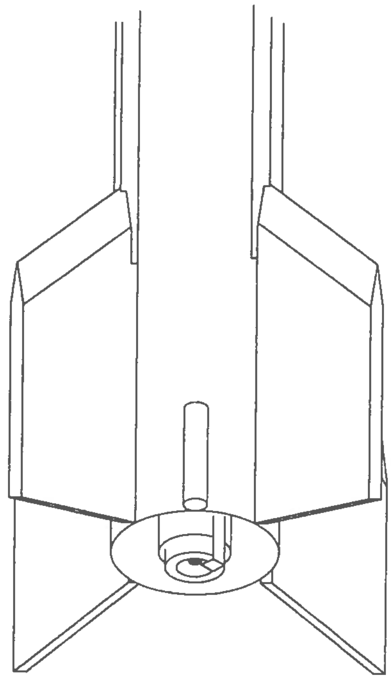


Aerobee 150A

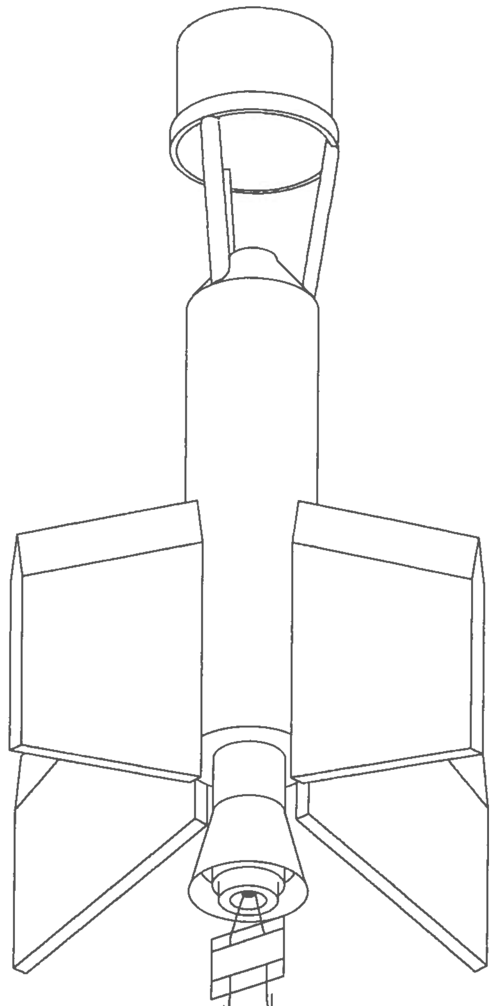
1/9.16 scale

Top off the booster with its conical front end. Make an extra cone to protect the permanent one from the upper stage blast.





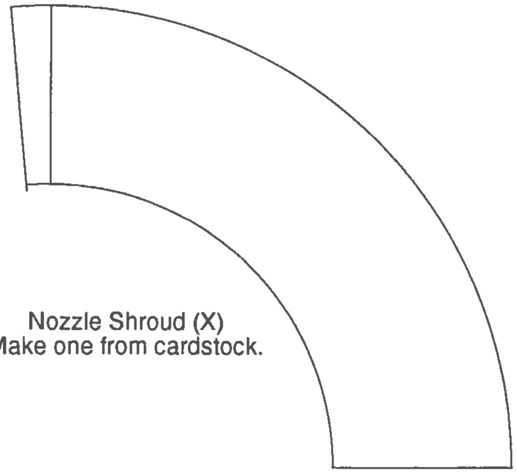
Add fins, finish off the top stage, and you're ready to fly.



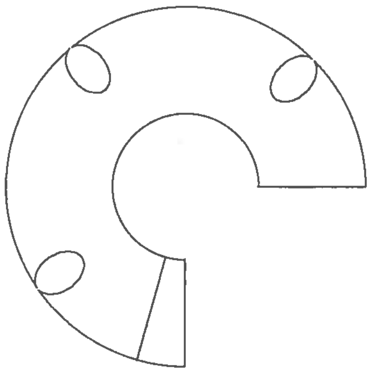
Staging this model is simple: Friction fit a C6-0 or B6-0 engine into the booster, and insert a B4-2, B4-4, B8-5, or C5-3 into the upper stage (use a C6-0 booster if you use the long-delay B4-4 or B8-5). You may wish to build a D version of this model, both for higher altitudes and more reliable staging.

Aerobee 150A

1/9.16 scale Patterns

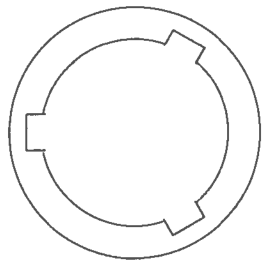


Nozzle Shroud (X)
Make one from cardstock.



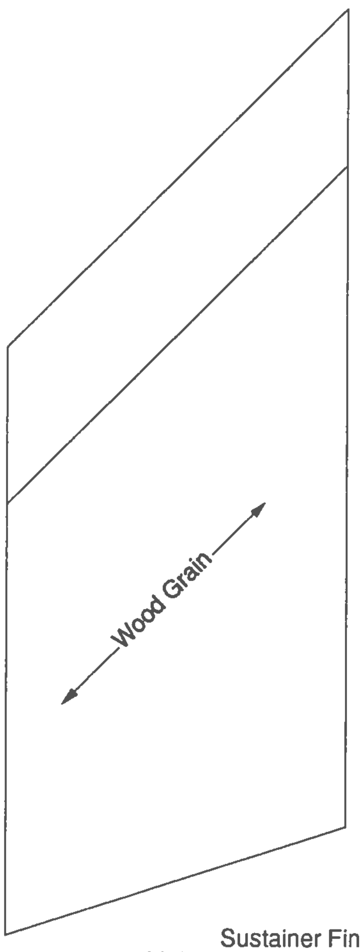
Booster Front End (N)
Make one from heavy cardstock. Make replaceable protectors from this pattern as well.

Booster Strut (M)
Make three from 3/16" dowel.

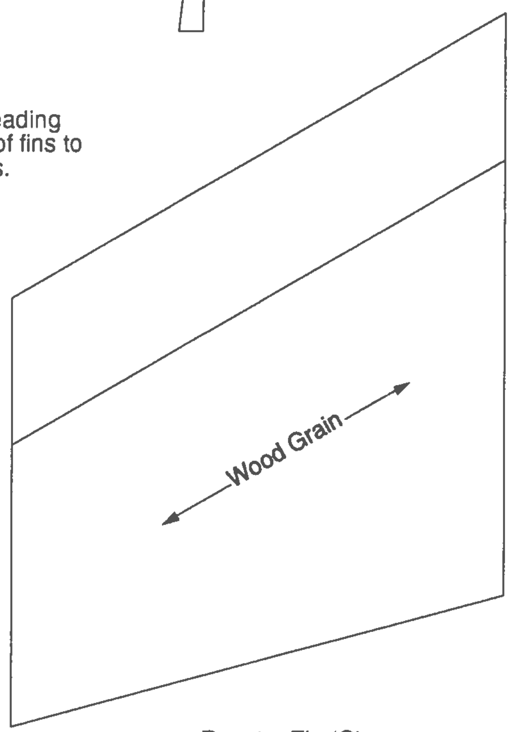


Booster Reinforcing Ring (O):
Make one from AR-5055 ring.

Sand leading edges of fins to wedges.

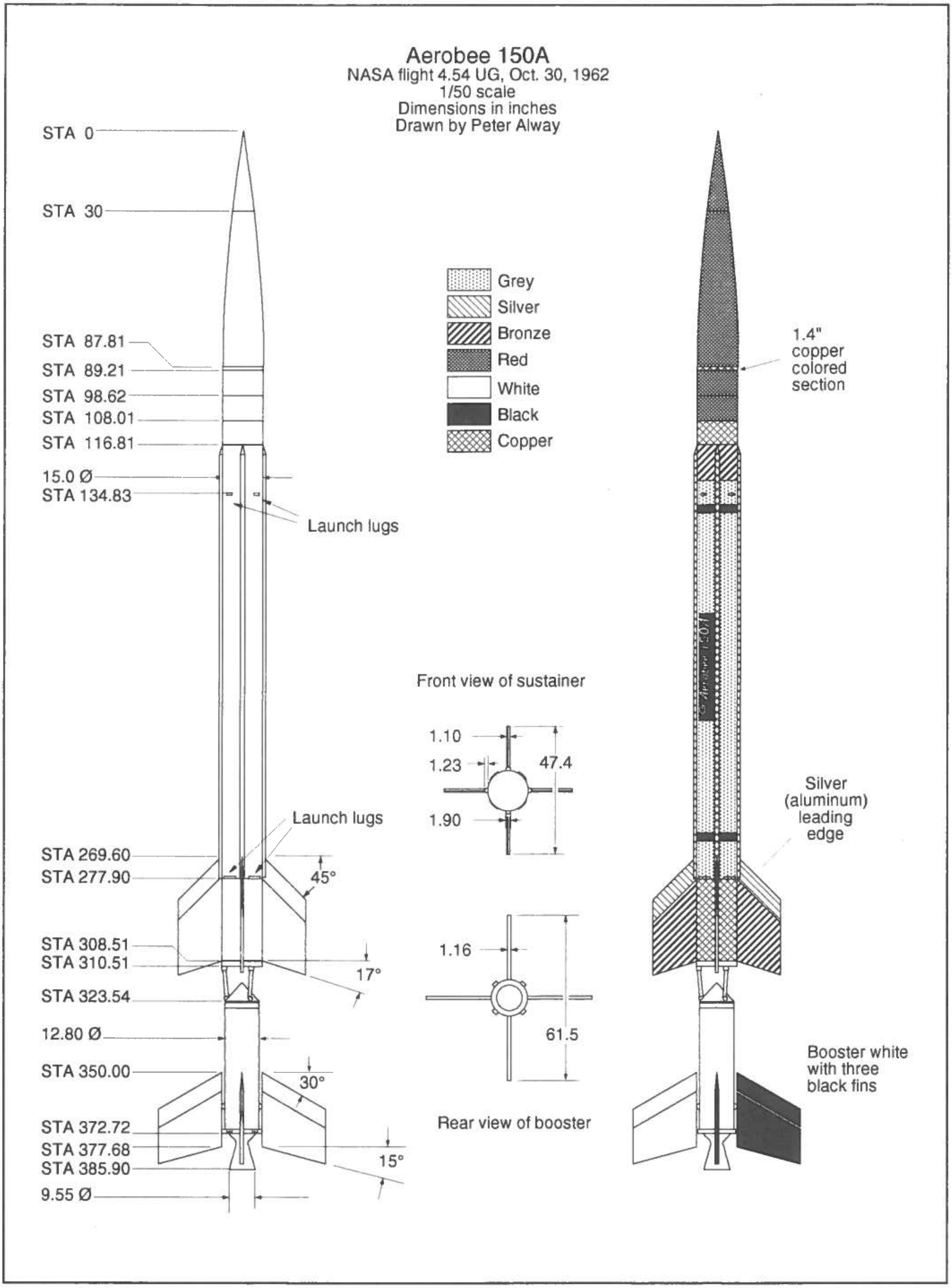


Sustainer Fin (H)
Make four from 1/8" basswood.



Booster Fin (Q)
Make four from 1/8" basswood.

Photocopy name decal and glue to model after painting

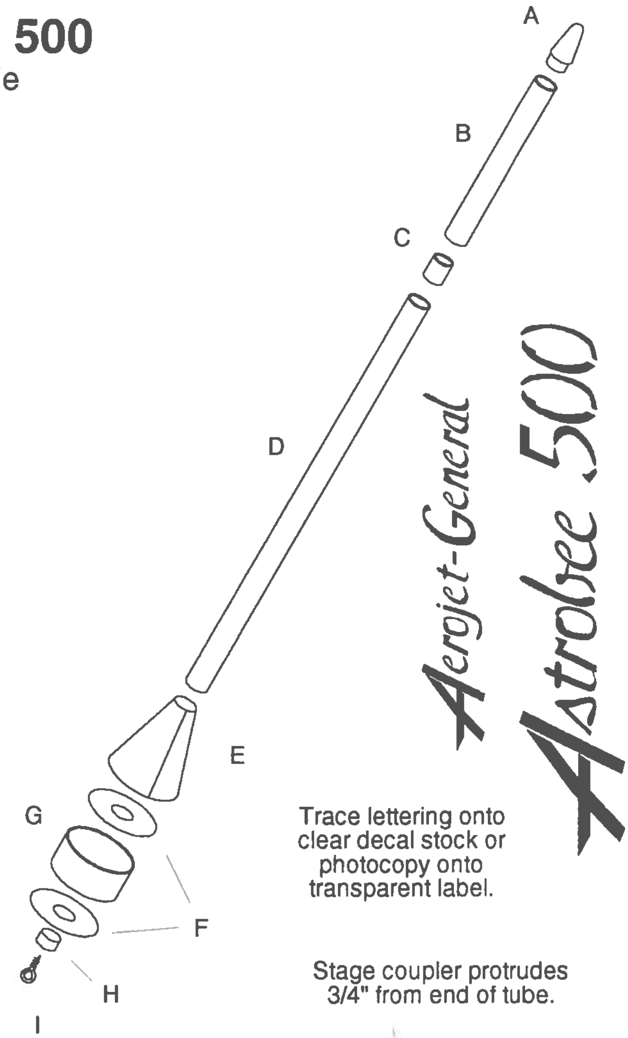

Aerobee 150A
NASA flight 4.54 UG, Oct. 30, 1962
1/50 scale
Dimensions in inches
Drawn by Peter Alway
STA 0
STA 30
STA 87.81
STA 89.21
STA 98.62
STA 108.01
STA 116.81
15.0 Ø
STA 134.83
Launch lugs
Grey
Silver
Bronze
Red
White
Black
Copper
1.4" copper colored section
Front view of sustainer
1.10
1.23
47.4
1.90
Launch lugs
STA 269.60
STA 277.90
45°
Silver (aluminum) leading edge
STA 308.51
STA 310.51
17°
1.16
STA 323.54
12.80 Ø
61.5
STA 350.00
30°
Booster white with three black fins
STA 372.72
STA 377.68
STA 385.90
15°
Rear view of booster
9.55 Ø

Astrobee 500

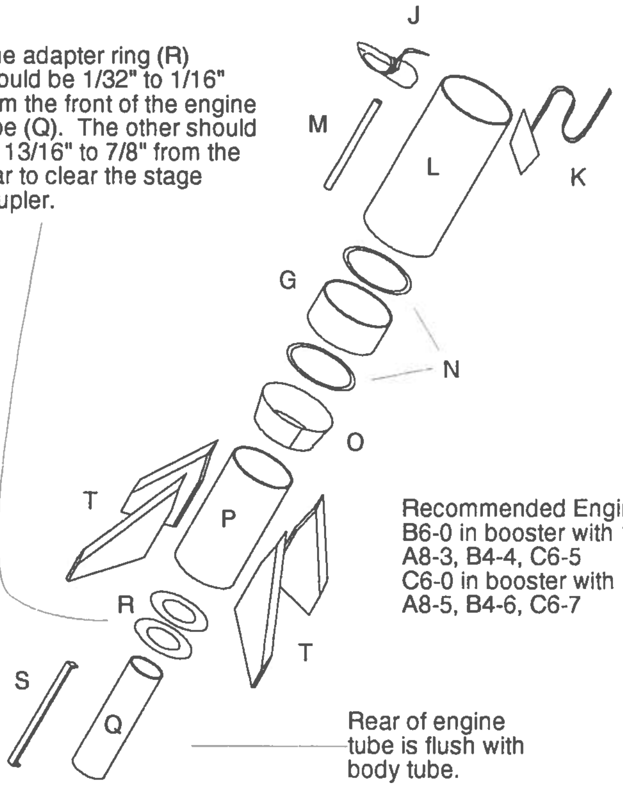
1/12 scale

Parts List:

A) Nose Cone, Estes BNC-5S rounded to 7/8" long
B) Payload Tube, 4 1/4" Estes BT-5
C) Payload Coupler, Estes JT-5C
D) Asp Body tube, 10 1/2" Estes BT-5
E) Upper Transition, from cardstock
F) Upper Transition Adapter Rings (2x), RA-560 from Estes multi-purpose ring set
G) Transition Supports (2x), 3/4" sections of Estes JT-60C
H) Nose Block, from 1/4" balsa
I) Screw Eye
J) 12" Parachute
K) Shock Cord and Mount
L) Second Stage Upper Body tube, 3 9/16" Estes BT-60
M) Launch Lug
N) Lower Transition Adapter Rings (2x), RA-5560 from Estes multi-purpose ring set
O) Lower Transition, from cardstock
P) Second Stage Lower Body Tube, 2 3/4" Estes BT-55
Q) Second Stage Engine Tube, 2 3/4" Estes BT-20
R) Engine Mount Adapter Rings (2x) RA-2055 from Estes multi-purpose ring set
S) Engine Hook
T) Upper Stage Fins (4x), from 3/32" balsa or basswood.
U) Stage coupler, Estes JT-55C
V) Booster Body Tube, 3 7/8" Estes BT-55
W) Centering Strips (3x), 0.273" x 1 1/4" x 3/32" balsa or basswood
X) Booster Engine Tube, 2 3/4" Estes BT-20
Y) Engine Block
Z) Nozzle Shroud, from cardstock
AA) Nozzle Adapter Ring, RA-2050 from Estes multi-purpose ring set
AB) Booster Fins (4x), from 3/32" balsa or basswood



Trace lettering onto clear decal stock or photocopy onto transparent label.

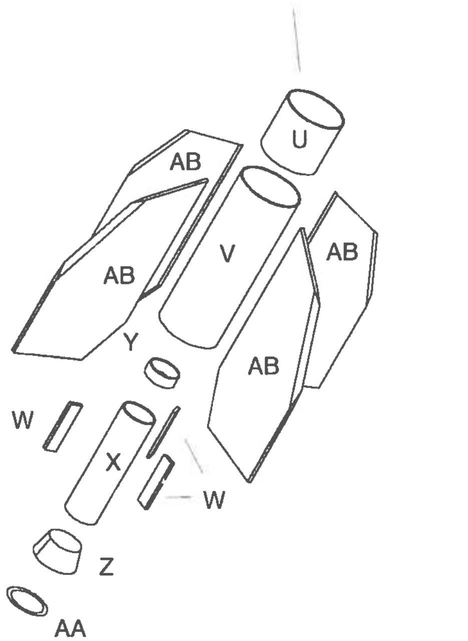


One adapter ring (R) should be 1/32" to 1/16" from the front of the engine tube (Q). The other should be 13/16" to 7/8" from the rear to clear the stage coupler.

Rear of engine tube is flush with body tube.

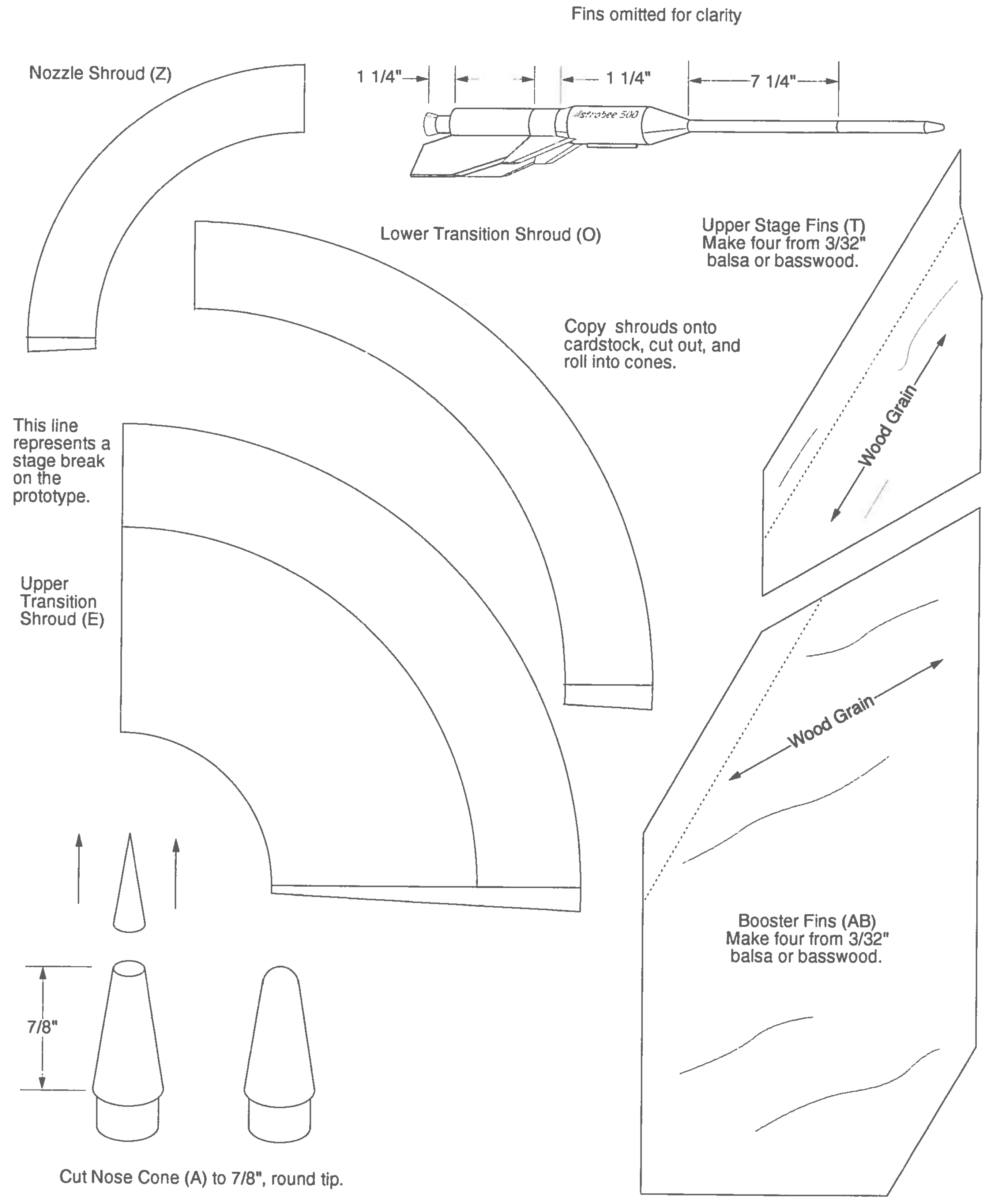
Recommended Engines:
B6-0 in booster with 1/2A6-2, A8-3, B4-4, C6-5
C6-0 in booster with 1/2A6-4, A8-5, B4-6, C6-7

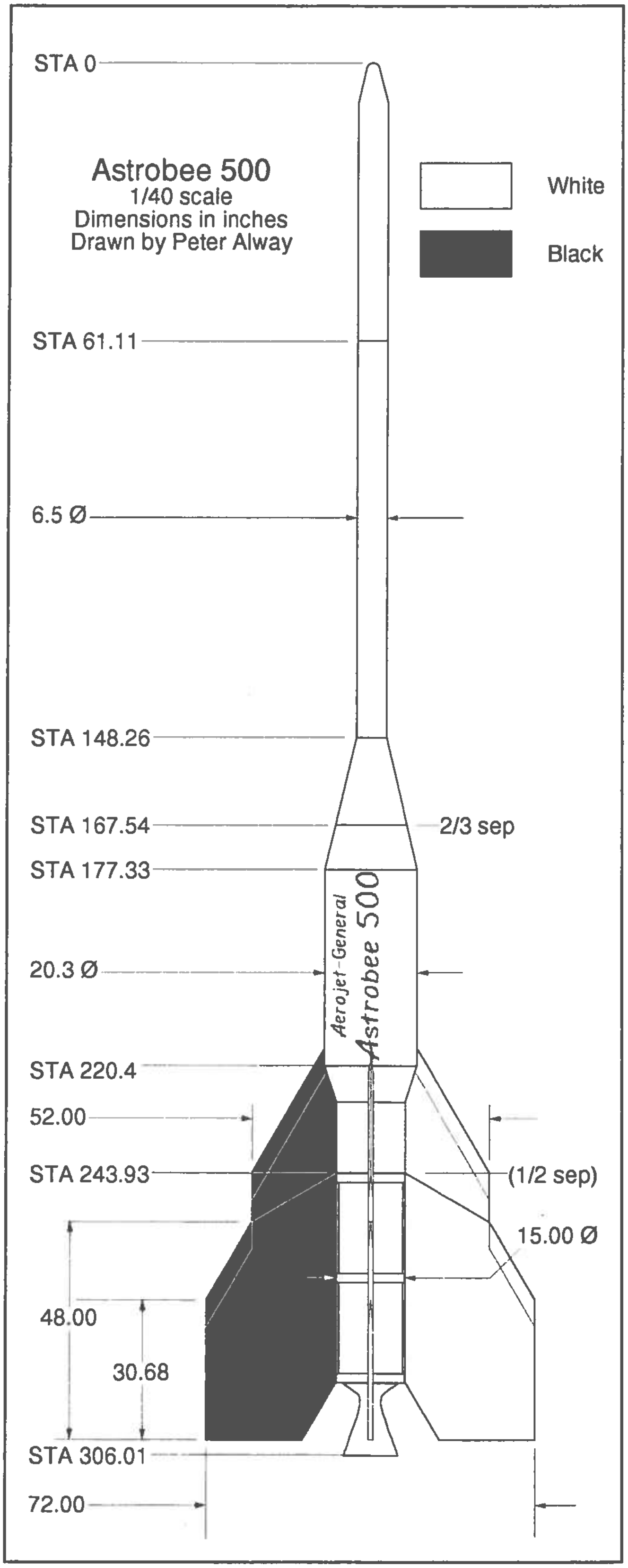
Stage coupler protrudes 3/4" from end of tube.

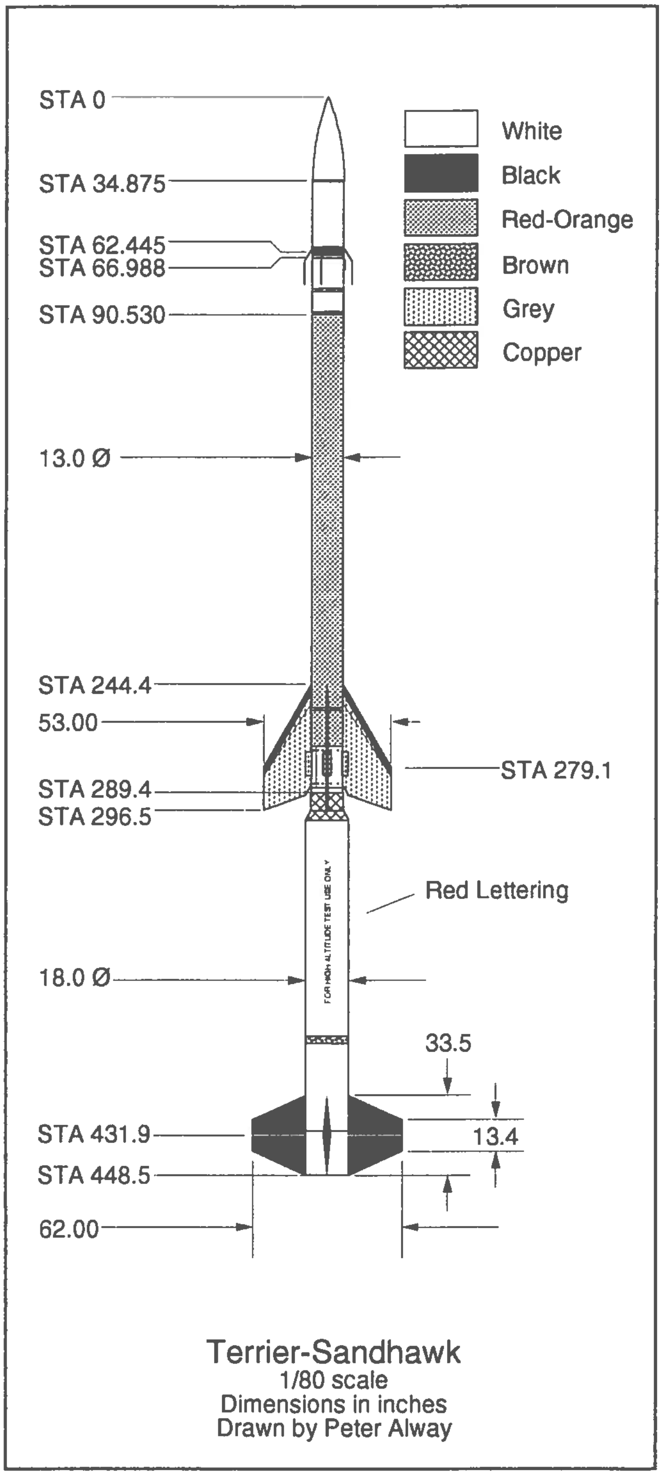


Astrobee 500

1/12 scale







Terrier-Sandhawk

The Terrier-Sandhawk combined the Sandia National Laboratory's Sandhawk motor with the booster from the Navy's Terrier surface-to-air missile. The rocket could carry a 200 lb payload to an altitude of about 260 miles.

The first Terrier-Sandhawk carried an X-ray astronomy payload aloft from Johnson Island in the Pacific on September of 1967. Dozens more flew from Alaska, Hawaii, and Western Australia, some during solar eclipses. Terrier-Sandhawks also made atmospheric measurements in support of weapons research. After more than 30 flights, the last Terrier-Sandhawk flew in September of 1977.

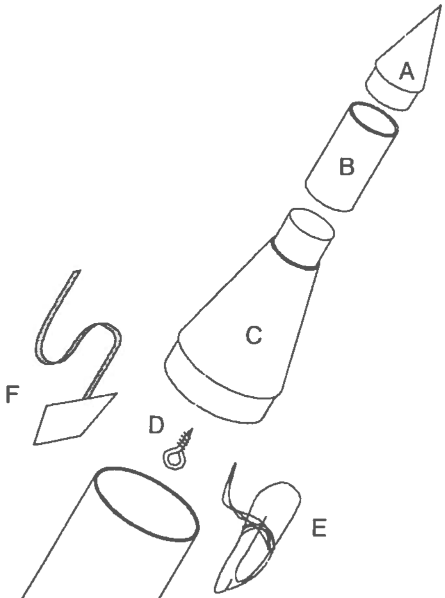
This data is presented without matching plans. Design your own model or build the Estes kit.

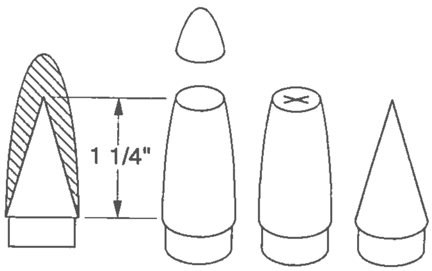
Juno II

1/64 scale

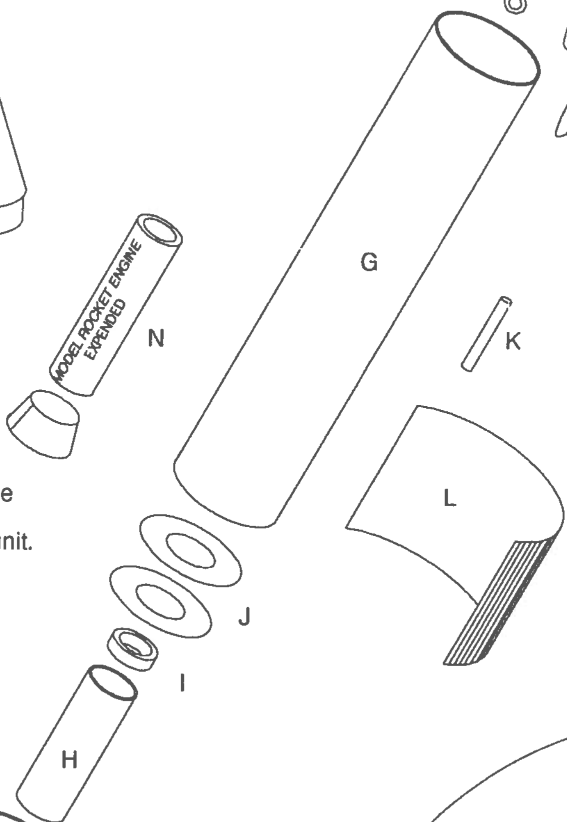
Parts List:

A) Nose Cone, Estes BNC-20B, R, or AM, trimmed to 1 1/4" cone
B) Payload Section, 1 3/8" Estes BT-20
C) Adapter, Estes TA-2060
D) Screw Eye
E) Parachute, 12" or 18"
F) Shock Cord (18" long) and Mount
G) Body Tube, 8 1/8" Estes BT-60
H) Engine Mount Tube, 2 1/4" Estes BT-20
I) Engine Block
J) Adapter Rings (2X), Estes AR-2060
K) Launch Lug
L) Body Wrap, 2 1/4" x 5 1/5" cardstock, corrugations scribed with dry ballpoint pen
M) Clear Fin Unit and Lock Ring, from Estes Beta Launch Vehicle kit or old stock Bail Out kit
N) Expended or Dummy Engine (18 mm standard)
O) Dummy Display Nozzle, from cardstock



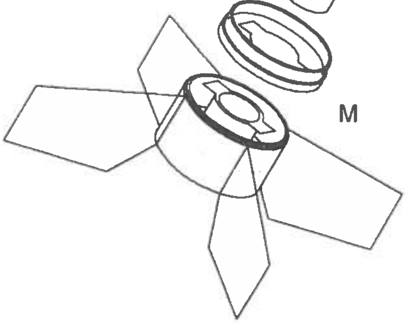


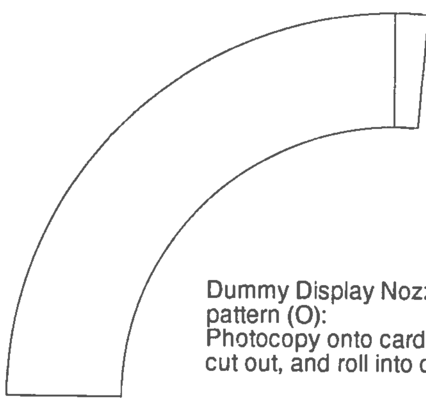
Cut nose cone (A) to length, mark center of cut end, and trim to conical shape.



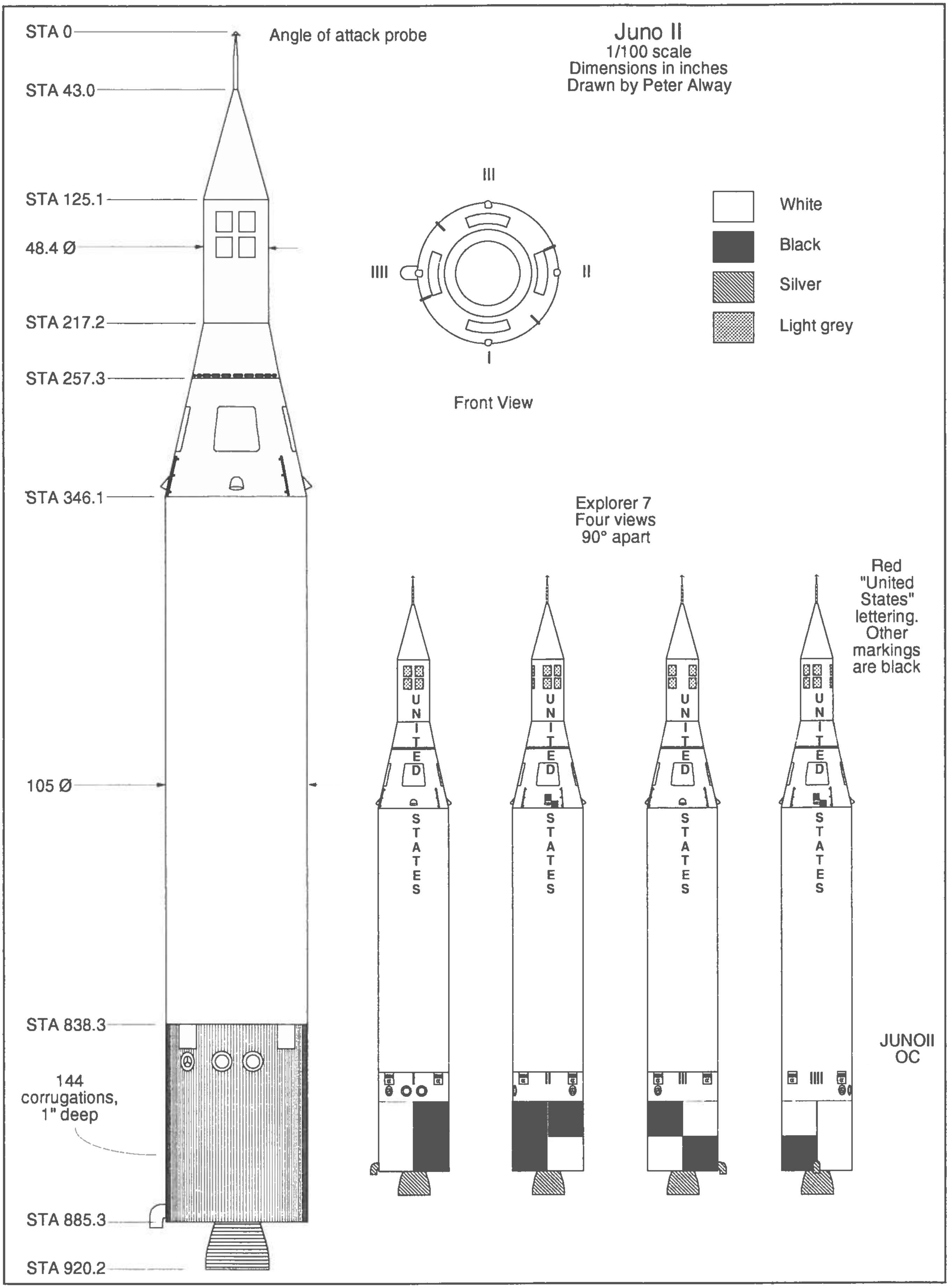
For shelf display, remove clear fin unit, and insert dummy display nozzle unit. Remove dummy nozzle assembly for flight.

Recommended Engines:
A8-3, B4-4, B6-4, C6-5





Dummy Display Nozzle pattern (O):
Photocopy onto cardstock, cut out, and roll into cone.

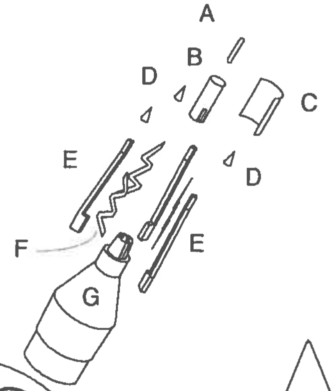

STA 0
Angle of attack probe
Juno II
1/100 scale
Dimensions in inches
Drawn by Peter Alway
STA 43.0
STA 125.1
48.4 Ø
STA 217.2
STA 257.3
STA 346.1
III
IIII
II
I
Front View
White
Black
Silver
Light grey
Explorer 7
Four views
90° apart
Red
"United
States"
lettering.
Other
markings
are black
UNITED
STATES
105 Ø
STA 838.3
144
corrugations,
1" deep
STA 885.3
STA 920.2
JUNOII
OC

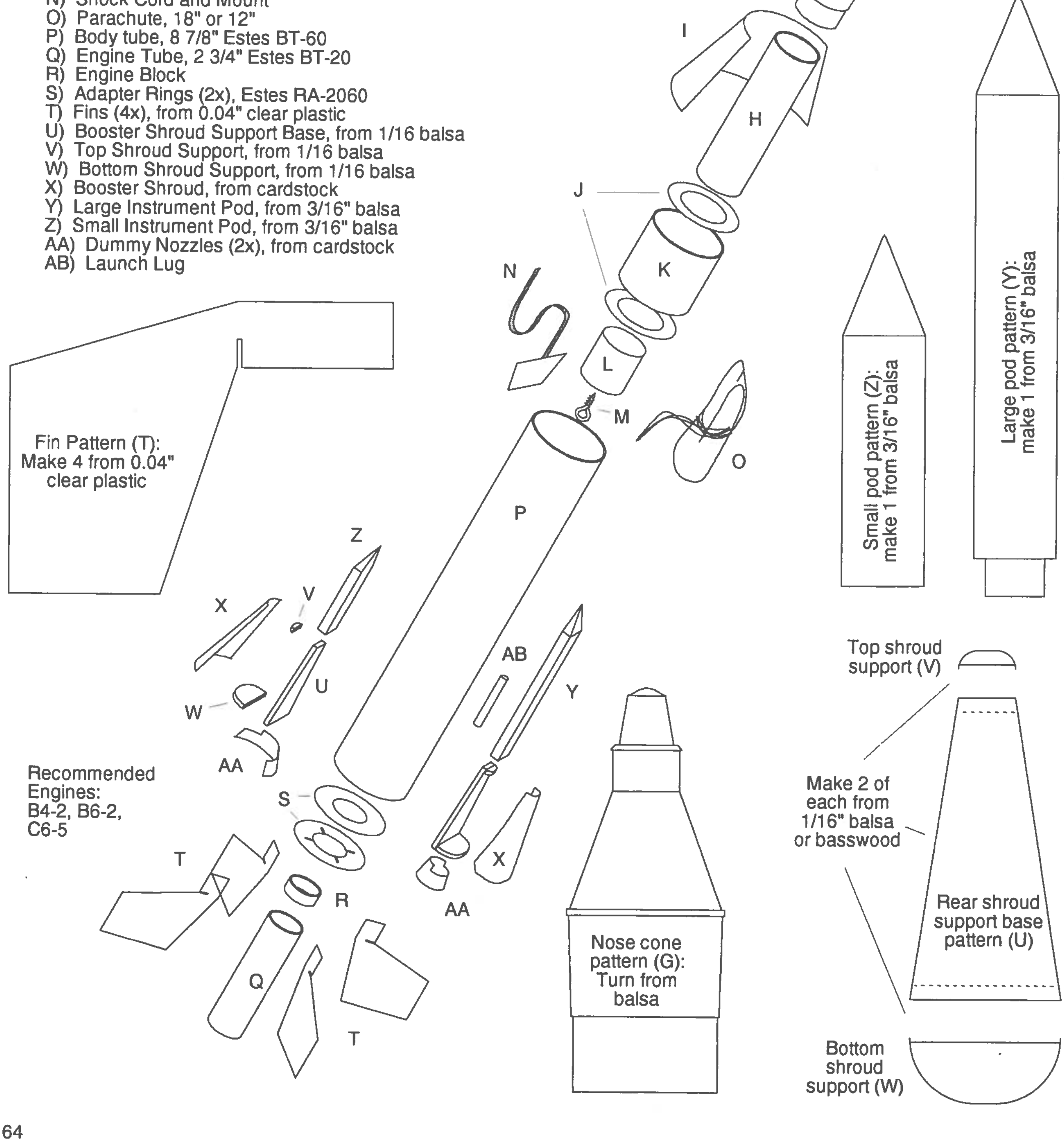
Mercury-Atlas

1/73 scale

Parts List:

A) Aerodynamic Spike, 1/2" toothpick
B) Escape Rocket, 1/4" balsa, 3/4" long
C) Escape Rocket Wrap, 3/4"x7/8" cardstock
D) Escape Rocket Nozzles (3x), from sharpened dowel
E) Escape Tower Struts (3x), from 1/16 basswood
F) Escape Tower Braces (3x), from cardstock
G) Nose Cone, turned from balsa
H) Shroud Body Tube, 3 1/2" Estes BT-50
I) Forward Shroud, from cardstock
J) Adapter rings (2x), Estes RA-5060
K) Stage Coupler, Estes JT-60
L) Nose Block, Estes NB-50
M) Screw Eye
N) Shock Cord and Mount
O) Parachute, 18" or 12"
P) Body tube, 8 7/8" Estes BT-60
Q) Engine Tube, 2 3/4" Estes BT-20
R) Engine Block
S) Adapter Rings (2x), Estes RA-2060
T) Fins (4x), from 0.04" clear plastic
U) Booster Shroud Support Base, from 1/16 balsa
V) Top Shroud Support, from 1/16 balsa
W) Bottom Shroud Support, from 1/16 balsa
X) Booster Shroud, from cardstock
Y) Large Instrument Pod, from 3/16" balsa
Z) Small Instrument Pod, from 3/16" balsa
AA) Dummy Nozzles (2x), from cardstock
AB) Launch Lug



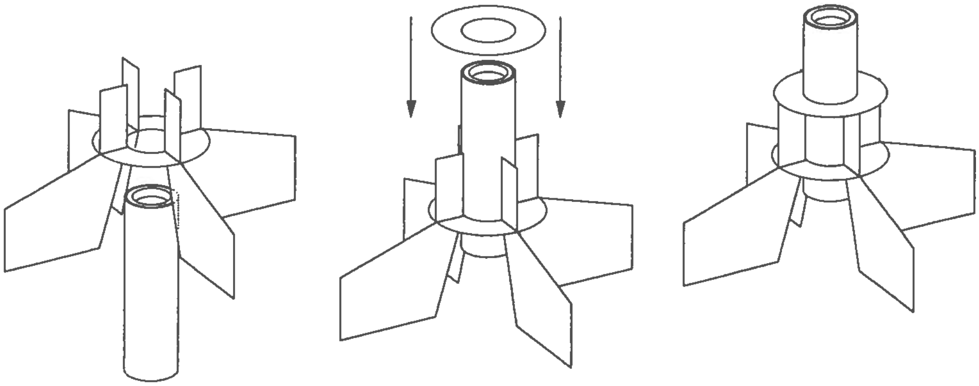


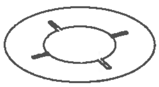
Recommended Engines:
B4-2, B6-2,
C6-5

Engine mount and fin attachment:

Cut fins from 0.40" clear plastic, such as that sold by Evergreen or Plastruct.

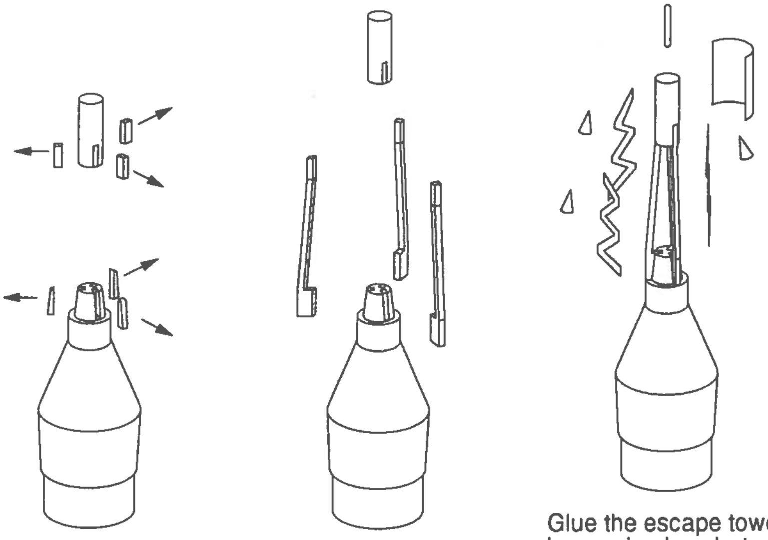
Glue engine block into front end of engine tube.





Cut four equally spaced notches in one RA-2060 adapter ring to accommodate the fins.

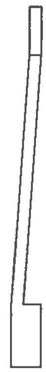
Dry fit the fins into the adapter ring. Slide the engine mount tube into place. Engine mount should protrude 1/2" behind ring. Epoxy fins, ring, and tube together. Complete unit by epoxying forward adapter ring to fron of fin tabs.



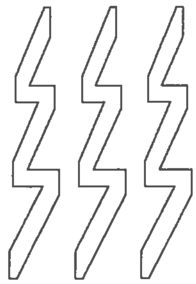
Cut notches in the capsule and escape rocket .

Glue escape tower struts into notches in capsule, glue escape rocket to top.

Glue the escape tower braces in place between the escape tower struts. Jab rocket nozzles and nose probe into escape rocket.



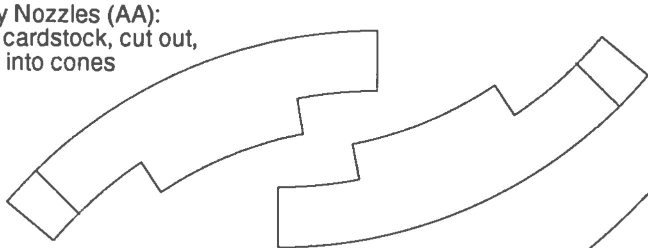
Escape Tower Strut Pattern (E): Make 3 from 1/16 basswood

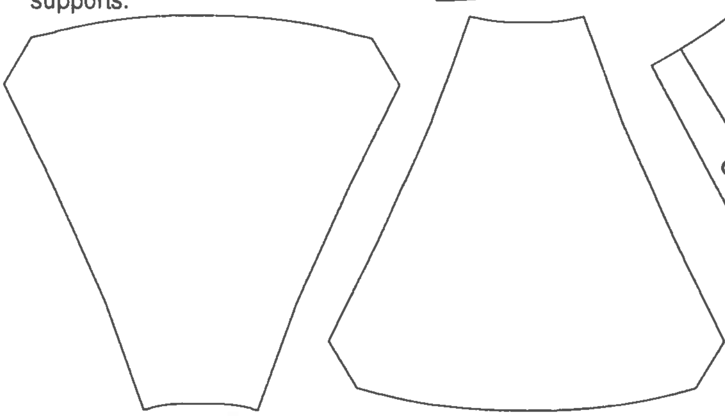


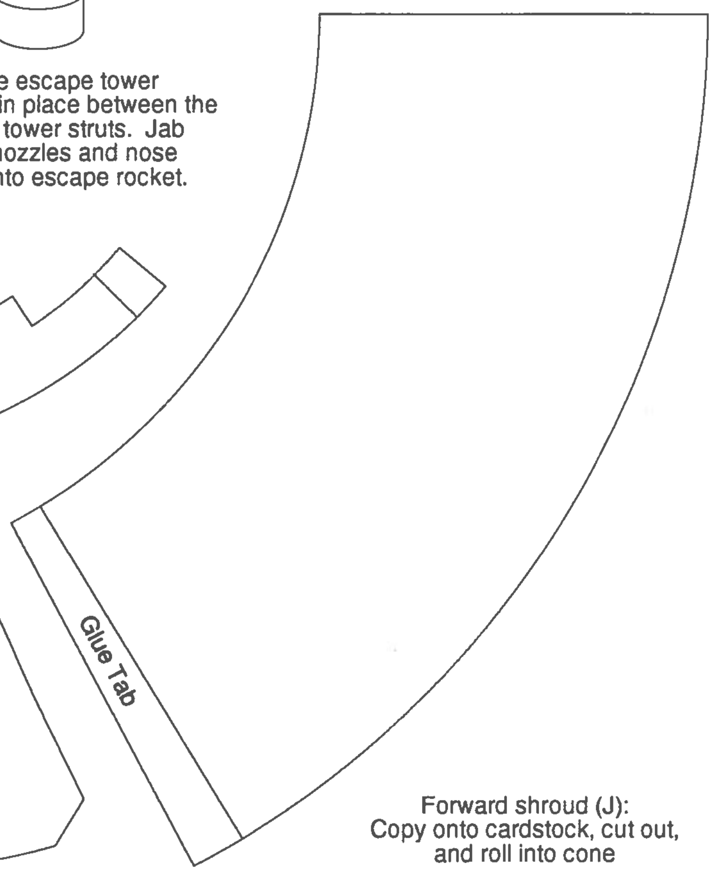
Escape tower Braces (F): Copy onto cardstock and cut out

Dummy Nozzles (AA): Copy onto cardstock, cut out, roll into cones

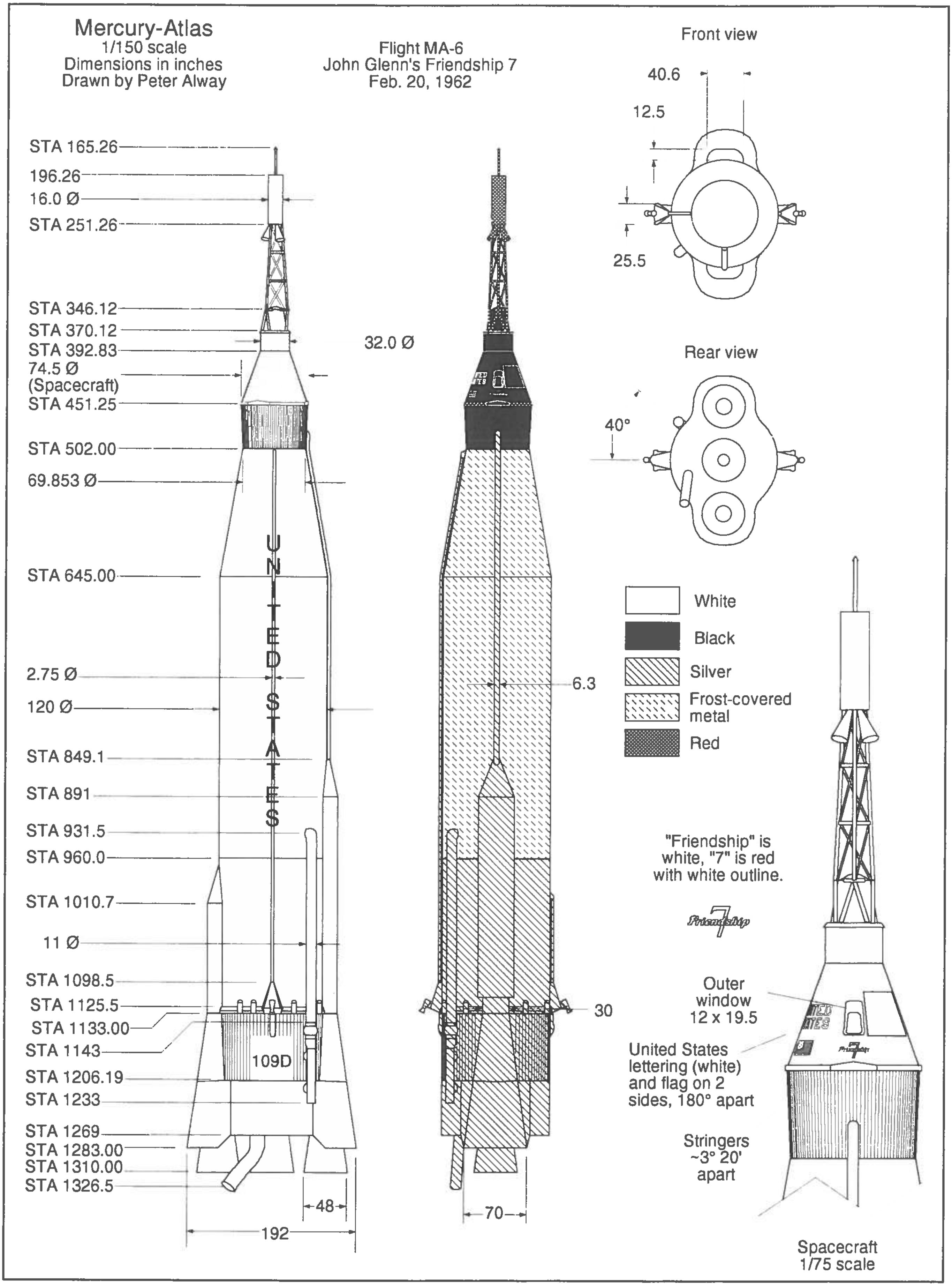
Booster Shrouds (X): Copy onto cardstock, cut out, glue over shroud supports.







Forward shroud (J): Copy onto cardstock, cut out, and roll into cone

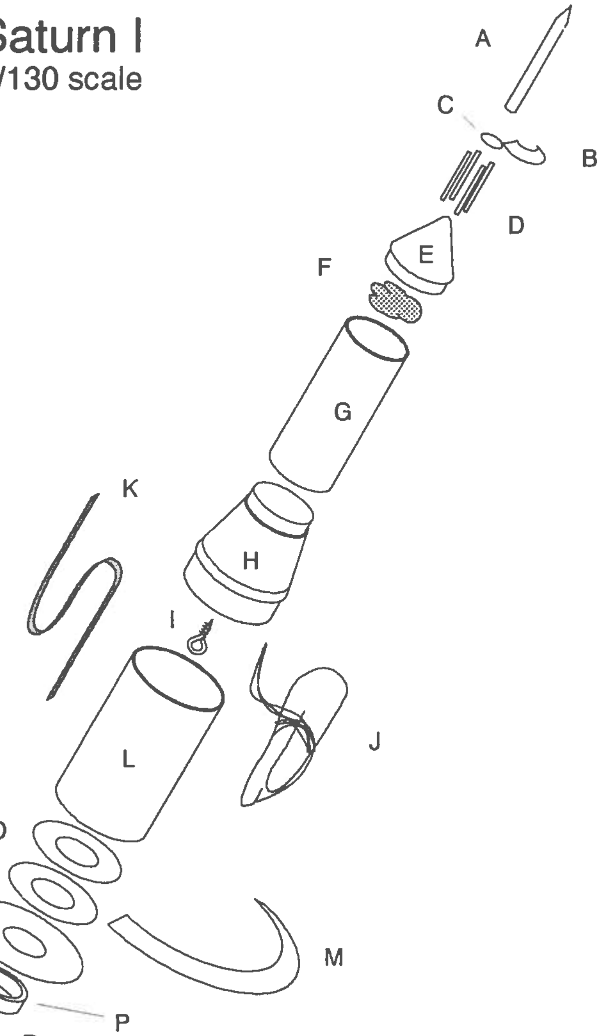

Mercury-Atlas
1/150 scale
Dimensions in inches
Drawn by Peter Alway
Flight MA-6
John Glenn's Friendship 7
Feb. 20, 1962
Front view
40.6
12.5
25.5
Rear view
40°
STA 165.26
196.26
16.0 Ø
STA 251.26
STA 346.12
STA 370.12
STA 392.83
74.5 Ø
(Spacecraft)
STA 451.25
STA 502.00
69.853 Ø
32.0 Ø
STA 645.00
2.75 Ø
120 Ø
6.3
STA 849.1
STA 891
STA 931.5
STA 960.0
STA 1010.7
11 Ø
STA 1098.5
STA 1125.5
STA 1133.00
STA 1143
STA 1206.19
STA 1233
STA 1269
STA 1283.00
STA 1310.00
STA 1326.5
30
109D
48
192
70
UNITED STATES
White
Black
Silver
Frost-covered metal
Red
"Friendship" is white, "7" is red with white outline.
Outer window 12 x 19.5
United States lettering (white) and flag on 2 sides, 180° apart
Stringers ~3° 20' apart
Spacecraft 1/75 scale

Saturn I

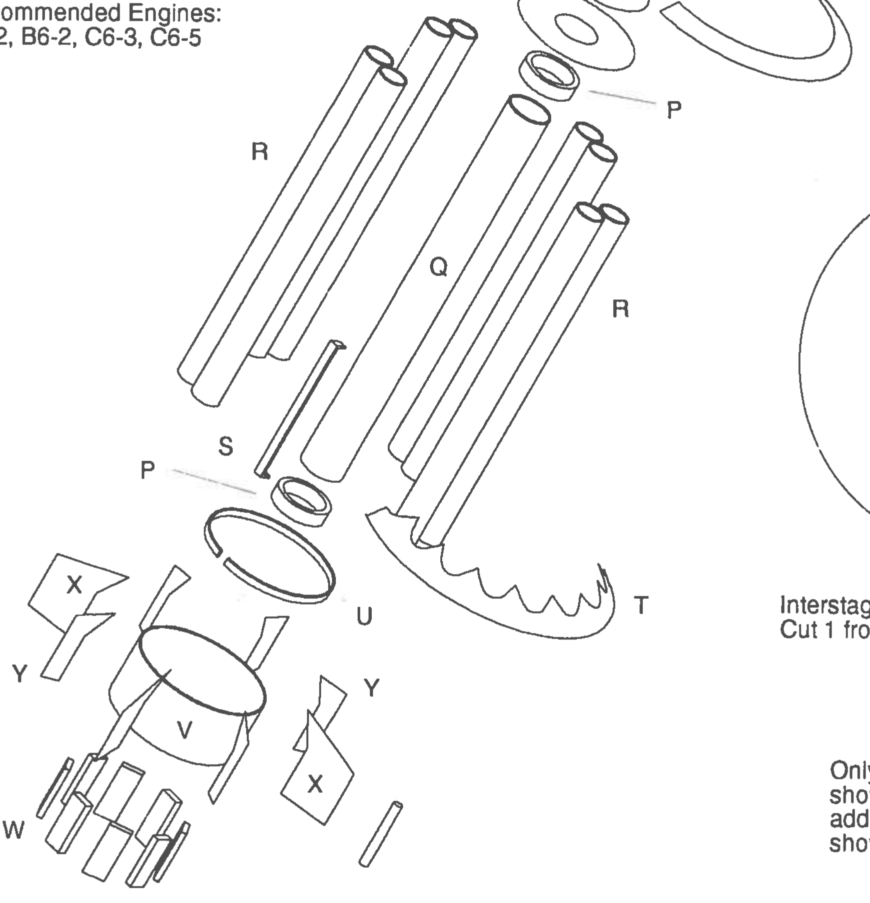
1/130 scale

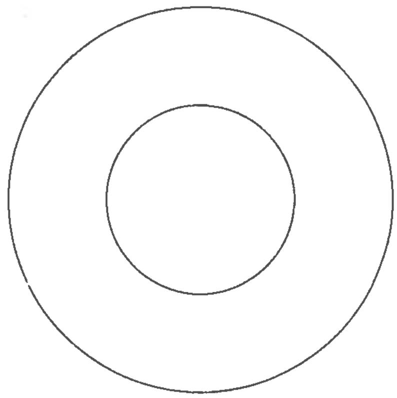
Parts list:

A) Launch Escape Rocket, from 3/16" dowel
B) Escape Rocket Shroud, from cardstock
C) Escape Rocket Base, 3/8" cardboard disk
D) Escape Tower Struts (4x), 1" toothpicks
E) Nose Cone, turned from balsa
F) Nose Weight, clay or lead
G) Payload Tube, 2.75" Quest T-30
H) S-IV Adapter, turned from balsa
I) Screw Eye
J) 12" or 18" Parachute
K) 18" Shock Cord
L) S-IV Tube, 2.8" Estes BT-60
M) Interstage Shroud, from cardstock
N) Interstage Adapter Ring, from 1/32" plywood or cardboard
O) S-IV Centering Rings (2x), Estes RA-2060
P) S-I Centering Rings (2x), Estes AR-2050, partially unwrapped
Q) S-I core, 7.5" Estes BT-20
R) S-I tanks (8x), 6.8" Estes BT-5
S) Engine Hook
T) Tail Shroud, from cardstock
U) Shroud Support, 1/8" Estes BT-70 slit to fit inside BT-70
V) Tail Tube, 1.05" Estes BT-70
W) Tail Shims (8x), 3/32" x 3/8" x 1" balsa
X) Large Fins (4x), from 1/8" balsa or basswood
Y) Stub Fins (4x), from 1/8" balsa or basswood
Z) Launch Lug



Recommended Engines:
B4-2, B6-2, C6-3, C6-5





Interstage Adapter Ring (N):
Cut 1 from 1/32" plywood or cardboard.

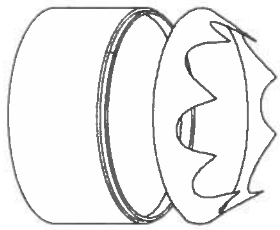
Only major components are shown in this diagram; additional detail parts are shown on last page of plan.

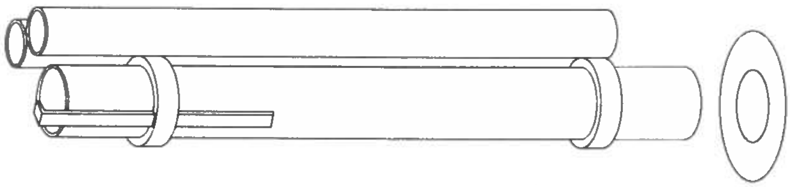
Saturn I

1/130 scale

1) On a flat surface, glue the 8 BT-5 tank tubes (R) together into four pairs. Be sure the best (factory cut) ends of the tubes are lined up exactly.

2) Peel down two AR-2050 adapter rings to 7/8" in diameter. Check to see that the 8 tank tubes will fit around the rings with no gaps. Peel further or built up with paper as needed.



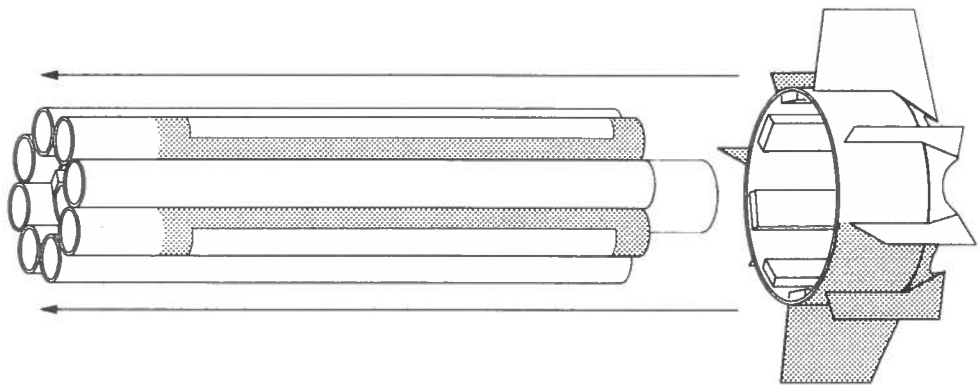


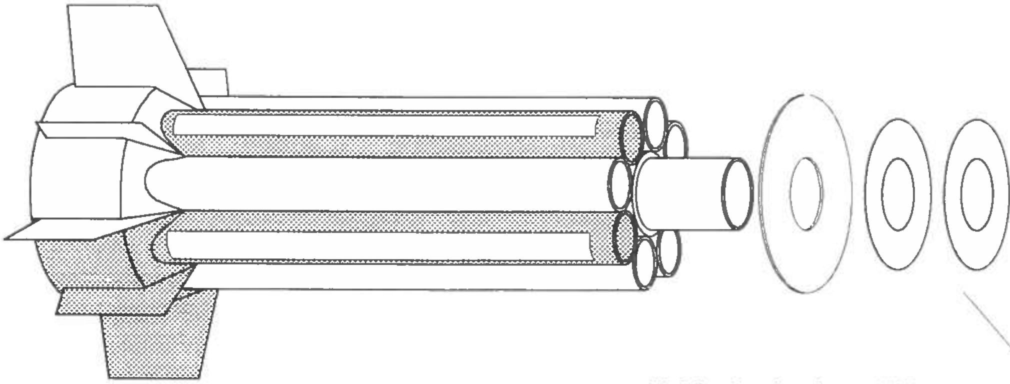
3) Make a 1/8" slit in the BT-20 core tube (Q) 2 1/2" from one end, and install an engine hook (S). Glue the two peeled adapter rings (P) in place, 1" from each end of the tube. Glue the pairs of tank tubes in place, with the good ends flush with the top adapter ring. You can slip one of the RA-2060 rings (O) over the BT-20 to help align the tops of the tubes. Remove the RA-2060 ring when you are done.

4) Slit the 1/8" ring of BT-70 (U) and fit it into the 1 1/16" tail tube (V). Glue the ends of the thin ring together for a tight fit inside the BT-70. When dry, glue the thin ring in the end of the BT-70 tail tube, protruding 1/16" from the end. Cut the tail shroud (T) from cardstock, and glue the tab to make a scalloped truncated cone. Glue this part to the tail tube and protruding thin ring. Glue the fins (X, Y) and launch lug (Z) to the outside of the tail ring, and glue the tail shims (W) to the inside. The shims should be in line with the scalloped openings in the tail shroud.

5) You may wish to paint the tank tubes and the tail section before gluing them together. If you do, then add any tail section details at this point. Be sure not to paint the lower 1" of the tank tubes.

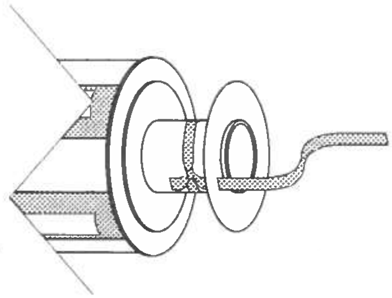
6) Glue the tail section to the tank section. Be sure that the tail tube extends about 1/16" beyond the end of the tank tubes.



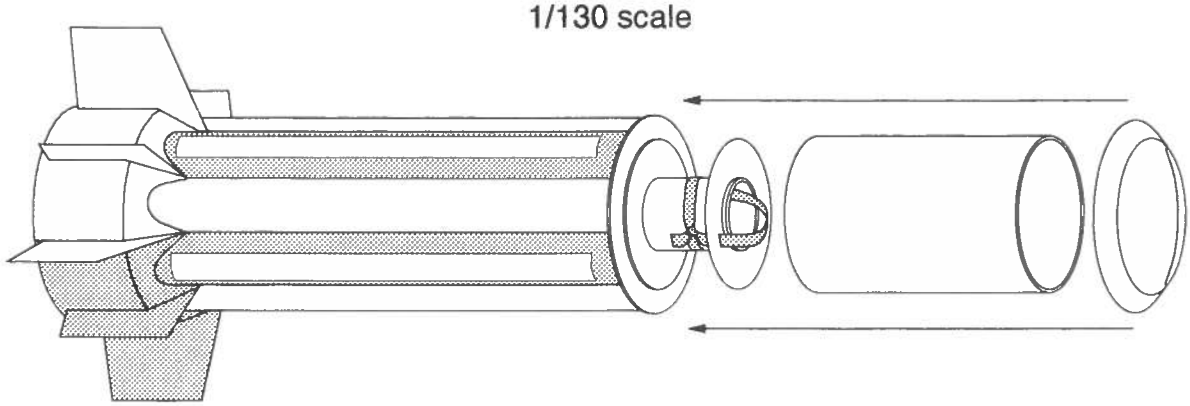


7) Glue the hand-cut interstage adapter ring (N) against the top of the tank tubes, and glue the first RA-2060 ring (O) to the hand-cut ring. Glue the second RA-2060 ring (O) about 1/32" from the end of the core tube.

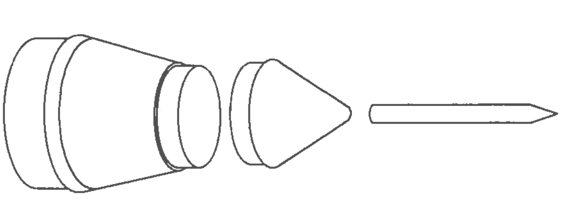
8) Tie the shock cord (K) around the core tube, and run it forward through a slit in the forward RA-2060 ring. Tuck the shock cord into the core tube to keep it out of the way during further construction steps.



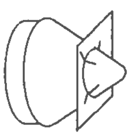
Saturn I
1/130 scale



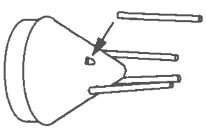
9) Glue the S-IV tube (L) over the RA-2060 adapter rings. Cut the interstage shroud (M) from cardstock, and glue the ends together to for a truncated cone. Slip the shroud over the S-IV tube and glue into place.



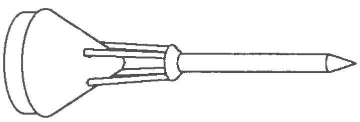
10) The nose section of this model requires three specially turned pieces. The S-IV adapter (H) and nose cone (E) are turned from balsa blocks using a power drill or lathe. The launch escape rocket (A) can be made from 3/16" dowel sharpened with a pencil sharpener. Alternatives include custom turnings from Balsa Machining Service, a paper shroud for the S-IV adapter, and a hand-carved nose cone.



11) Glue a 3/8" cardboard disk (C) to the base of the escape rocket (A). Cut out the escape rocket shroud (B) from cardstock, and glue it into a cone. Slip the cone down over the escape rocket and glue it into place.

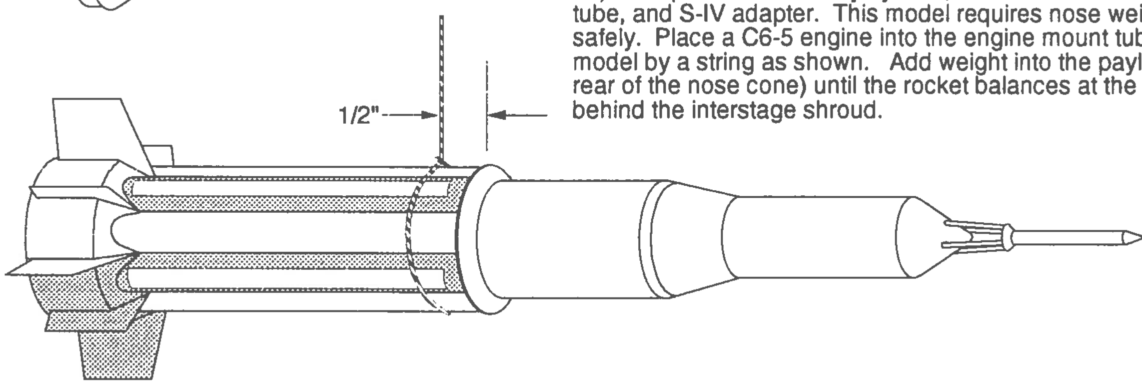


12) Use the template on the pattern page to mark the positions of the bottom ends of the escape tower struts on the nose cone. Cut four notches equally spaced around the nose cone (E) for the escape tower struts (D). Glue the struts into place. Use the escape rocket as a pattern to be sure the upper ends are spaced properly.



13) Carefully trim the upper ends of the struts so that the escape rocket is properly aligned. Then glue the escape rocket into place.

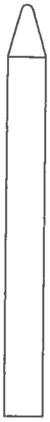
14) Complete the recovery system, and attach the nose cone, payload tube, and S-IV adapter. This model requires nose weight (E) to fly safely. Place a C6-5 engine into the engine mount tube. Suspend the model by a string as shown. Add weight into the payload section (at the rear of the nose cone) until the rocket balances at the point shown, 1/2" behind the interstage shroud.



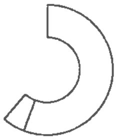
This is a complete, flyable model rocket. For a more detailed model, refer to details on p. 71 and the scale data drawings on pp. 72-73.

Saturn I

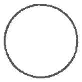
1/130 scale Patterns



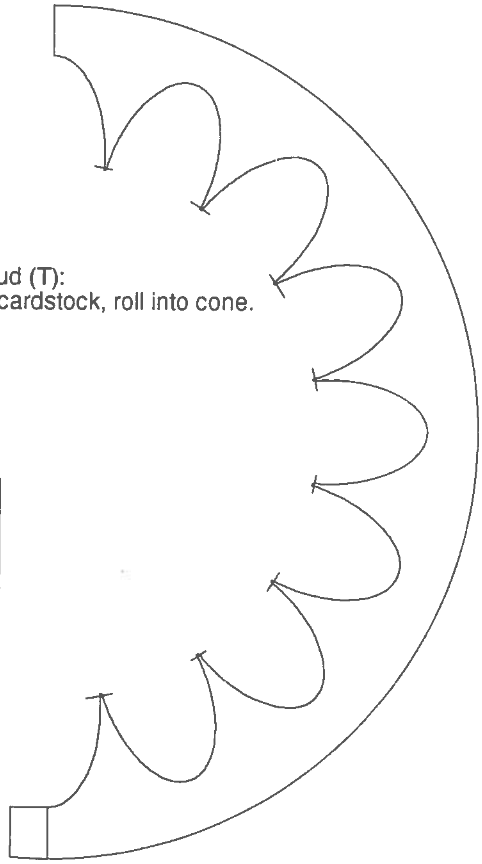
Escape Rocket (A):
Sharpen 3/16" dowel.



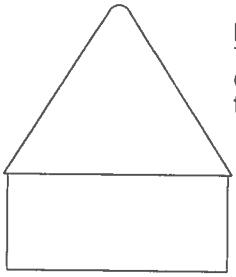
Escape Rocket Fairing (B):
Cut from cardstock, roll into cone, glue to escape rocket



Escape Rocket Base (C):
Cut from cardboard, glue to base of escape rocket and escape rocket fairing.

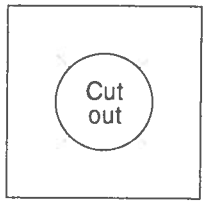


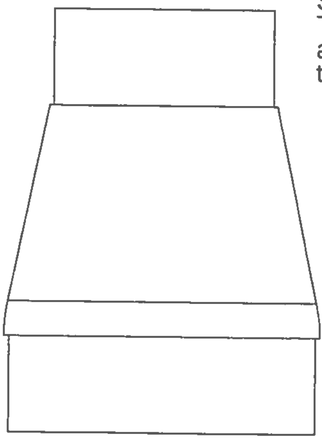
Tail Shroud (T):
Cut from cardstock, roll into cone.



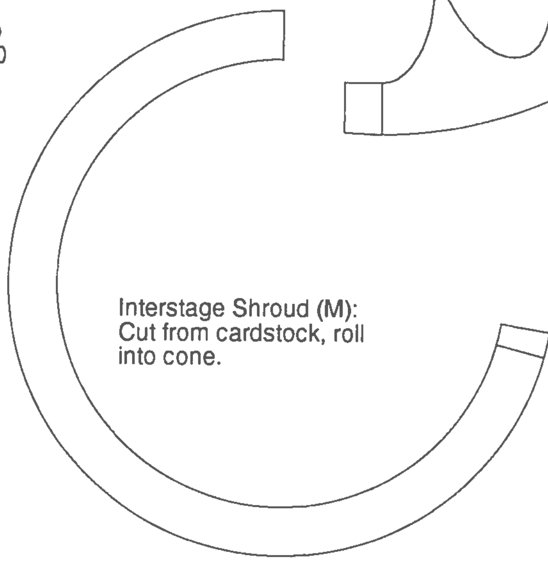
Nose Cone (E):
Turn from balsa to fit Quest T-30 body tube.

Nose cone marking template



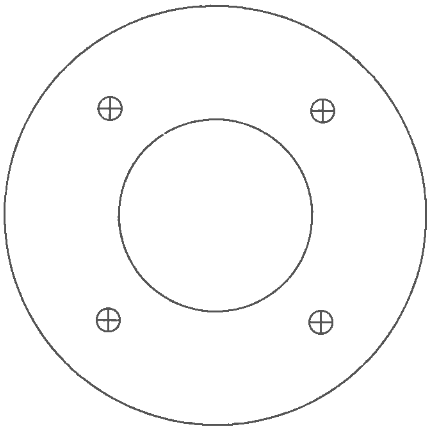


S-IV Adapter (H):
Turn from balsa to adapt Estes BT-60 to Quest T-30.

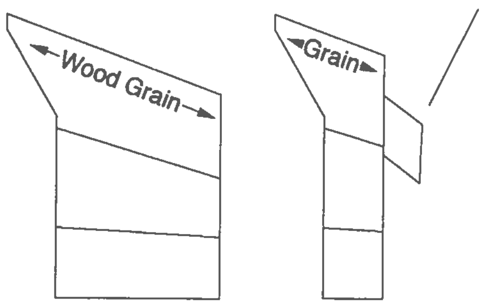


Interstage Shroud (M):
Cut from cardstock, roll into cone.

Heat shield (optional):
Cut from 1/16" basswood, cut or drill holes for dummy engines, glue into tail tube, flush with rear end.



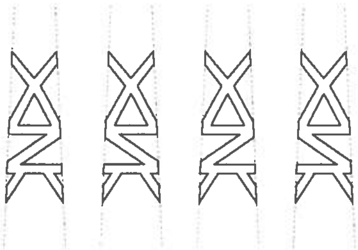
LH2 vent on three fins (optional), cut from 1/16" basswood, sand leading and trailing edges sharp

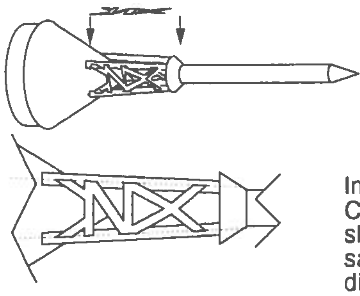


Fins: Cut four large fins (X) and four stub fins (Y) from 1/8" basswood. Sand leading edge sharp, leave trailing, tip edges flat.

Saturn I
1/130 scale
Optional Detail Parts

Escape tower frame:
Copy frame patterns onto cardstock, cut out, and glue between struts.

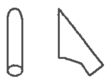


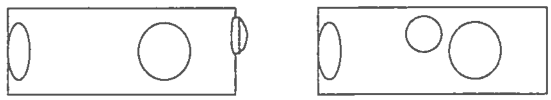


Reaction control system (RCS) engines:
Make four junction boxes from basswood, 16 nozzles from small wood dowel milled in pencil sharpener.

Instrument unit:
Cut four holes through payload tube (G). Be sure shoulder of transition (H) under instrument unit is sanded and sealed. Make horizon detector from disc of plastic.

Ullage rockets: Make four from basswood.





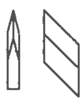
Liquid hydrogen lines:
Make three of each from 1/8" dowel or plastic tube.

Upper section, glued adjacent to spider beam ends.

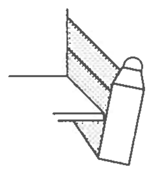
Lower section, glued between tanks, in line with fins.

Round end, cut slit in end to fit over fin.

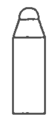
Fairings above numbered fins. Make four from 1/16" basswood.



Fairings above stub fins (shaded area of pattern). numbered fins. Make four from 1/16" basswood.



Retro-rockets: turn four from 3/16" dowel in drill chuck



Antenna panels

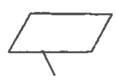
Panels: Make 2 of each from cardstock

Antennas: Make 4 of each from 1/16" basswood

Above fins I and III

Above fins II and IIII

Turbine exhaust vents:
Make 4 from 1/16" basswood.
Sand leading and trailing edges sharp, glue 22.5° to the right of large fins.

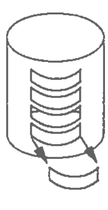


Root Edge

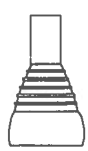
Cross-section

Engine fairings

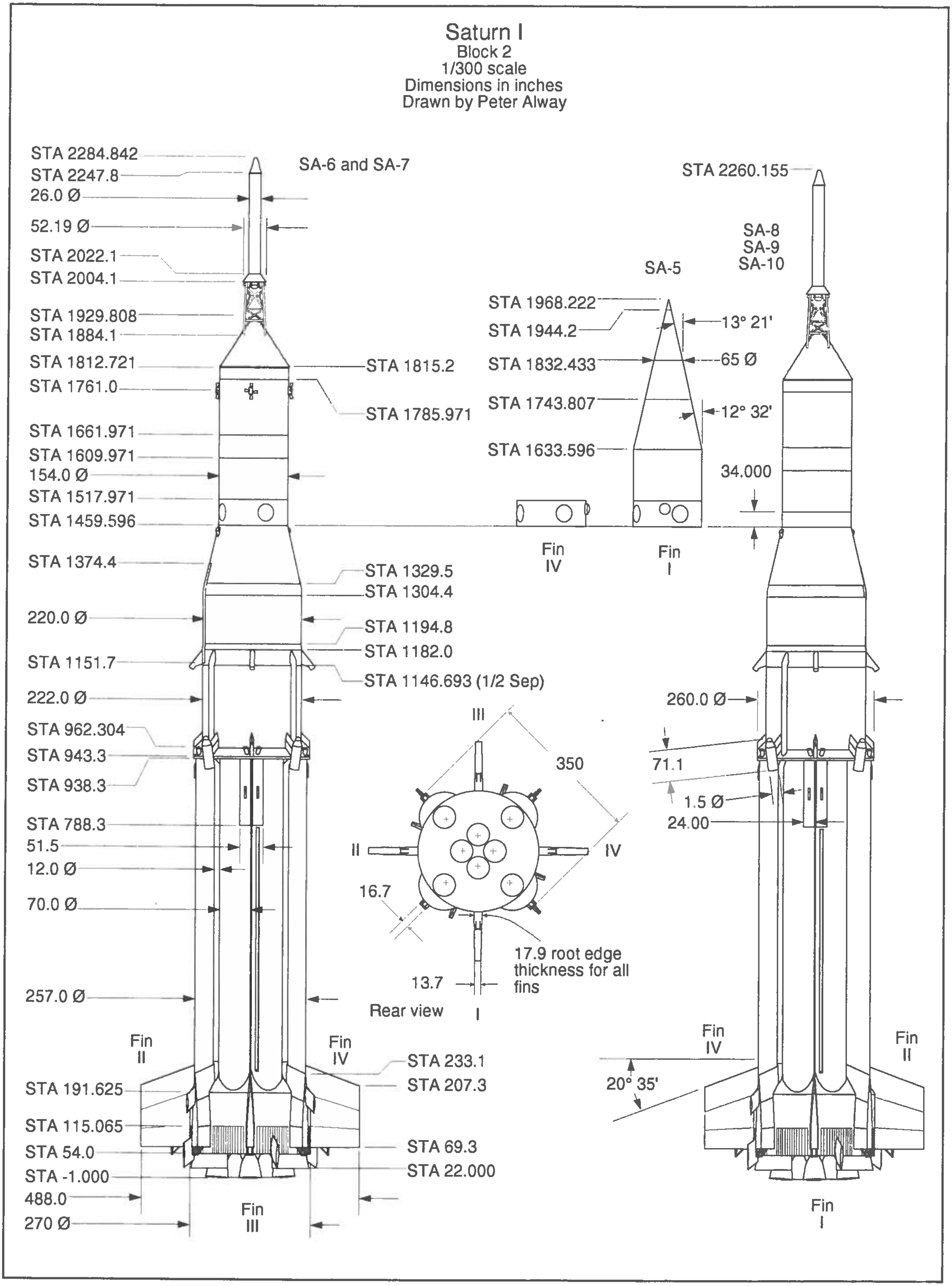
Cut four from a scrap of BT-60 tubing. Glue to base of tail tube under stub fins.

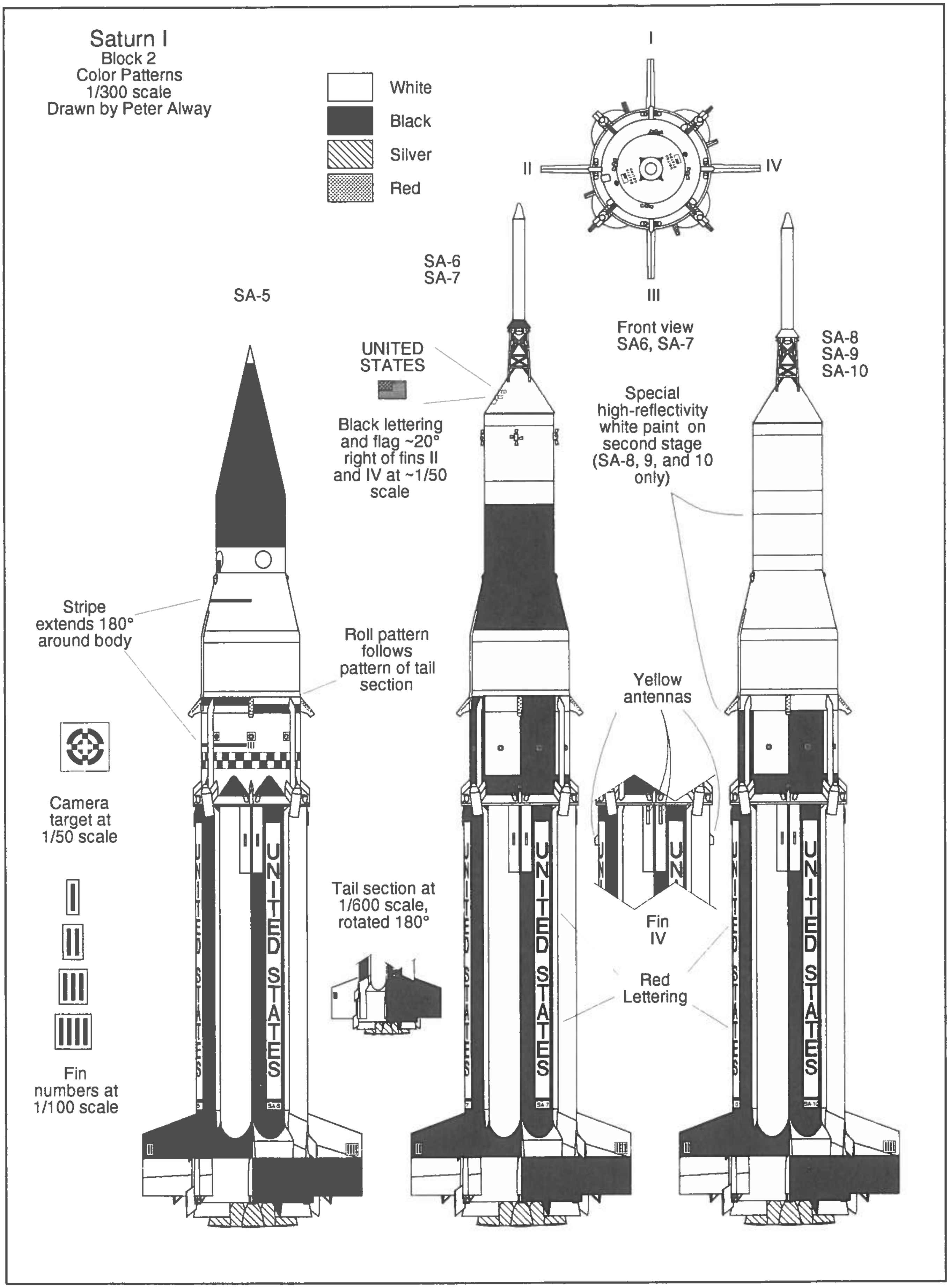


Engines: Turn four from 1/2" dowel, glue into holes in heat shield, tilted 6° outward.



Tank Lettering:
Use 1/4" red Vinyl or dry transfer lettering for UNITED STATES lettering on booster tanks.


Saturn I
Block 2
1/300 scale
Dimensions in inches
Drawn by Peter Alway
SA-6 and SA-7
STA 2284.842
STA 2247.8
26.0 Ø
52.19 Ø
STA 2022.1
STA 2004.1
STA 1929.808
STA 1884.1
STA 1812.721
STA 1815.2
STA 1761.0
STA 1785.971
STA 1661.971
STA 1609.971
154.0 Ø
STA 1517.971
STA 1459.596
STA 1374.4
STA 1329.5
STA 1304.4
220.0 Ø
STA 1194.8
STA 1182.0
STA 1151.7
STA 1146.693 (1/2 Sep)
222.0 Ø
STA 962.304
STA 943.3
STA 938.3
STA 788.3
51.5
12.0 Ø
70.0 Ø
257.0 Ø
Fin II
Fin IV
STA 233.1
STA 207.3
STA 191.625
STA 115.065
STA 54.0
STA 69.3
STA -1.000
STA 22.000
488.0
270 Ø
Fin III
SA-5
STA 1968.222
STA 1944.2
13° 21'
STA 1832.433
65 Ø
STA 1743.807
12° 32'
STA 1633.596
Fin IV
Fin I
III
350
II
IV
16.7
17.9 root edge thickness for all fins
13.7
Rear view
I
STA 2260.155
SA-8
SA-9
SA-10
34.000
260.0 Ø
71.1
1.5 Ø
24.00
Fin IV
Fin II
20° 35'
Fin I



Saturn I
Block 2
Color Patterns
1/300 scale
Drawn by Peter Alway
White
Black
Silver
Red
I
II
IV
III
Front view
SA6, SA-7
SA-5
SA-6
SA-7
SA-8
SA-9
SA-10
UNITED
STATES
Black lettering and flag ~20° right of fins II and IV at ~1/50 scale
Special high-reflectivity white paint on second stage (SA-8, 9, and 10 only)
Stripe extends 180° around body
Roll pattern follows pattern of tail section
Yellow antennas
Camera target at 1/50 scale
Tail section at 1/600 scale, rotated 180°
Fin IV
Red Lettering
Fin numbers at 1/100 scale
UNITED STATES

Saturn V

Apollo 11
1/500 scale
Dimensions in inches
Drawn by Peter Alway

The Saturn V was the largest rocket ever to fly. It carried nine crews of three astronauts each to the vicinity of the Moon. On July 16, 1969, Apollo 11 lifted off from Florida. Neil Armstrong and Buzz Aldrin became the first humans to walk on the Moon on July 20. By the time of the last Apollo flight in 1972, 6 pairs of astronauts had landed on the Moon.

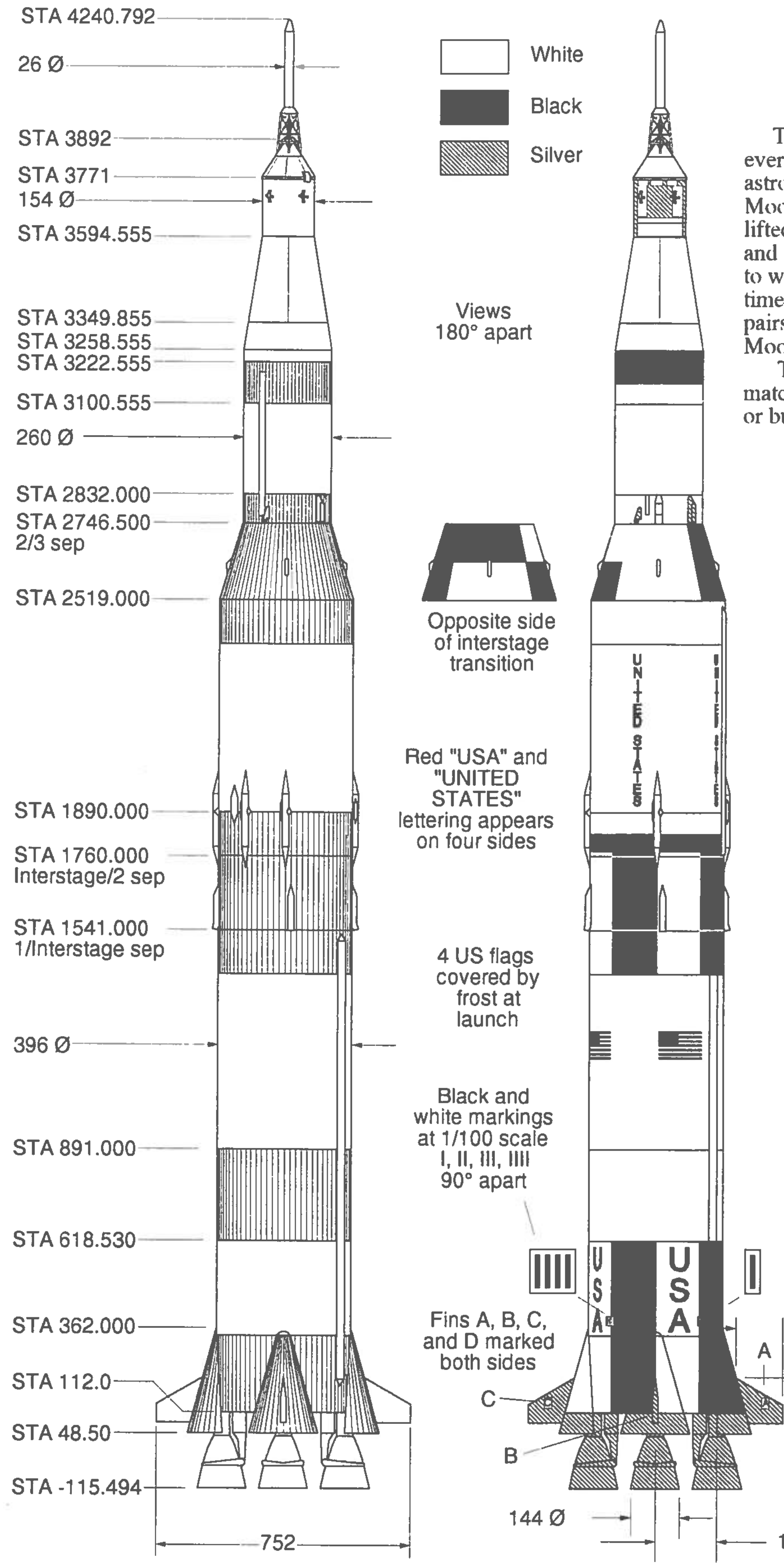
This data is presented without matching plans. Design your own model or build the Estes kit.

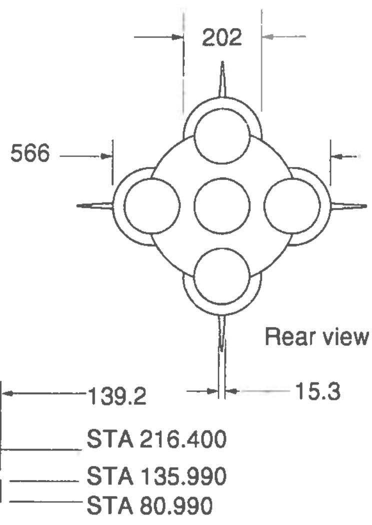
3rd stage corrugations
Forward skirt:
108 .813 x 1.25 high stringers
Aft skirt:
144 1 x 1.375 high stringers

2nd stage corrugations
Transition section:
144 1.2 x 2.162 high stringers
Forward skirt:
144 1.3 x 1.625 high stringers
Aft skirt:
216 2 x 2 stringers

Interstage corrugations
216 2 x 2 stringers

1st stage corrugations
Forward skirt:
216 2 x 2 stringers
Intertank skirt:
108 3.5 high stringers
Tail skirt:
3 x 3 stringers 2° 48' apart



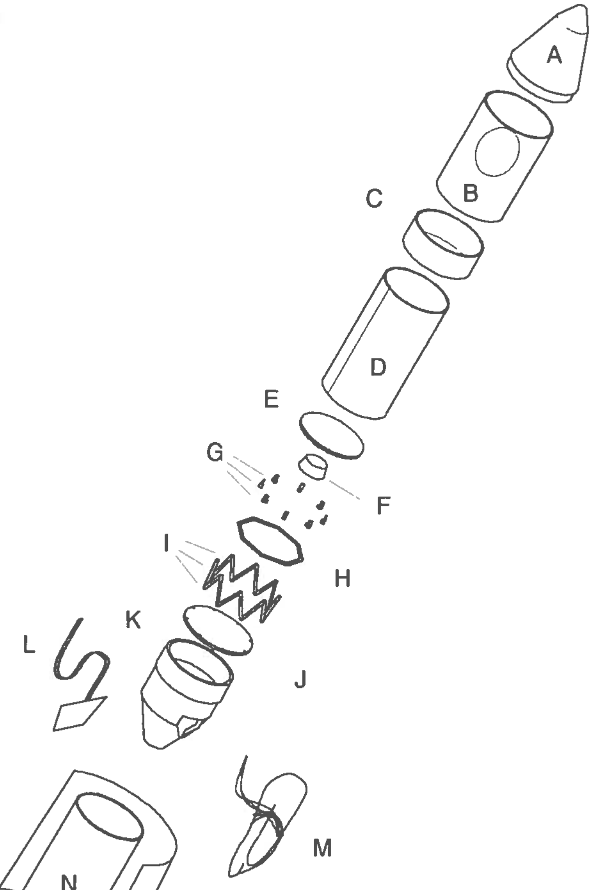


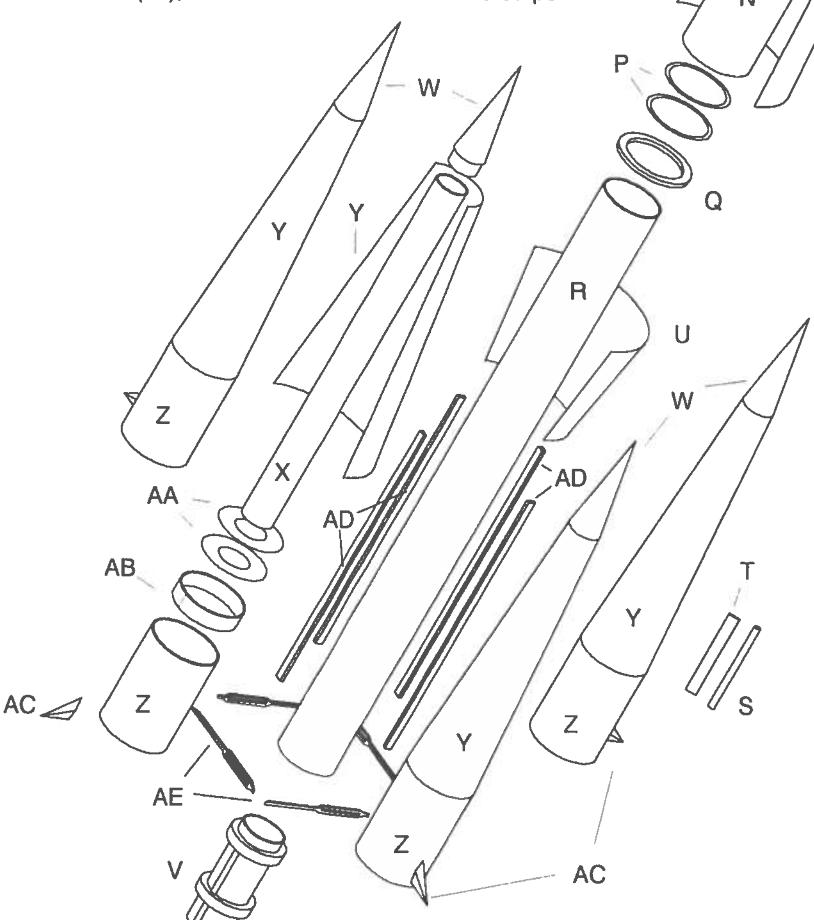
Vostok

1/63 scale

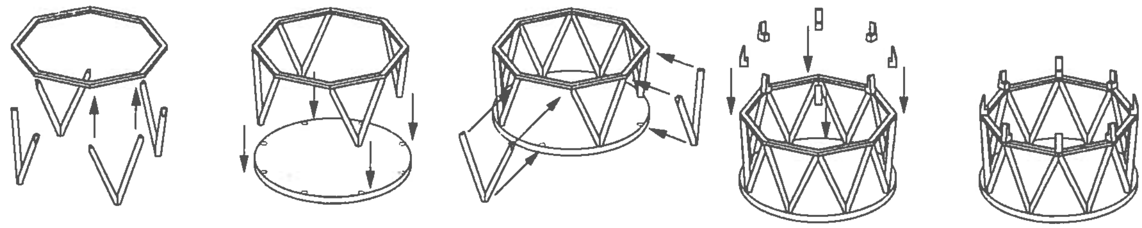
Parts list:

A) Nose Cone, turned from balsa
B) Fairing Tube, 2 3/8" Estes BT-60
C) Insulation, 5/8" Estes BT-60
D) Upper Stage Tube, 3" Estes BT-60 slit and reduced (or 2 Estes JT-60C's end-to end)
E) Upper Stage Base, from 1/16" basswood or plywood
F) Upper Stage Nozzle, from cardstock
G) Upper Stage Supports, (8x) from 1/16" basswood
H) Interstage Truss Octagon Ring, from 1/16" plywood
I) Interstage Struts, (16x) from 1/12" dowel
J) Blast Shield, cut from 1/16" basswood or plywood
K) Guidance Section, shoulder and 1/2" of exposed length cut from base of Estes PNC-60MS or PNC-60AH nose cone
L) 18" Shock Cord and Mount
M) 18" Parachute
N) Upper Core Tube, 3 1/2" Estes BT-60
O) Upper Core Shroud, from cardstock
P) Core Adapter Rings (2x), Estes AR-5560 from multipurpose ring set
Q) Core Max Diameter Support, from 1/16" plywood, 1.82" outside diameter
R) Lower Core Tube, 14 3/8" Estes BT-55
S) Launch Lug, 1/8" x 2 1/8"
T) Launch Lug Standoff, 1/4" x 2 1/8" from 1/16" plywood
U) Lower Core Shroud, from cardstock
V) D Engine Mount, Estes EM-5055/60
W) Booster Nose Cone (4x), 2 1/2" long hand turned or trimmed down from Estes BNC-20R
X) Inner Booster Tube (4x), 9" Estes BT-20
Y) Booster Shroud (4x), from cardstock
Z) Booster Base (4x), 2 1/2" Estes BT-60
AA) Booster Adapter rings (8x), Estes RA-2060
AB) Booster Shroud Supports (4x), 3/8" sections of slit Estes BT-60
AC) Booster Fins (4x), from 1/16" basswood
AD) Booster Standoff (4x), 1/16" x 1/8" x 7" basswood
AE) Booster Brace (4x), from 1/16" x 1/16" basswood strips



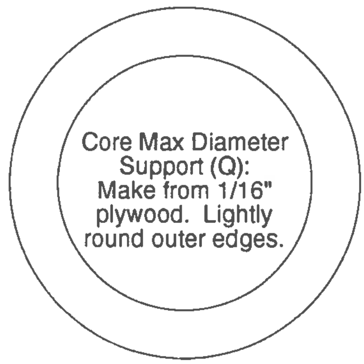


Note: This plan may be simplified by converting it into Sputnik 1. Replace parts A-K with a 2" conical wood nose cone. Be sure to test for stability and add nose weight as required.

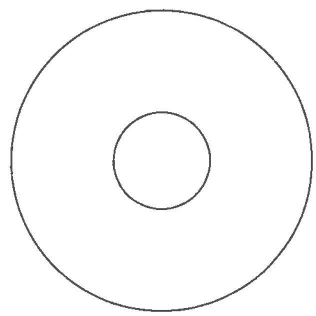


Interstage struts: Glue interstage struts (I) into V's over pattern. Glue four V-shaped pairs to the octagon ring (H). While glue is still slightly soft, glue this assembly to the blast shield (J). Once glue is dry, glue remaining four pairs of struts into place. Glue upper stage supports (G) to octagon ring, checking position against upper stage tube (D). Base of upper stage tube should fit into notch in upper stage supports.

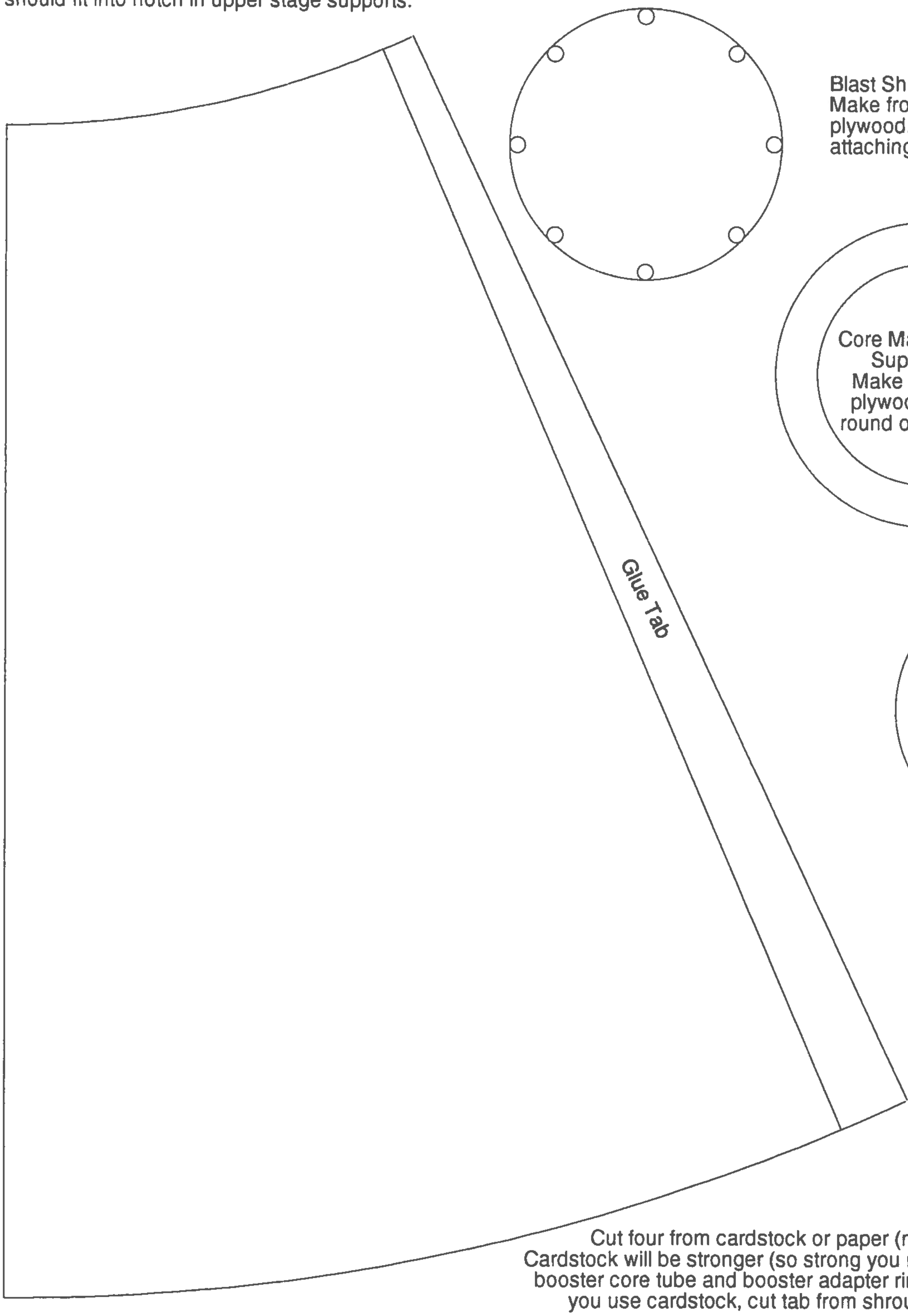
Blast Shield (J):
Make from 1/16" basswood or plywood. Mark small circles for attaching interstage struts.



Core Max Diameter Support (Q):
Make from 1/16" plywood. Lightly round outer edges.

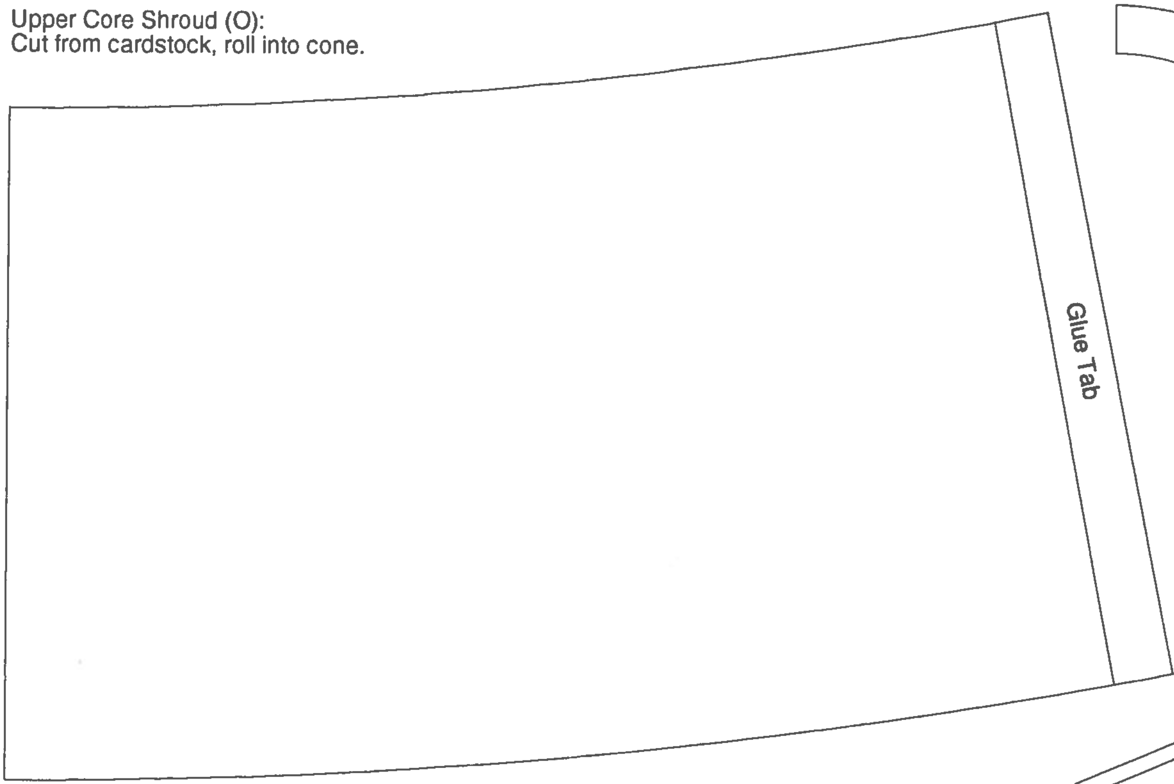


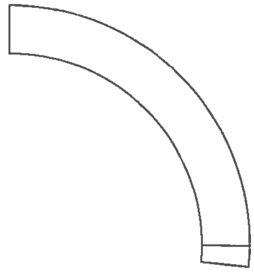
Upper Stage Base (E):
Make from 1/16" basswood or plywood. Mark inner circle for attaching upper stage nozzle.



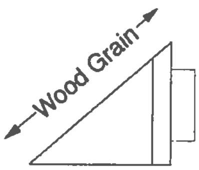
Booster Shroud (Y):
Cut four from cardstock or paper (make plenty of extra copies). Cardstock will be stronger (so strong you may be able to leave out the booster core tube and booster adapter rings), but is difficult to roll. If you use cardstock, cut tab from shroud and glue to inside of joint.

Upper Core Shroud (O):
Cut from cardstock, roll into cone.

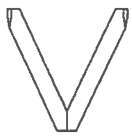




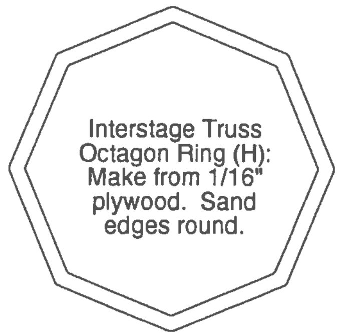
Upper Stage
Nozzle (F):
Cut from
Cardstock, roll
into cone.



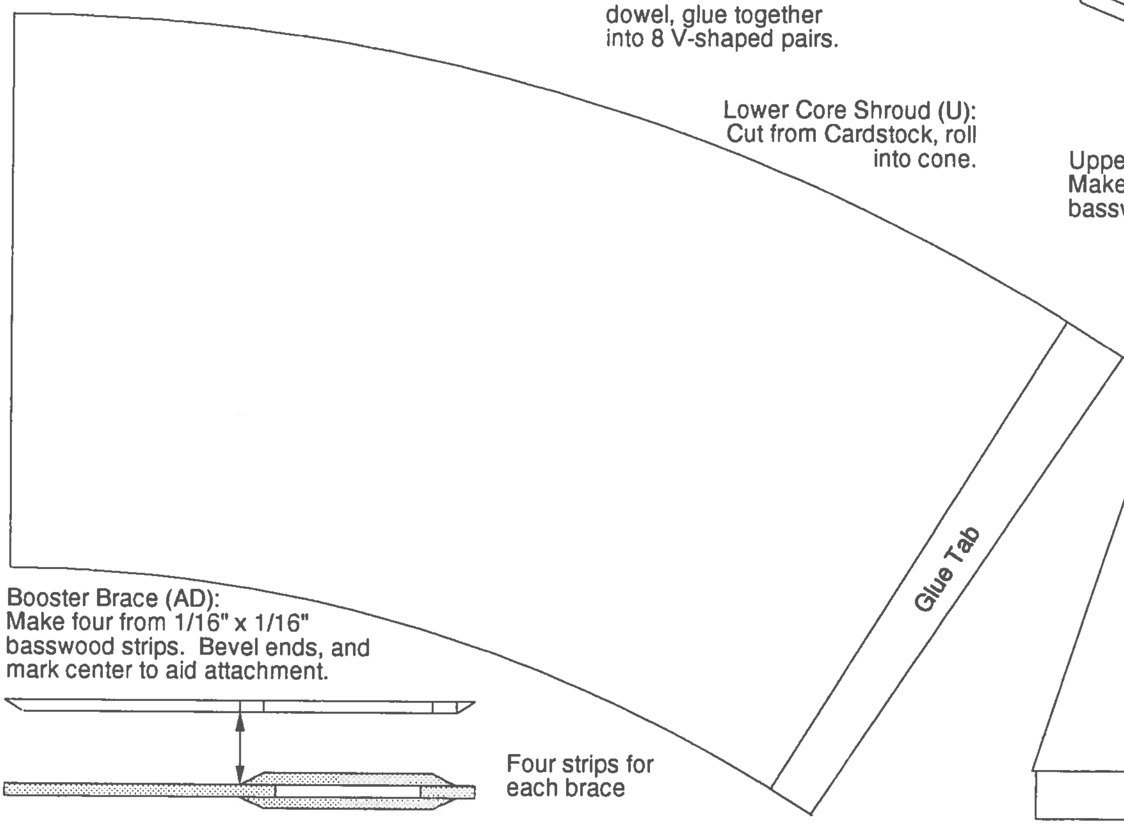
Fins (AC):
Make four from 1/16"
basswood. Sand
leading and trailing
edges sharp. Tab for
through-the-wall
attachment is optional.



Interstage Struts (I):
Make 16 from 1/12"
dowel, glue together
into 8 V-shaped pairs.



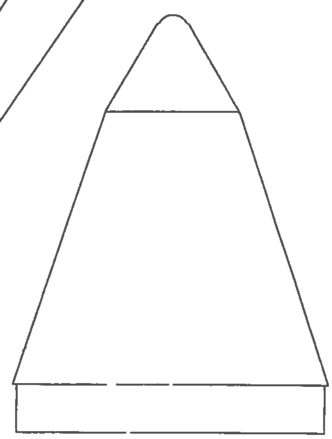
Interstage Truss
Octagon Ring (H):
Make from 1/16"
plywood. Sand
edges round.



Lower Core Shroud (U):
Cut from Cardstock, roll
into cone.

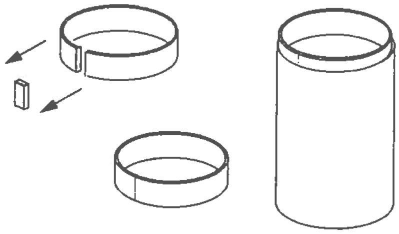
Upper Stage Supports (G):
Make eight from 1/16"
basswood or plywood

Nose Cone (A):
Turn from balsa.

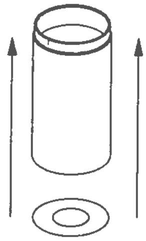


Booster Brace (AD):
Make four from 1/16" x 1/16"
basswood strips. Bevel ends, and
mark center to aid attachment.

Four strips for
each brace

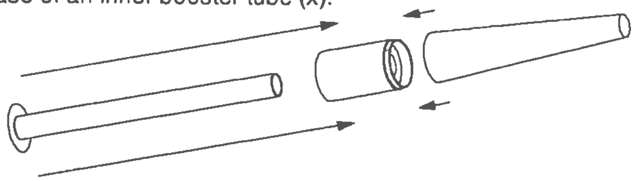


Cut a 1/16" slice from each 3/8" long booster shroud support (AB). The remaining slit ring should fit tightly inside the end of a BT-60 booster base tube (Z). Trim shroud support to fit if needed, and glue into booster base protruding 3/16".



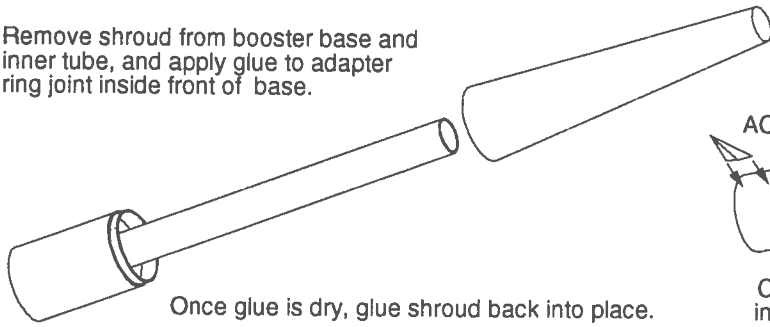
Glue one booster adapter ring (AA) into the booster base. Press it all the way up against the shroud support.

Glue one booster adapter ring (AA) to the base of an inner booster tube (x).



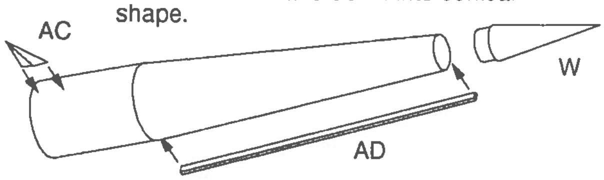
Dry fit booster base, inner booster tube, and booster shroud (Y) together. Depending on the thickness of the booster shroud material, the top of the inner tube may fit flush with the top of the shroud, or it may stop as much as 1/4" short. As long as the top of the inner tube supports the upper end of the shroud, all is well. Apply glue to the adapter ring joint inside the bottom of the base tube.

Remove shroud from booster base and inner tube, and apply glue to adapter ring joint inside front of base.

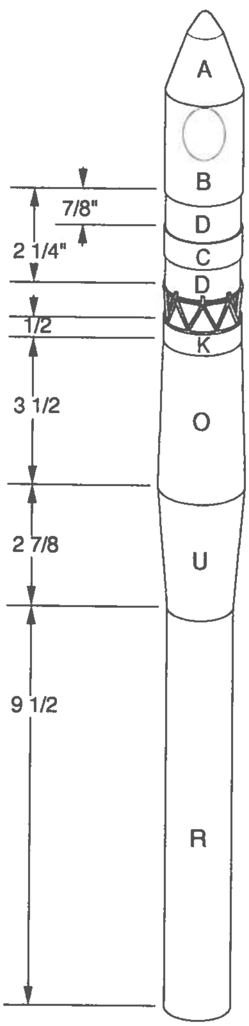


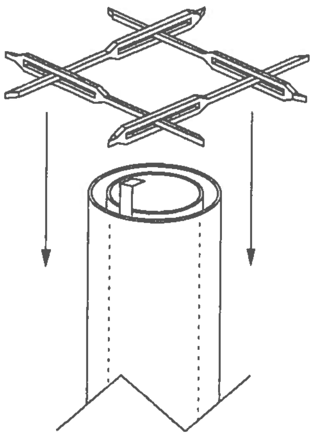
Once glue is dry, glue shroud back into place.

Booster nose cone should be 2 1/2" long. Turn nose from balsa, or trim 1/4" from BNC-20R and sand down into conical shape.

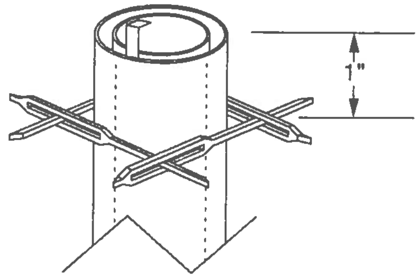


Complete booster by gluing nose cone (W) and fin (AC) into place. Be sure fin is directly opposite shroud seam. Glue booster standoff (AD) over shroud seam.





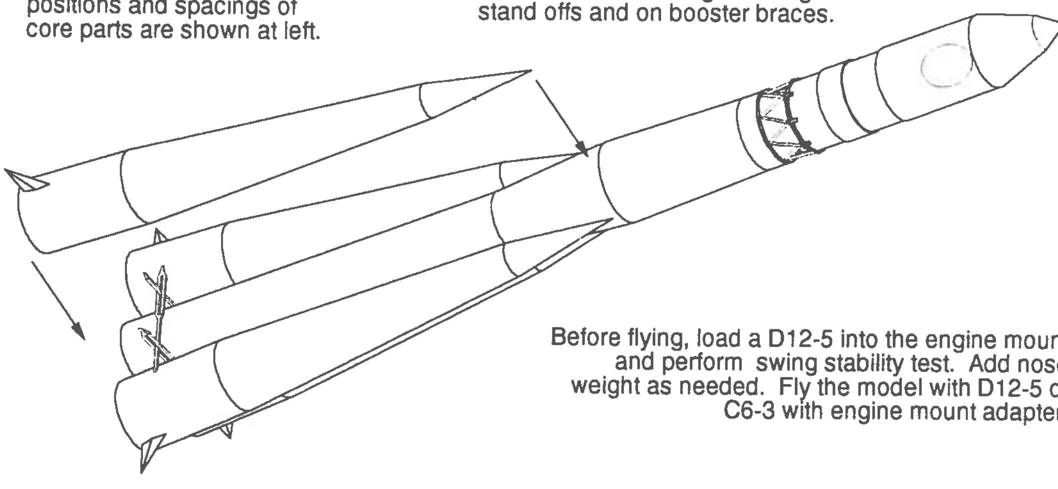
Assemble core components following exploded diagram, positions and spacings of core parts are shown at left.



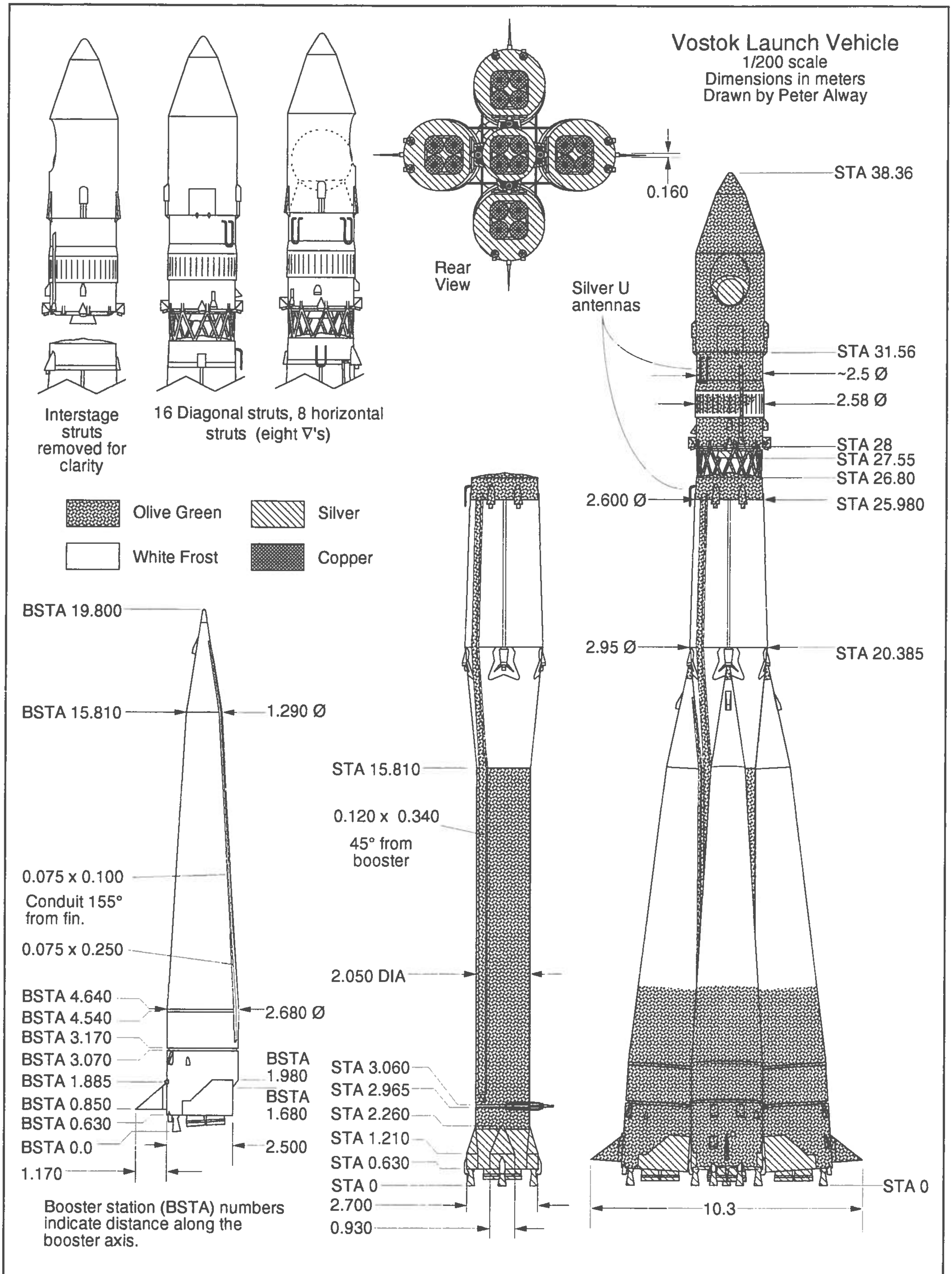
Assemble four booster braces (AD) as shown. Glue them into place 1" from the bottom of the core tube. Line up centers of braces with booster placement lines.

For additional details, study drawing of prototype on next page.

Glue boosters to core with glue along booster stand offs and on booster braces.



Before flying, load a D12-5 into the engine mount and perform swing stability test. Add nose weight as needed. Fly the model with D12-5 or C6-3 with engine mount adapter.



Vostok Launch Vehicle
1/200 scale
Dimensions in meters
Drawn by Peter Alway
Rear View
0.160
STA 38.36
Silver U antennas
STA 31.56
~2.5 Ø
2.58 Ø
STA 28
STA 27.55
STA 26.80
2.600 Ø
STA 25.980
2.95 Ø
STA 20.385
Interstage struts removed for clarity
16 Diagonal struts, 8 horizontal struts (eight ∇'s)
Olive Green
Silver
White Frost
Copper
BSTA 19.800
BSTA 15.810
1.290 Ø
STA 15.810
0.120 x 0.340
45° from booster
0.075 x 0.100
Conduit 155° from fin.
0.075 x 0.250
2.050 DIA
BSTA 4.640
BSTA 4.540
2.680 Ø
BSTA 3.170
BSTA 3.070
BSTA 1.980
BSTA 1.885
BSTA 1.680
BSTA 0.850
BSTA 0.630
BSTA 0.0
2.500
1.170
STA 3.060
STA 2.965
STA 2.260
STA 1.210
STA 0.630
STA 0
2.700
0.930
STA 0
10.3
Booster station (BSTA) numbers indicate distance along the booster axis.

Kits and Manufacturers

Numerous flying scale model rocket kits are sold by the major and minor model rocket manufacturers. Many are highly accurate representations of important sounding rockets, missiles, and space boosters. Most are at least good starting points for excellent models. If you are an experienced hobbyist new to flying model rockets, all the Estes, MRC, and Quest kits are good introductions to the hobby. If you are new to modeling, and would like to start into model rocketry with a scale kit, the Quest Tomahawk and Nike-Smoke, Estes Mini Patriot, and MRC Sidewinder and Standard Arm are good first kits.

Aerotech

Aerotech, Inc / ISP
1955 South Palm St., Suite 15
Las Vegas, NV 89104
(702) 641-2301 or 2302

Aerotech is the premier manufacturer of high impulse rocket engines E and larger. Aerotech scale kits feature injection molded fins for greater realism and ease of construction. The kits also include detailed drawings of their prototypes.

IQSY Tomahawk (1/4.7 scale)

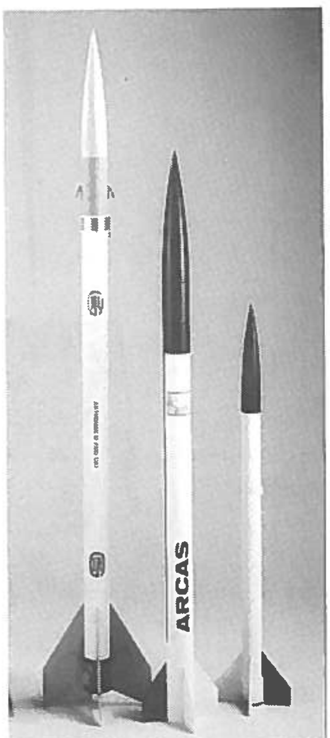
A US sounding rocket, the IQSY Tomahawk is a favorite subject of beginning modelers.

Length: 41" Diameter: 1.9"

HV-Arcas (1/1.7 scale)

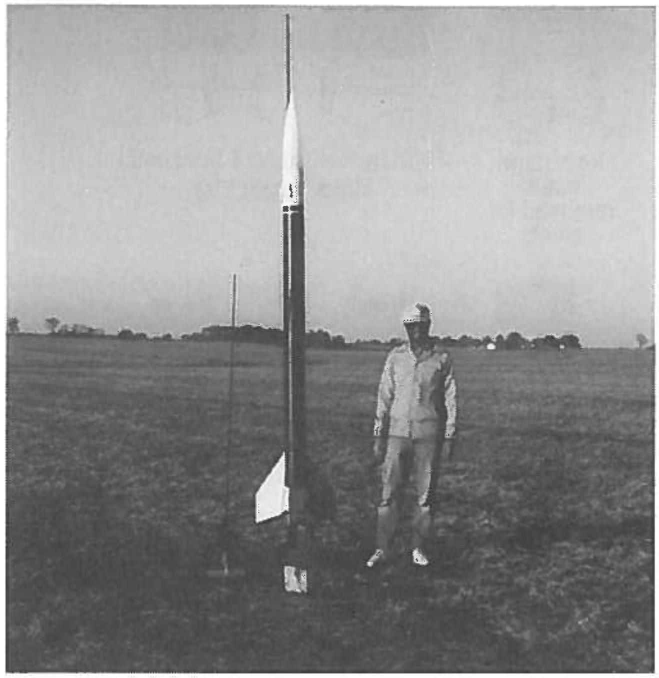
The HV version of the Arcas was specifically sesigned as an upper stage for various 2-stage sounding rockets.

Length: 56" Diameter: 2.6"



Aerotech's scale kits (left to right): Astrobee D, HV-Arcas, IQSY Tomahawk. (Aerotech Photo)

Cluster R's Sandhawk requires High Power Certification (Cluster R photo)



Astrobee-D (1/2.3 scale)

Small US sounding rocket. This kit is a favorite among modelers, featuring several neat plastic detail components.

Length: 68" Diameter: 2.6"

Cluster R

Cluster R
c/o Larry Russel
604 Lakeview Drive
East Peoria, IL 61611
(309) 698-0726

Sandhawk (2 kits)

US Sandia National Laboratory sounding rocket.
1/5 scale kit—Diameter: 2.6"
1/3.25 scale kit—Diameter: 4"

Standard ARM (2 kits)

US air-to-surface anti-radar missile.
1/5.2 scale version—Diameter: 2.6"
1/3.4 scale version—Diameter: 4"

Cox

Cox Manufacturing, Inc.
1506 East Warner Ave.
Santa Ana, California 92705

Cox produces a number of pre-fabricated almost-ready-to-fly rockets. Made of injection molded plastic, these models are rather heavy. The kits are intended for use with Estes or similar black powder engines, but many modelers report that they should be flown with higher-impulse composite engines, such as those produced by Aerotech, in order to insure sufficient altitude for safe ejection.

Saturn IB (1/130 scale)

US booster for earth-orbit manned Apollo and Skylab missions. This model is flawed by a superfluous launch lug on the service module, inexplicable slots in the first stage, and first stage tanks that are flattened from their full cylindrical shape. Correction of the first two flaws is possible, but would require a complete re-finishing of the model.

Length: 21.5" Diameter: 2"

Saturn V (1/130 scale)

US Apollo manned Moon rocket.

Length: 34" Diameter: 3"

X-15

US Hypersonic research aircraft from the 1960's.

Length: 13"

Honest John

US Army surface-to-surface missile.

Length: 13"

Estes Industries

Estes Industries, Inc.
PO Box 227
1285 H Street
Penrose, CO 81240
(719) 372-6565 or (800) 525-7561

Estes is the dominant model rocket manufacturer in the US. Estes is constantly changing its product line; the following scale kits were listed in the 1994 catalog. Careful searching of hobby shops may turn up some older kits, and at the time of writing the company is reported to have two new scale kits in the works for 1995.

Saturn V (1/100 scale)

US Apollo manned Moon rocket. The Saturn rockets have always been the ultimate scale subjects and the Estes 1/100 Saturn V is the ultimate scale model rocket kit. Built straight from the box, it makes an impressive showpiece. The model contains one deliberate inaccuracy: the fins are oversized to make the model stable. With compensating nose weight, it is possible to get the model to fly with correct fins, but the extra weight requires more powerful engines.

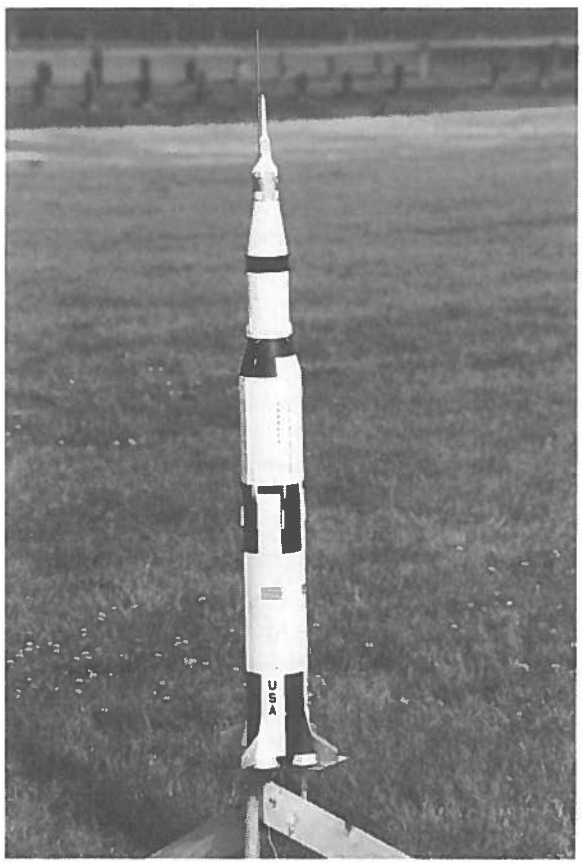
The painting instructions for the Apollo Service Module leave something to be desired. Change the order of painting and masking so that the silver paint is applied last to the service module, over the white paint. The kit also suggests painting the service module all silver, when there were conspicuous white panels on the original. I also had difficulty using spray adhesive as suggested in the instructions for attaching corrugations. I used wood glue, carefully spread by a piece of scrap balsa. Others have suggested epoxy. Yet another suggests that the only adequate spray adhesive is 3M's "77" spray.

This model will be your pride and joy. Because it uses large black powder engines, there is a possibility of a catastrophic failure. Be sure to keep your D12-3's and E15-4's out of hot parked cars, and be sure that any Estes E-15's do not have an X in the date code. With these precautions, this model will make many beautiful flights.

Length: 43.2" Diameter: 3.938"

Black Brant II (1/13 scale)

Canadian sounding rocket. This is a favorite scale kit. Reasonably accurate, it builds into an attractive model without too much effort. There are a few recommended fixes. The payload antennas on the model are fragile. I would suggest cutting or drilling tiny holes



The Estes Saturn V is the king of scale model rocket kits. Here is the author's model. (Mark O'Brien photo) for the toothpicks used to represent the antennas, and providing some reinforcement on the inside of the tube. Some modelers would go so far as to make the antennas from piano wire, again anchoring them inside the model. Another problem is that the D-powered model is recovered with an 18" parachute. This combination is likely to drift beyond all but the biggest flying fields on all but the calmest days. I would suggest flying the model with smaller engines (using an engine mount adapter sold by Estes) or with a 12" parachute, or both.

Length: 24.9" Diameter: 1.325"

Mini-Patriot (1/22 scale)

Famous surface-to-air missile. Designed for simplicity, this is a good first model rocket.

Length: 10" Diameter: 0.736"

Space Shuttle (1/162 scale)

Features a glide-recovery orbiter. Wings have been enlarged and extra removable fins have been added to make this model flightworthy. Vacuform construction makes this a difficult model to assemble. One suggested modification is to replace the opaque fin units (consisting of fins and body tubes that are inserted into the SRB's) with transparent fins cut from Plastruct or Evergreen clear plastic sheet (available at hobby shops). Long tabs on the fins can be inserted into the SRB's.

Length: 13.6" Orbiter wing span: 7.1"

Terrier-Sandhawk (1/9.8 scale)

This large and popular model features a highly accurate Sandhawk sounding rocket atop a less accurate Terrier booster. Booster fins are oversized for safety reasons. The recommended paint scheme for the Sandhawk is correct for the single-stage variant but not for the 2-stage Terrier-Sandhawk. One correct 2-stage scheme appears in the scale data section of this book.

Length: 46" Diameter: 1.835"

Jayhawk (1/5 scale)

Missile target drone.

Length: 30" Diameter: 2.5"

Patriot, Pro Series (1/5 scale)

Famous US surface-to-air missile powered by a cluster of four D engines.

Length: 39" Diameter: 3"

FSI

Flight Systems, Inc.
9300 East 68th Street
Raytown, MO 64133
(816) 566-2011

FSI is the oldest manufacturer of E and F engines, and sells a number of large kits to take advantage of them. These kits may take some extra effort to fill turned wood parts.

Nike-Tomahawk (1/8 scale)

Single-stage model of 2-stage US sounding rocket.

Length: 46" Diameter: 2.00"

Flight System's Javelin. (FSI photo)

Black Brant II (1/8 scale)

Canadian sounding rocket

Length: 41.5" Diameter: 2.1"

Wasp (1/8 scale)

Special-purpose NASA research rocket.

Length: 34.75" Diameter: 2.00"

Sandia Sandhawk (1/6 scale)

US sounding rocket.

Length: 49" Diameter: 2.00"

Nike Smoke (1/8 scale)

US Sounding rocket; its smoke trails revealed upper-atmosphere winds.

Length: 28.6" Diameter: 2.00"

Javelin (1/10 scale)

Single-stage model of 4-stage US sounding rocket.

Length: 55.375" Diameter: 2.25"

The Launch Pad

The Launch Pad
8470 Misty Blue Ct.
Springfield, VA 22153

The Launch Pad is a new entry into the model rocket kit market. Specializes in 2.6" diameter models of missiles from around the world.

ALARM

British anti-radar missile. 2 D engines.

Length: 44.5" Diameter: 2.6"

ASRAAM

British-German-American air-to-air missile.

Length: 34.75" Diameter: 2.6"

Some rockets built from Launch Pad kits and plans: Bullpup, Hawk, Saab RB 05A (plan only), Exocet MM.40, Sidewinder, Tan-San, Exocet AM.39 (plan only), Lance, ASRAAM, Flail (non-scale). (launch Pad photo)

Bullpup AGM-12B (1/4.6 scale)
US air-to-ground missile. D engine.
Length: 29" Diameter: 2.6"

Exocet MM.40 (1/5.3 scale)
French anti-ship missile.
Length: 42" Diameter: 2.6"

Hawk MIM-23A (1/5.4 scale)
US surface-to air missile. 2 D engines.
Length: 37" Diameter: 2.6"

Kormoran AS.34 (1/5.2 scale)
German air-to-ground missile.
Length: 33.3" Diameter: 2.6"

Lance MGM-52 (1/8.5 scale)
US surface-to-surface missile.
Length: 28.75" Diameter: 2.6"

Standard AGM-78 (1/5.2 scale)
US air-to-ground missile.
Length: 34.6" Diameter: 2.6"

Tan-Sam
Japanese surface-to air missile.
Length: 44" Diameter: 2.6"

LOC

LOC Custom Engineering
PO Box 221
Macedonia, OH 44056
(216) 467-4514

LOC is a leading supplier of high power rocketry components and kits. They produce one huge scale kit:

V-2 (1/8.47 scale)
This model requires a high-power J engine to fly. You will need Tripoli or NAR High Power Rocketry certification (and some High Power Rocketry experience) to fly this model.
Length: 65.24" Diameter: 7.765"

MRC Trailblazer kit. (MRC photo)

MRC

Model Rectifier Corporation
2500 Woodbridge Ave.
Edison, New Jersey 08817

Trailblazer II (1/18 scale)
US sounding rocket used for re-entry research. Plastic parts make this an excellent stating point for an accurate model.
Length: 34.3" Diameter: 1.75"

Standard ARM (1/7.7 scale)
US air-to-surface anti-radar missile.
Length: 25" Diameter: 1.75"

Sidewinder (1/4 scale)
US air-to-air missile.
Length: 30.28" Diameter: 1.325"

LOC V-2 is readied for a J-powered flight. (LOC photo)

MRED

MRED Industries, Inc.
PO Box 126
Petersburg, NY 12138-0126
(518) 658-9132

V-2 (1/5.57 scale)
WWII German missile, later used as research rocket. A model of epic proportions, release of the complete kit is imminent as this book goes to press.
Length: 8' Diameter: 11.67"

Black Brant II (1/7.6 scale)
Canadian sounding rocket.
Length: 43.2" Diameter: 2.26"

IQSY Tomahawk (1/4 scale)
US sounding rocket.
Length: 49.4" Diameter: 2.26"

North Coast Rocketry

North Coast Rocketry
Suite 424
4848 South Highland Drive
Salt Lake City, UT 84117

North Coast Rocketry specializes in high power rocketry kits and NAR competition kits. As this book goes to press, NCR is on the verge of producing engines as well.

Patriot (1/4 scale)
Famous US surface-to-air missile.
Length: 54.5" Diameter: 4"

Corporal (1/16 scale)
Early US Army surface-to-surface missile.
Length: 41.5" Diameter: 1.88"

Space Shuttle (1/72 scale)
Vacuformed orbiter uses glide recovery. Release of this kit is imminent as this book goes to press.
Length: 36"

Public Missiles

Public Missiles Ltd.
38300 Long
Mt Clemens, MI 48045

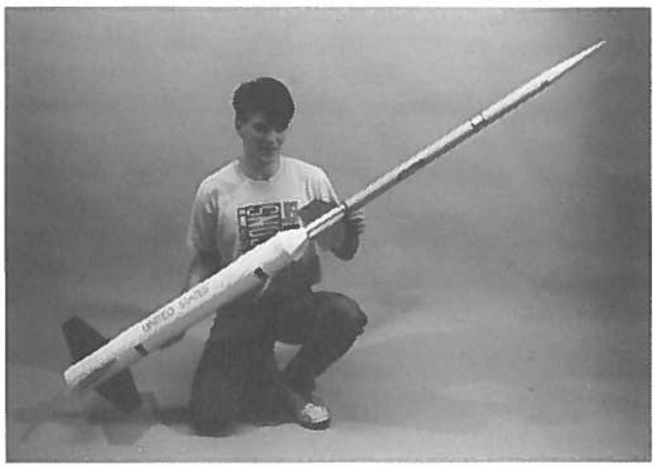
Public missiles specializes in high-power models featuring phenolic tubes.

Nike-Apache (1/4 scale)
Two-stage NASA sounding rocket. The model can be adapted for 2-stage flight with additional components.
Length: 79.25" Diameter: 4"

Patriot (2 kits)
Famous US surface-to-air missile.
1/4 scale kit—Length: 52" Diameter: 4"
1/2 scale kit—Length: 97" Diameter: 7.5"

Amraam (2 kits)1/2.4 scale)
US Air-to-air missile.
1/2.4 scale kit—Length: 56" Diameter: 3"
1/1.8 scale kit—Length: 72" Diameter: 4"

Andrew Miller readies his North Coast Rocketry Patriot model for its first-place flight at the 1994 national meet, NARAM 34. (NCR photo)



Public Missiles produces this kit of the Nike-Apache sounding rocket. (Public Missiles photo)

Quest Aerospace

Quest Aerospace Education, Inc.
PO Box 42390
519 West Lone Cactus Drive
Phoenix, AZ 85989-2390
1-800-858-7302

Quest is a relatively new model rocket company, although most Quest components were first produced by MPC around 1970. Quest produces kits of future space projects now on the drawing board, such as the Space Clipper (DC-Y), National Aerospace Plane (X-30) as well as the following models of historical sounding rockets.

Sandia Tomahawk (1/11.4 scale)

This simple kit features a plastic fin unit for nearly instant assembly. The photographs and scale drawing included with the kit show four antennas in the payload section. While not included in the kit, these can be modeled with fine wire anchored inside the model with a piece of 19 mm engine mount tubing. The included documentation also shows different shades of silver on the nose cone which can be modeled with different silver spray paints.

Length: 18.75" Diameter: 0.787"

Nike-Smoke (1/11.6 scale)

This very simple kit features a plastic fin unit for nearly instant assembly.

Length: 19.5" Diameter: 1.378"

THOY

Tiffany Hobbies of Ypsilanti
PO Box 467
Ypsilanti, MI 48197
(313) 741-0847

THOY specializes in high power rocket kits, including one scale model.

Phoenix (1/3.8 scale)

Air-to-air missile powered by a G engine.

Length: 46" Diameter: 3.9"

Vaughn Brothers

Vaughn Brothers Rocketry
4575 Ross Dr.
Paso Robles, CA 93446
(805) 239-3818

Asp (1/5 scale)

US sounding rocket, model takes 24 mm engines.

Length: 33" Diameter: 1/33"

Supplies, Services, and Out-of-Production Kits,

Acme

Acme Rocket Company
Box 28283
Tempe, AZ 85285-8283
(602) 838-3629

Acme Rockets specializes in hard-to find out-of-production kits, components, and books. Stock varies over time. Acme also sells reprints of classic *Model Rocketry* magazines.

Apogee Components

Apogee Components Inc.
19828 North 43rd Drive
Glendale, AZ 85308
(602) 780-2WIN (780-2946)

Apogee components produces only non-scale kits, but their components and engines are useful for scale modeling as well as competition modeling.

Balsa Machining Service

BMS Company
1002 Florence St.
Lemont, IL 60439
(708) 257-5420

BMS will produce nose cones and transitions from balsa at reasonable prices. Just give them the dimensions you need, and they will produce good quality parts.

Commonwealth Displays

Commonwealth Displays, Inc.
12649 Dix-Toledo Road
Southgate, MI 48195
(313) 282-1055

Commonwealth Displays specializes in hard-to-find out-of-production kits including numerous scale kits. Commonwealth maintains a list of their current stock, which varies over time.

Vacuum Form

Vacuum Form
272 Morganhill Drive
Lake Orion, MI 48360
800-391-2974

Vacuform machines (you provide the oven and shop vac). 6" x 9" for $59, 9" x 12" for $89, and 12" x 18" for $129. Actual working area is about 2" less in each direction.

Researching Scale Data

To build models of rockets not covered in this book, you will need to locate drawings and photos of the original rockets. An excellent starting point is the companion volume to this book, *Rockets of the World: A Modeler's Guide.* In 384 pages *Rockets of the World* covers over 200 versions of 133 rockets from 14 countries and Europe with dimensioned and color-keyed drawings and 179 photographs. Available by mail order from the publisher: Saturn Press, PO Box 3709, Ann Arbor, MI 48106-3709. *Rockets of the World* does not cover every rocket; for instance, military missiles are entirely absent. For many rockets you will have to dig on your own. Here are some tips:

What to Look For: The Scale Data Hunt

Before setting out on a search for scale data, be sure you know exactly what you need. Are you collecting data to build, or will you be using it to document a contest model? If you are building for NAR competition, familiarize yourself with the rules of the *Scale* and *Sport Scale* events. You will find that the requirements for *Sport Scale* are surprisingly loose, while full *Scale* competition is much more strict. These are the documentation requirements:

Sport Scale:

- Photograph or published illustration clearly showing the profile/configuration of the vehicle
- Photograph or published illustration clearly showing the color pattern of the vehicle

Scale:

- Photograph or clear half-tone of the vehicle
- Length of vehicle
- Principle diameters of the vehicle
- Transition lengths
- Nose cone lengths
- Fin length and width
- Drawings, color photos, or descriptions documenting the color scheme on all sides

Color Photos:

A good color photo is all you need for *Sport Scale* competition. It is easy to find color photographs of the best known rockets since about 1960. There are many books in libraries and bookstores that cover the history of manned spaceflight in pictures, and planetary exploration is covered in many books as well. Missile modelers are well aware that there is a large sector of the coffee table publishing industry specializing in weapons of mass destruction. But color photos are very rare in some fields. Keep an eye out for even poor color reproductions of sounding rocket photos and any pre-1960 photographs. Record the source along with a Xerox. Make an extra Xerox and label the colors.

If you need a color copy, there are two approaches. The first is to photograph the source. If you do not have color-balanced light to illuminate the original, you can ask the photo-finishers to adjust the color on the prints. The second option is a color photocopy. These cost about $1-$3 for an 8 1/2" x 11" print. The quality of the copies is variable, so shop around.

Supplemental Photos:

Get photos of both sides of the vehicle. Even a poor Xerox of a black and white photo of "the other side" can help when you sit down to paint.

Dimensioned Drawings:

Dimensioned drawings are the holy grail of scale modelers. Xerox all dimensioned drawings by reflex. You never know when you might be interested, or someone else might be. Take a moment to go through a checklist of NAR required dimensions. If they aren't in the drawing, keep looking. They may be in the text or a separate figure. This is especially critical if you find a set of drawings too big to Xerox. If a Xerox isn't practical, then record the source so you can come back to it later. If you do Xerox the drawing, still record the source, just in case you need further information later.

Flight Logs:

It is often difficult to insure that a given photo or satellite launch corresponds to a given booster type. There have been dozens of Delta versions, many of which look similar, but most photo captions will just indicate that the rocket was a "Delta." Keep an eye out for lists that correlate dates, payloads, and rocket versions. Such lists can be as essential to completing scale packets as dimensioned drawings.

Where To Search

Public and University Libraries:

Every search begins in the library. Don't underestimate the power of your local library. Even if your local library has a tiny collection, you may be able to get an incredible range of books through inter-library loan. And don't be afraid to make use of a nearby university library. University libraries are generally open to the public; sometimes borrowing cards are available for local residents and alumni. Large universities may have several library sites, covering specialized subjects.

Although books are usually short on detailed dimensioned data, data suitable for fun scale models and *Sport Scale* documentation is common in publications intended for the general public. Other good resources are back issues of *Aviation Week & Space Technology, Spaceflight, Flight International,* and other trade journals. *The Journal of the British Interplanetary Society* has occasional historical articles that can be very useful. Newspapers and news magazines are occasionally of use as well. There are a number of annuals that are worth checking for as well. *Jane's All the Worlds Aircraft* included extensive coverage of the world's sounding rockets in the late 1960's and early 1970's. Today much of this can be found in the *Interavia Space Directory* published annually by Jane's.

If a nearby library is a US government depository library, its government documents may be kept separate from other books, and not indexed in the card catalog. So there may be a stash of NASA pamphlets and books you didn't know was there. If the library is a regional depository library, or if it is part of a university with a strong aerospace program, it may own a collection of NASA serials, such as *Technical Notes* and *Contractor Reports.* Often useful data is buried in them.

Special Libraries and Archives:

There are a number of little-known libraries which are open to the public. For example, the National Air and Space Museum Library, the NASA audio-visual library, the NASA History Office, and the Air Force Museum Library are open to modelers, either by walking in or by appointment. Have specific goals in mind, and tell the staff that you are after model making information. There are libraries at many other museums and NASA centers that you may be able to use if you make advance arrangements.

Always load up on change and small bills for photocopies before you go anywhere to research. Copy the title page of every source you copy. You may realize later that you need more information or that you need to document a source.

Look around to see if you have a choice of copiers. Some machines can reproduce even photographs surprisingly well. If you are copying a half-tone from a publication, make enlarged copies if possible, as photocopiers usually do a better job printing a larger dot pattern. Xerox photos twice: once with the machine on the darkest setting and once on the lightest. Between the two copies you'll get most of the grey scale of the photo. If there is information on the back of a photographic print, copy that, too, and staple that copy to the copy of the photo. You may bring home a clue that helps identify the photo later.

If you copy a large drawing, leave plenty of overlap between Xeroxes. Lay out all your copies before you leave to be sure you got everything. If possible, compare photos and drawings before you leave, to be sure they really match.

Many archives allow users to photograph documents. This is particularly useful for color photographs. Some places even provide copy stands for this purpose. I would recommend print film for such photography, as you will have no control over the lighting, and prints can be color corrected after the fact. A macro lens would be ideal for copying photographs, but close-up lenses are available to screw over the lenses of most 35 mm cameras, and these are satisfactory.

As insurance against Murphy's Law, I would recommend Xeroxing everything you photograph, along with caption information. This will allow you to identify your pictures and salvage information if your photos are botched.

Hobby Publications:

Scattered among model rocketry newsletters and magazines are numerous tidbits of scale data. The National Association of Rocketry sells scale data both through its magazine and through its Technical Services (NARTS). Numerous local newsletters publish scale data from time to time.

Fellow Scale Modelers:

Over the years, scale modelers have written various companies and agencies and have gotten tidbits of information. Some have explored specialized archives and libraries. Other modelers may have copies of out-of-print sources such as old issues of *Model Rocketry*, *Model Rocketeer*, or *Space Frontiers*, none of which are likely to be available at a library. You can place an ad in *Sport Rocketry* or your local newsletter requesting data on a particular subject. I have found that building a sport scale model of an unusual prototype, and showing it off, can bring all sorts of data out of the woodwork. Scale modelers can be quite generous with Xeroxes of data, especially if you reciprocate with the fruits of your own research. Much of this book comes from the files of other modelers.

Users and Manufacturers:

Find the builder's, user's or sponsor's address in the *Interavia Space Directory,* the *International Reference Guide to Space Launch Systems, Jane's All the World's Aircraft,* or another industry directory.

When writing, specify exactly which information you need. A neatly-drawn sketch with the required dimensions marked can help.

Sadly, many people write companies and institutions (and authors) for drawings and photos, and never use them. This discourages recipients of letters from taking the time from paying work to chase down information that may be buried deep in archives. Build a fun scale or "boilerplate" model and send photos of it along with your requests for data. This lets the recipient of your letter know that you will actually *do* something with the information you seek. If you can't be bothered to build a preliminary model with the information that first inspired you to research the subject, will you ever get around to building the perfect model with the information you seek?

Used Book Stores:

Keep your eyes peeled for used book stores. You may be surprised by what you might find: a like-new copy of the *McGraw-Hill Encyclopedia of Space*, a copy of Homer E. Newell's *Sounding Rockets*, or a complete set of *Petersen's Guide to Man in Space*. All of these purchases of 20-plus-year old books occurred in the last few years. Willy Ley's classic books are common in used book stores.

Some Sources of Scale Data

The following companies, organizations, and archives can provide scale data on many rocket vehicles.

Acme Rocket Company:

Back issues of *Model Rocketry* magazine, assorted books and other publications, some in limited quantities.

ACME Rockets
Box 28283
Tempe, AZ 85285-8283
(602) 838-3629

Advanced Rocketry Group:

Photo sets and large format, highly detailed dimensioned drawings of rockets from the former Soviet Union, as well as Ariane data. Subscriptions to *The Ukrainian Journal of Space Modelling (Ukrainskiy Raketomodelism)* are also available through ARG.

Advanced Rocketry Group, Limited
PO Box 1272
Postal Station "B"
Mississauga, Ontario L4Y 4G2
Canada

Clark University:

Clark University maintains the primary collection of Robert Goddard's photographs. Photographs are of the highest quality, and are filed by date. Select photos from the *Papers of Robert H. Goddard,* found in large research libraries, which has many photos indexed by date.

Robert H. Goddard Library
Special Collections
Clark University
950 Main Street
Worcester, MA 01610-1477

Department of Defense Still Media:

Military photos that have not yet passed to the Smithsonian or the National Archives are available from the Still Media center. The collection is strong in Air Force sounding rocket, missile, and space vehicle photos. Visit the collection by appointment, or the staff will search for a fee.

DoD Still Media Records Center
Code SMRC
Bldg. 168, Anacostia
2701 So. Capital St. S.W.
Washington, DC 20374-5080
(202) 433-2166

Knollwood Books:

A used book dealer specializing in astronomy and space subjects. Their selection is far better than any ordinary used book store, but the prices are much higher. If you absolutely need an out-of-print book, these are the people to contact.

Knollwood Books
PO Box 197
Oregon, WI 53575-0197
(608) 835-8861

NASA Photo (A-V) Library:

NASA Headquarters, Washington, DC: NASA provides photographs free of charge to publications, including model rocket newsletters, but individuals must purchase them from a contractor. In either case, the NASA photo library is available for inspecting a collection of prints in order to select photographs. The variety is good for space vehicles, but sounding rockets are represented by a few photos depicting typical rockets of each type.

NASA also publishes a catalogue of photographs available in many libraries (sometimes in a separate government document section). NASA Headquarters does not fill orders for the general public, but they can direct you to the contractor who will.

Broadcast and Image Branch
Mail Code PMD
NASA Headquarters
300 E Street SW
Washington, DC 20546
(202) 358-1741

NASA History Office:

New NASA HQ: This little library of filing cabinets contains an assortment of fascinating tidbits. While not as useful as the NASM library, there are still some good sources here. Worth a stop if you are working on a specific topic, as there are some helpful people here.

NASA History Office
Code ICH
NASA Headquarters
300 E Street SW
Washington, DC 20546
(202) 358-0384

National Air and Space Museum Library:

Washington DC: Be prepared with a list of subjects you're researching. The Librarian/Archivist will bring you folders full of information on the topic you request. Bring a 35 mm camera with close focus to mount on the library's copy stand to copy photos. Library staff prefers that you not bring any bags with you. There is a Xerox machine available for your use. You will be charged for the copies ($0.15 each) when you leave. The files are voluminous, and be prepared to spend an hour or two on each subject. The collection is not complete from a scale modeler's viewpoint, but there are many gems hidden in the stacks. There are files for both individual vehicles and satellite projects, so look under both. The file organization is being revised so that it should eventually be possible to go straight to drawings and photographs.

Make an appointment by calling (202) 357-3133, and ask for the library and archives. If you intend to bring a camera to take photos of photos, reserve the copy stand when you make your appointment.

In addition to photos and drawings in the file system, there is an extensive photo catalog on video disk. Video frame prints of these photos are available for $0.20 each. Photographic reproductions in color or black and white are also available.

Archives
National Air & Space Museum
Mail Stop 322
Smithsonian Institution
Washington, DC 20560

National Archives:

Washington DC: Buried in the military documents and photographs, you may find a few space-related gems here, but it may not be worth the effort. Bring camera, loose sheets of paper, a pencil, and nothing else, as security precautions are extreme at the archives. Your bags will be searched, you'll be expected to catalog your photo equipment, and no notebooks are allowed in the research rooms. Each division has a couple pages of rules to read. You can order copies of photographs for a few dollars each. Photos are not indexed very helpfully, but some of the staff can find things for you. Plan to spend a whole day, as you'll use half of it just getting to the materials of interest.

The National Archives holds older photographs passed to it by the armed forces, including photos of Wac Corporal, Viking, and Aerobee rockets.

National Archives-College Park
8601 Adelphi Rd.
College Park, MD 24740-6001

National Association of Rocketry:

The NAR publishes *Sport Rocketry,* which frequently includes historical articles illustrated with photos and dimensioned drawings, and scale model plans. Other services include NARTS, the NAR's Technical Services, and NARTREK, a program for modelers improving their skills, which keeps a file of scale data.

National Association of Rocketry
1311 Edgewood Dr.
Atloona, WI 54270
(715) 832-1946

NARTS:

NAR Technical Services sells scale data packets on the Saturn IB and V, Sandhawk, IQSY Tomahawk, Aerobee 350, and Super Loki-Dart. NARTS also sells back issues of *Model Rocketeer.* More packets are in the works. NARTS sells many other essential rocketry publications, including the *Handbook of Model Rocketry* and *Rockets of the World.*

NARTS
PO Box 1482
Saugus, MA 01906

Space Commerce Corporation:

SCC's main business is marketing former Soviet launch services in the US. They also sell Soviet space-related items including photographs and launch vehicle user's guides.

Space Commerce Corporation
5718 Westheimer
Suite 1515
Houston, TX 77057

Quest: The History of Spaceflight Magazine:

Published quarterly, *Quest* Magazine is not connected with Quest Aerospace Education. *Quest* is devoted to space history, and regularly includes scale drawings and photographs of use to modelers. $19.95 per year in the US, $25.00 foreign, $35.00 overseas airmail.

Quest Magazine
PO Box 9331
Grand Rapids, MI 49509-0331

Space In Miniature:

SIM publishes books for static space modelers. Currently a Space Shuttle book is available, a book on Soviet spacecraft is coming, and a Gemini book may be re-issued.

Space In Miniature
7714 Aragorn Ct
Hanover, MD 21076

T Minus 5:

Published by the Huron Valley Rocket Society (HUVARS), prints scale data regularly. Many of the drawings in this book first appeared in *T-Minus-5.*

Huron Valley Rocket Society
c/o Jim Fackert
10555 McCabe Rd.
Brighton, MI 48116

Scale Data Bibliography

Selected Publications

AAS History Series, American Astronautical Society. Volumes 7-10 are proceedings of various space history conferences, and are packed with information and photographs to be found nowhere else. Especially useful for early rocketry.

Apollo Expeditions to the Moon, NASA SP-350, 1975. A collection of articles by various authors. Lavishly illustrated source of color photos useful for modelers.

Aviation Week & Space Technology, McGraw Hill. This weekly trade journal has covered space subjects for decades, even when it was simply called *Aviation Week.* The annual industry directory issue in March is an excellent place to begin research on many rockets.

The Cambridge Encyclopedia of Space, ed. by Michael Rycroft, Cambridge University Press, 1990, 386 pages. The most voluminous book on the subject in print, covering historical and contemporary subjects. Many good color photos and nice cut-away drawings.

Encyclopedia of Space (*McGraw-Hill Encyclopedia of Space*), Various authors, 1967-69, various publishers. This monumental 2" thick book has been published by Editions Rombaldi, McGraw-Hill, and Hamlyn Group. It is lavishly illustrated with color photographs and gives an excellent overview of 1960's space technology.

Fire across the Desert: Woomera and the Anglo-Australian Joint Project, 1946-1980, Peter Morton, Australian Government Publishing Service, 1989, 575 pages. Details the history of the Woomera range and the projects conducted there, including most British and Australian rocket programs, the ELDO Europa, and the American Sparta.

The History of Manned Spaceflight, David Baker, New Cavendish Books, 1981, 544 pages. This book is the most complete reference available on American manned space programs through Skylab. Soviet programs are also covered in some detail. Photos of the most important manned rockets are included.

History of Rocketry and Space Travel, Third Revised Edition, Wernher von Braun and Frederick I. Ordway III, Thomas Y. Crowell Co., 1975. Nicely illustrated, this book is a handy reference for the early years of rocketry.

The History of Rocket Technology, ed. by Eugene M. Emme, Wayne State University Press, 1964. A collection of historical papers on the major rocket programs of the 1950's and 1960's, illustrated with photos and drawings. Includes the story of Bell's rocket pack.

The History of the US Nuclear Arsenal, James Norris Gibson, Brompton Books, 1989. Includes historical summaries and color photos of numerous missiles.

Illustrated Encyclopedia of Space Technology, Kenneth Gatland, Orion books, 1981 and 1989. Loads of historical and current information crammed into just over 300 pages. Includes color photos, cutaway drawings, and a center section with dozens of space launch vehicles drawn to constant scale.

International Reference Guide to Space Launch Systems, Steven J. Isakowitz, American Institute of Aeronautics and Astronautics, 1991, 295 pages. This book covers the performance and basic dimensions of all satellite boosters in existence at the time of publication. Most illustrations are unsuitable for modeling, but there are some rare photos and useful addresses.

Interavia Space Directory, Jane's publishing group. This annual has taken over the material once covered in *Jane's All the World's Aircraft.* Includes specifications for all current space launchers and a number of sounding rockets as well. Includes current addresses to write for more information.

Jane's All the World's Aircraft, Jane's publishing group. This annual book on aircraft included useful section on missiles, space vehicles, and sounding rockets in the late 1960's and early 1970's. An excellent starting place for research on obscure rockets of the period.

A New Dimension: Wallops Island Flight Test Range: The First Fifteen Years, NASA RP-1028. This NASA book covers the early history of Wallops Island through the NACA years up to the early NASA years. Full of B&W photos of early sounding rockets and free-flight model test rockets. Good historical background on early sounding rockets.

The Rocket, David Baker, Crown Publishers, 1978. A comprehensive history of rocketry including a useful compendium of large missiles and space vehicles. Many photographs.

Rockets and Missiles, Bill Gunston, Leisure books/Salamander books, 1979. An illustrated encyclopedia of military missiles. Includes color photos and historical sketches of the military antecedents of many space and sounding rockets.

Rockets, Missiles, and Space Travel, Revised Edition, Willy Ley, Viking, 1957. After more than 35 years, this book holds up as a useful reference on early rocketry, with firsthand accounts of the work of the VfR. Illustrated with photos and drawings. It is relatively easy to find at used book stores.

Rockets of the World: A Modeler's Guide, Peter Alway, 1993. This book drawings and photos of over 100 sounding rockets and space launch vehicles compiled specifically for modelers.

Sounding Rockets, Homer E. Newell, McGraw Hill, 1959. This collection of papers gives an overview of sounding rocket technology in the late 1950's, including sections devoted to a number of specific vehicles. Illustrated with dimensioned drawings and B&W photos.

The Soviet Manned Space Program, Philip Clark, Orion Books/Salamander Books, 1988. A well-illustrated book, and as up-to-date as a 1988 book on the Soviet Union could be. Many color photographs.

Spaceflight, British Interplanetary Society. This monthly magazine includes both current and historical information. In recent years, it has been a clearing house for new historical information emerging from the former Soviet Union.

Space Frontiers, Theodore Talay. This magazine published numerous historical articles geared toward modelers. While it has ceased publication, back issues are available from Space Frontiers, PO Box 6488, Newport News, VA 23606.

The Viking Rocket Story, Milton W. Rosen, Harper, 1955. A dramatic first-hand account of the Viking program through the 10th flight.

Computer Data Base

Spaceworks, Keith Scala: A collection of databases, including launch logs for US sounding rockets, satellites, and missile tests. Available for Appleworks (Apple II format) and Microsoft Works (Macintosh and IBM format), $44 plus shipping. Spaceworks, PO Box 6246, Bridgeport, CT 06606.

Modeling Books

Basics of Model Rocketry, Douglas Pratt, Kalmbach Books. An inexpensive introduction to model rocketry for beginners. If you haven't flown a model rocket before, *Basics of Model Rocketry* will cover the essentials not covered in the present volume.

Do It Yourself Vacuum Forming, RC Modeler, $9.95. RCM, PO Box 487, Sierra Madre, CA 91205, (800) 523-1736

Handbook of Model Rocketry, by G. Harry Stine, Wiley, $17.95. This standard model rocketry "bible" is an essential part of any model rocketeer's library.

Second Stage: Advanced Model Rocketry, Michael Banks, Kalmbach Books. This companion to *Basics of Model Rocketry* covers payloads, scale modeling, and other topics in more depth.

Sources by Vehicle

A-3: *Rockets of the World,* Alway, dimensioned drawing; *The Rocket,* Baker, dimensioned drawing, B&W photo; *Cambridge Encyclopedia of Space,* Rycroft, B&W photo; *Blueprint for Space,* Ordway and Liebermann, B&W photo

A-4: See V-2

A-4B (Winged V-2): *Cambridge Encyclopedia of Space,* Rycroft, B&W photo; *Space Frontiers,* Vol. 4 No. 1, dimensioned drawings, B&W photos

Aero-High: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Model Rocketry,* Oct. 1971, dimensioned drawing, B&W photos, color description

Aerobee (Standard): *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Sounding Rockets,* Newell, partially dimensioned drawing; *The X-Planes,* Miller, B&W photos; *Rocket Power and Space Flight,* Stine, B&W photos, undimensioned drawing; *Rockets, Missiles, and Space Travel,* Ley, partially dimensioned drawing, B&W photo

Aerobee 100 (Aerobee Jr.): *Sounding Rockets,* Newell, B&W photo

Aerobee 150 (Aerobee Hi): *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Sounding Rockets,* Newell, partially dimensioned drawing, B&W photos; *National Geographic,* April 1957, B&W photos; NASA TR-226, dimensioned drawings, B&W photos; *The X-Planes,* Miller, B&W photos; *Cambridge Encyclopedia of Space,* Rycroft, B&W photo;

Aerobee 150A: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; NASA photo 68-HC-027 color launch; NASA photo 68-HC-028, color, in tower/night launch double exposure, 4.54 UG; NASA TR-226, partially dimensioned drawings, B&W photos; *McGraw-Hill Encyc. of Space,* B&W photo; *The Rocket,* Baker, B&W photo; NASA photo 68-HC-026, color, horizontal from front, probes extended, 4.93 II, 4.94 II, 4.138 II or 4.139 II

Aerobee 300: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; NASA TR-226, B&W photos; *Aviation Week & Space Tech.,* Dec. 22 1958, B&W photos

Aerobee 300A: NASA TR-226, partial dimensions, B&W photos

Aerobee 350: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; NARTS data pack, color photos, dimensioned drawings; NASA photos 68-HC-025, 68-HC-029, (17.01 GT); *The Rocket,* Baker, B&W photo

Agate: *Journal of the British Interplanetary Society,* Vol. 40 (1987), pp. 51-66, Gire and Schibler, dimensioned drawing

Aigle: *Journal of the British Interplanetary Society,* Vol. 40 (1987), pp. 51-66, Gire and Schibler, dimensioned drawing

American Rocket Society: *Rockets of the World,* Alway, dimensioned, color keyed drawing; *Cambridge Encyclopedia of Space,* Rycroft, B&W photo; *Blueprint for Space,* Ordway and Liebermann, B&W photo

Apollo Pad Abort Test: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; NASA photos 64-H-1146, 64-H-1147, (BP-22A)

Arcas: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Model Rocketry,* April 1969, Stine, dimensioned drawing, B&W photos, color description; *McGraw-Hill Encyc. of Space,* B&W photo; NASA photos 68-HC-032, 63-Arcas-2

Arcon: *Sounding Rockets,* Newell, partially dimensioned drawing, B&W photo

Ariane 1: *Rockets of the World,* Alway, dimensioned, color keyed drawing; *Cambridge Encyclopedia of Space,* Rycroft, color photo; *Illus. Encyc. of Space Tech.,* Gatland, color drawing

Ariane 3: *Cambridge Encyclopedia of Space,* Rycroft, color photo; *Illus. Encyc. of Space Tech.,* Gatland, color drawing

Ariane 4: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space,* Rycroft, color photo, cutaway diagram; *Illus. Encyc. of Space Tech.,* Gatland, color drawing

Aries: *Rockets of the World, Alway,* dimensioned, color keyed drawing, B&W photo

ASAT: *Cambridge Encyclopedia of Space,* Rycroft, B&W photo

ASLV (India): *Illus. Encyc. of Space Tech.,* Gatland, color photo, color drawing; *Cambridge Encyclopedia of Space,* Rycroft, color photo

Asp: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Model Rocketry,* May 1969, Stine, dimensioned drawing, B&W photos, color descriptions; *Sounding Rockets,* Newell, B&W photos, drawings; *Rocket Power and Space Flight,* Stine, B&W photos; *Rockets, Missiles, and Space Travel,* Ley, partially dimensioned drawing

Astrobee 1500: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; NASA photos 64-H-2554 (16.02 GT), 68-HC-030 (Wishbone 2/Herb's Hope), 68-HC-031, 71-HC-373, 71-HC-374, 71-HC-375; *Model Rocketry,* July 1969, Mandell, dimensioned drawing, B&W photos, color description

Astrobee 500: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo

Astrobee D: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Model Rocketry,* Nov. 1970, Stine, dimensioned drawing, B&W photos, color descriptions

Atlas missile: *National Geographic,* Oct. 1959 and May 1961, color photos; *The History of Rocket Technology,* Emme, B&W photo, undimensioned drawing; *McGraw-Hill Encyc. of Space,* B&W photo; *The Rocket,* Baker, B&W photo

Atlas-Able: *American Spacemodeling,* Aug. 1988, Desind, B&W photos; *Apollo Expeditions to the Moon,* Cortright, B&W photo

Atlas-Agena: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W

photo; NASA photo 66-HC-1867, color, launch, Gemini 12 target; *American Spacemodeling,* Sept. 1987, model plans; *National Geographic,* Oct. 1962 and Nov. 1964, color photos; NASA photo 66-HC-1867; *Illus. Encyc. of Space Tech.,* Gatland, color photo, color drawing; *McGraw-Hill Encyc. of Space,* color photo; *Cambridge Encyclopedia of Space,* Rycroft, color photo

Atlas-Centaur: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; NASA photos 67-HC-713 (Surveyor 6), 68-HC-3 (Surveyor 7); *American Spacemodeling,* Sept. 1987, model plans; *McGraw-Hill Encyc. of Space,* color photo; *The Rocket,* Baker, color photo; *Cambridge Encyclopedia of Space,* Rycroft, color photo; *Illus. Encyc. of Space Tech.,* Gatland, color drawing

Atlas-Score: *Rockets of the World,* Alway, dimensioned, color keyed drawing; *Space Frontiers,* Vol. 3 no. 6, dimensioned drawing, B&W photos, color description

Berenice: *Aviation Week & Space Tech.,* Aug. 12, 1963, partially dimensioned drawing, B&W photo; *McGraw-Hill Encyc. of Space,* color photo

Black Arrow: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space,* Rycroft, color photo; *Illus. Encyc. of Space Tech.,* Gatland, color drawing

Black Brant II: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *McGraw-Hill Encyc. of Space,* B&W photo; *Model Rocketry,* Dec. 1971, dimensioned drawing, B&W photo, color description

Black Brant III: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Sport Rocketry,* February 1994, dimensioned drawing, color description, B&W photos; NASA photo 68-HC-035; NASA photos 71-HC-376 through 71-HC-378 (12.04 GT); *Model Rocketry,* Sept. 1966, dimensioned drawing, B&W photo, color description

Black Brant IV: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo

Black Brant V: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo

Black Brant X: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space,* Rycroft, color photo

Black Knight: *Rockets of the World,* Alway, dimensioned, color keyed drawing

Boosted Arcas: NASA photo 68-HC-033, color, horizontal/vertical

Bullpup-Cajun: NASA photos 71-HC-353, 71-HC-354

Bumper (V-2/Wac Corporal): *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Space Frontiers,* Vol. 4 No. 2, partially dimensioned drawings, B&W photos; *Cambridge Encyclopedia of Space,* Rycroft, B&W photo; *The History of Rocket Technology,* Emme, *The Rocket,* Baker, B&W photo

Chaparral missile: *American Spacemodeling,* June, July, Oct. 1987, dimensioned drawings, B&W and color photos

Cosmos: See Kosmos

D-Region Tomahawk: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *American Spacemodeling,* January-February 1992, Biedron and Corway, dimensioned drawing, color photos; *Model Rocketry,* June 1971, dimensioned drawings, B&W photos, color descriptions; NASA photos 71-H-402, 71-HC-352

Deacon Rockoon: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Sounding Rockets,* Newell, Partially dimensioned drawings, B&W photos; *National Geographic,* April, 1957, B&W photos; *Reminiscences of 30 Years of Space Research,* Friedman, color photos

Delta (various versions): *McGraw-Hill Encyc. of Space,* color photo; *Illus. Encyc. of Space Tech.,* Gatland, color drawing; *The Rocket,* Baker, color photo; Delta 3914, *Cambridge Encyclopedia of Space,* Rycroft, color photo; NASA photos Echo 1-26 (Echo 1), 73-HC-191, 73-HC-212 (Geos-C/Delta 109), 74-HC-123, (Delta 92), 75-HC-229 (Anik-3)

Delta B: *Rockets of the World,* Alway, dimensioned, color keyed drawing

Delta D: NASA photos 65-H-591, 65-H-592(Early Bird/Delta 30)

Delta E: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo

Delta L: NASA photo 68-HC-529 (Intelsat II-A)

Delta M: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo

Delta II: *Rockets of the World,* Alway, dimensioned, color keyed drawing; *Space Age,* William J. Walter, color photo

Diamant A: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *McGraw-Hill Encyc. of Space,* color photo; *Cambridge Encyclopedia of Space,* Rycroft, color photo; *Illus. Encyc. of Space Tech.,* Gatland, color drawing; *Journal of the British Interplanetary Society,* Vol. 40 (1987), pp. 51-66, Gire and Schibler, dimensioned drawing

Diamant B: *Rockets of the World,* Alway, dimensioned, color keyed drawing; *Journal of the British Interplanetary Society,* Vol. 40 (1987), pp. 51-66, Gire and Schibler, dimensioned drawing

Diamant B-P4: *Rockets of the World,* Alway, dimensioned, color keyed drawing; *Illus. Encyc. of Space Tech.,* Gatland, color drawing; *Cambridge Encyclopedia of Space,* Rycroft, color photo; *Journal of the British Interplanetary Society,* Vol. 40 (1987), pp. 51-66, Gire and Schibler, dimensioned drawing

Dragon: *Rockets of the World,* Alway, dimensioned, color keyed drawing; *Cambridge Encyclopedia of Space,* Rycroft, B&W photo

EA 41 (France): *Cambridge Encyclopedia of Space,* Rycroft, B&W photo

Emeraud: *Cambridge Encyclopedia of Space,* Rycroft, color photo

Energiya: *Aviation Week & Space Tech.,* June 8 1987, Mar 28, Nov. 21, Dec. 12, 1988, Undimensioned drawing, color photos; *Illus. Encyc. of Space Tech.,* Gatland, color photos; *The Soviet Manned Space Program,* Clark, color photos; *Cambridge Encyclopedia of Space,* Rycroft, color photo

Energiya-Buran; *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space,* Rycroft, color photo; *Illus. Encyc. of Space Tech.,* Gatland, color drawing

Enzian (Germany): *Cambridge Encyclopedia of Space,* Rycroft, B&W photo

Europa: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *McGraw-Hill Encyc. of Space,* B&W photo; *The Rocket,* Baker, color photo; *Cambridge Encyclopedia of Space,* Rycroft, B&W, color photos; *Illus. Encyc. of Space Tech.,* Gatland, color drawing

Falcon missile: *Model Rocketry,* Sept. 1970, dimensioned drawing, B&W photos

Gemini-Titan 2: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *American Spacemodeling,* Feb. 1986, dimensioned spacecraft drawing; *National Geographic,* April 1966, color spacecraft photos; *Illus. Encyc. of Space Tech.,* Gatland, color photo, color drawing; *Apollo Expeditions to the Moon,* Cortright, color photo; *McGraw-Hill Encyc. of Space,* color photo; NASA photo 65-HC-303 (Gemini 4); *Cambridge Encyclopedia of Space,* Rycroft, B&W photo

GIRD 09: *Cambridge Encyclopedia of Space,* Rycroft, B&W photo; *Illus. Encyc. of Space Tech.,* Gatland, B&W photo.

GIRD X: *Cambridge Encyclopedia of Space,* Rycroft, B&W photo; *Space Age,* William J. Walter, B&W photo

Goddard: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space,* Rycroft, B&W photo; *Space Age,* William J. Walter, B&W photo; *The Papers of Robert H. Goddard,* diagrams, B&W photos

H-1 (Japan): *Illus. Encyc. of Space Tech.,* Gatland, color drawing

H-2 (Japan): *Illus. Encyc. of Space Tech.,* Gatland, color drawing

HAD (Australia): *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Model Rocketry,* April 1970, dimensioned drawing, B&W photo, color description

Hermes RV-A-10: *Rockets of the World,* Alway, dimensioned, color keyed drawing

Honest John: *American Spacemodeling,* August 1987, dimensioned drawing, color description

INTA-255: *Rockets of the World,* Alway, dimensioned, color keyed drawing

IQSY Tomahawk: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; NARTS data pack, *Handbook of Model Rocketry 5th ed.,* Stine, dimensioned drawings, B&W photo, color description

Iris: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Sounding Rockets,* Newell, partially dimensioned drawing, B&W photo

Javelin: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; NASA photos 66-H-1256, 66-HC-1826, (Barium expt), 68-HC-038, 68-HC-039, 71-HC-361, 71-HC-362, 71-HC-363, 71-HC-3641

Juno I: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *American Spacemodeling,* Jan. 1988, dimensioned drawings, color descriptions, B&W photos; *The History of Rocket Technology,* Emme, partially dimensioned drawing, B&W photo; *McGraw-Hill Encyc. of Space,* color photo; *The Rocket,* Baker, B&W photo; *Cambridge Encyclopedia of Space,* Rycroft, B&W photo

Juno II: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *American Spacemodeling,* April 1989, B&W photo; *American Spacemodeling,* April 1987, model plan; *National Geographic,* Oct. 1959, color photos; NASA photos Exp. VII-9, Exp. VII-10, Exp-25/Exp XI-7, color photos; *Space Frontiers,* Vol. 3 no. 5, dimensioned drawing, B&W photos, color description; *Illus. Encyc. of Space Tech.,* Gatland, color photo, color drawing; *Apollo Expeditions to the Moon,* Cortright, color photo; *The Rocket,* Baker, B&W photo

Jupiter C: *Space Frontiers,* Vol. 1 No. 2, undimensioned drawings, color descriptions; *McGraw-Hill Encyc. of Space,* B&W photo

Jupiter missile: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *National Geographic,* Oct. 1959, color photo; *The Rocket,* Baker, B&W photo

Kappa: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo, *Sounding Rockets,* Newell, partially dimensioned drawing, B&W photo; *McGraw-Hill Encyc. of Space,* B&W photo

Kosmos, small (B-1 / SL-7): *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space,* Rycroft, color photo; *Illus. Encyc. of Space Tech.,* Gatland, color drawing

Kosmos, large (C-1 / SL-8): *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space,* Rycroft, B&W photo; *Illus. Encyc. of Space Tech.,* Gatland, color drawing

Lambda 4-S: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *Illus. Encyc. of Space Tech.,* Gatland, color drawing

Little Joe 1: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *American Spacemodeling,* Oct. 1988, B&W photo; *National Geographic,* July 1960, color photo; *The History of Rocket Technology,* Emme, partially dimensioned drawing, B&W photo; *Apollo Expeditions to the Moon,* Cortright, B&W photo; *The Rocket,* Baker, B&W photo; NASA photos Little Joe-1, through Little Joe-16, color photos; *Cambridge Encyclopedia of Space,* Rycroft, color photo

Little Joe II: *Rockets of the World,* Alway, dimensioned, color keyed drawing, B&W photo; *American Spacemodeling,* May-June 1991, July-August 1991, Gassaway & Beach, dimensioned drawings, color photos; *Model Rocketry,* Sept. 1969, dimensioned drawings and color pattern; *Apollo Expeditions to the Moon*, Cortright, partial color photo; *McGraw-Hill Encyc. of Space*, B&W photo; NASA photos Little Joe-19 through Little Joe-35, color; NASA photo 63 Little Joe II-5 (A-001); NASA photo 64-H-2805 (Controllable fins)

Loki HASP: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photo 68-HC-036

Loki Rockoon: *Rockets of the World*, Alway, dimensioned, color keyed drawing; *Sounding Rockets*, Newell, dimensioned drawing

Loki-Wasp: *Sounding Rockets*, Newell, partially dimensioned drawing, B&W photo

Long March 1: *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Long March 2: *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Illus. Encyc. of Space Tech.*, Gatland, color photos, color drawing

Long March 3: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Illus. Encyc. of Space Tech.*, Gatland, color photos, color drawing

Luna: see Vostok

M-100B: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *McGraw-Hill Encyclopedia of Space*, B&W photos

Maul Camera Rocket: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

Mercury-Atlas: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *American Spacemodeling*, Sept. 1987, Model plans; *Illus. Encyc. of Space Tech.*, Gatland, color photo, color drawing; *Apollo Expeditions to the Moon*, Cortrightcolor photo; *McGraw-Hill Encyc. of Space*, color photo; *The History of Rocket Technology*, Emme, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo

Mercury-Redstone: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *National Geographic*, May, 1961, color photos; *The History of Rocket Technology*, Emme, partially dimensioned drawing, B&W photo; *Apollo Expeditions to the Moon*, Cortright, color photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Illus. Encyc. of Space Tech., Gatland*, color drawing

Meteor 1 (Poland): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo.

Meteor 2K: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

Meteor 3: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

MMR-06: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

MR-12: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

MR-20: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

Mu 3-C: *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Mu-3H: *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Mu-3SII: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo

Mu-4S: *Rockets of the World*, Alway, dimensioned, color keyed drawing; *Illus. Encyc. of Space Tech.*, Gatland, color drawing

MX-774: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Space Frontiers*, Vol. 1 No. 4, undimensioned drawings, color description; *The X-Planes*, Miller, B&W photos; *The Rocket*, Baker, B&W photo

N-1 (USSR G-1): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Man in Space*, H. J. P. Arnold, B&W photo; *Aviation Week & Space Tech.*, Feb. 18, 1991, Sept. 30, 1991, Nov. 9, 1992, drawing, B&W photos; *Spaceflight*, Sept. 1992, B&W photos; *Scientific American*, June 1994, B&W photos

N-1 (Japan): *Illus. Encyc. of Space Tech.*, Gatland, color drawing

N-2: *Cambridge encyclopedia of Space*, Rycroft, color photo; *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Nike-Ajax missile (Nike I): *National Geographic*, July 1954, color photos; *Rockets, Missiles, and Space Travel*, Ley, B&W photos

Nike-Apache: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photos 68-HC-040, 71-H-416, 71-HC-372; *Model Rocketry*, Nov. 1969 dimensioned drawing, B&W photos, color description; NASA TN-D 1699, partially dimensioned drawings, B&W photo

Nike-Asp: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Sounding Rockets*, Newell, B&W photo; *McGraw-Hill Encyc. of Space*, B&W photo; *Reminiscences of 30 Years of Space Research*, Friedman, color photos

Nike-Cajun: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photo 61-Nike-Cajun-10; NASA photo 68-HC-53, color, Horizontal/Vertical; NASA photos 71-HC-365 through 371, color; *Sounding Rockets*, Newell, partially dimensioned drawings, B&W photo; *Rocket Power and Space Flight*, Stine, B&W photo

Nike-Deacon: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Sounding Rockets*, Newell, B&W photo; *Rockets, Missiles, and Space Travel*, Ley, partially dimensioned drawing, B&W photo; *Reminiscences of 30 Years of Space Research*, Friedman, color photo

Nike-Hercules missile (Nike B): *American Spacemodeling*, Aug. 1984, dimensioned drawing, B&W photos, color descriptions

Nike-Smoke: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Model Rocketry*, Oct. 1969, dimensioned drawing, B&W photos; NASA TN D-2009, TN D-2277, dimensioned drawings, B&W photo; NASA photo 66-HC-55; *Handbook of Model Rocketry*, 6th ed., Stine, dimensioned drawing

Nike-Tomahawk: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photos 71-HC-358 through 71-HC-360; *Model Rocketeer*, Feb. 1974, dimensioned drawing, B&W photos, color description

Orion II (Argentina): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

OTRAG: *Rockets of the World*, Alway, dimensioned, color keyed drawing; *Aviation Week & Space Tech.*, Sept. 12, 1977, B&W photos; *Popular Science*, March, 1978, B&W photos

Patriot missile: *American Spacemodeling*, March-April, Gassaway, dimensioned, color-keyed drawing, B&W photo

Pegasus: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Aviation Week & Space Tech.*, June 6 and 27, 1988, partially dimensioned drawings, color artist's conception

Pershing 1 missile: *Model Rocketry*, Jan. 1970, dimensioned drawing, B&W photos, color descriptions; *The Rocket*, Baker, B&W photo

Proton (D-1e / SL-12): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Aviation Week & Space Tech.*, Feb. 9, 1987, undimensioned drawing; *Aviation Week & Space Tech.*, Jul. 18, Jul. 25, Aug. 1, 1988, color photos; *The Soviet Manned Space Program*, Clark, color photographs; *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Illus. Encyc. of Space Tech.*, Gatland, color drawing

R-7/SS-6 Sapwood: *The Soviet Manned Space Program*, Clark, B&W and color photos; *Cambridge Encyclopedia of Space*, Rycroft, B&W photo

RAM A: NASA TN D-1611, partially dimensioned drawing, B&W Photos

RAM B: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA TN D-2437, detailed dimensioned drawings, B&W photos; NASA photos 68-HC-58 through 68-HC-60; *McGraw-Hill Encyc. of Space*, B&W photo

Rasko 2 (Poland): *Rockets of the World*, Alway, dimensioned, color keyed drawing

Redstone Missile: *The History of Rocket Technology*, Emme, partially dimensioned drawing; *Apollo Expeditions to the Moon*, Cortright, B&W photo; *The Rocket*, Baker, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, B&W photo

Repulsor (VfR) 2-stick: *Cambridge Encyclopedia of Space*, Rycroft, B&W photo; *Blueprint for Space*, Ordway and Liebermann, B&W photo

Rockair : *Sounding Rockets*, Newell, partially dimensioned drawing, B&W photo

Rockoon: see Deacon, Loki

Rohini RH-75 (India): *Rockets of the World*, Alway, dimensioned, color keyed drawing; *Model Rocketry*, Aug. 1969, dimensioned drawing, B&W Photo

RP-3 (Poland): *Rockets of the World*, Alway, dimensioned, color keyed drawing

Rubis: *Journal of the British Interplanetary Society*, Vol. 40 (1987), pp. 51-66, Gire and Schibler, dimensioned drawing

Sandhawk: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NARTS data pack, dimensioned drawings, color photo

Sandia Tomahawk: *Rockets of the World*, Alway, dimensioned, color keyed drawing

Saphir: *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Journal of the British Interplanetary Society*, Vol. 40 (1987), pp. 51-66, Gire and Schibler, dimensioned drawing

Saturn I, Block 1: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photos Saturn 2, Saturn 1-11, Saturn 13 (SA-1), Saturn 2-20 (SA-2), Saturn 3-31, Saturn 3-33 (SA-3), Saturn 4-41, Saturn 4-58, Saturn 4-52, 64-SA4-13 (SA-4); NASA TN D-2001, partially dimensioned drawing; *Illus. Encyc. of Space Tech.*, Gatland, color photo; *The History of Rocket Technology*, Emme, B&W photo

Saturn I, Block 2: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photos Saturn 5-63, Saturn 5-75, Saturn 5-86, 64-SA5-4 (SA-5), Saturn 6-101, Saturn 6-105 through Saturn 6-109, Saturn 6-111, 64-SA6-24 (SA-6), Saturn 7-140, Saturn 7-145 (SA-7), Saturn 9-154 (SA-9), 65-HC-312, 65-HC-313 (SA-8), 65-HC-546, 65-HC-547, 65-HC-559 (SA-10); *The History of Rocket Technology*, Emme, B&W photo (on dust jacket); *McGraw-Hill Encyc. of Space*, color photos; *The Rocket*, Baker, color photo

Saturn 1B: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NARTS data pack, dimensioned drawings; *McGraw-Hill Encyc. of Space*, color photo; *The Rocket*, Baker, color photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo; NASA photos 66-HC-016, 66-HC-052 (SA-201), 66-HC-888, 66-H-919, 66-HC-890 (SA-203), 67-HC-151, 68-H-45, 68-HC-332 (Apollo 5), 68-H-948, 68-HC-555, 68-HC-561, 68-HC-564, 68-HC-638, 68-HC-640, 68-HC-645 (Apollo 7), 75-HC-433 (Apollo-Soyuz); *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Saturn V: *Rockets of the World*, Alway, dimensioned, color keyed drawing, color photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Blueprint for Space*, Ordway and Liebermann, color photo; *American Spacemodeling*, July 1989, November 1989, December 1989, March-April 1991, Pursley, dimensioned drawings, color and B&W photos; *National Geographic*, Dec., 1969, color photos; NARTS data pack, dimensioned drawings; *Illus. Encyc. of Space Tech.*, Gatland, color photo, color drawing; *Apollo Expeditions to the Moon*, Cortright, color photo; *McGraw-Hill Encyc. of Space*, color photo

Saturn V-Skylab: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photos 73-HC-237, 73-HC-422, 73-HC-425; *Illus.*

Encyc. of Space Tech., Gatland, color drawing

Scout: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photos Explorer XIX-78 (Explorer 19), 66-HC-21 (Reentry test), 68-H-734, 68-H-735 (RAM C-B), 68-HC-152 (Explorer 37), 72-HC-858 (ESRO IV); *American Spacemodeling*, Sept. 1988, Desind, color photos; NASA photos 66-HC-21, 68-HC-152; *McGraw-Hill Encyc. of Space*, B&W photo; *The Rocket*, Baker, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Shotput: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photo 68-HC-062, color, Horizontal/Vertical, Italian launch

Skua (British): *Model Rocketry*, Oct. 1970, dimensioned drawing, B&W photo, color description; *McGraw-Hill Encyc. of Space*, B&W photo

Skylark (British): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Sounding Rockets*, Newell, partially dimensioned drawing; *McGraw-Hill Encyc. of Space*, B&W photo

SLV-3 (India): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo; Illus. *Encyc. of Space Tech.*, *Gatland*, color drawing

Sonda 1 (Brazil): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

Sonda 2 (Brazil): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

Soyuz: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photos 75-HC-606; 75-HC-619; *American Spacemodeling*, Jan. 1986, Pursley, dimensioned drawing, B&W photo; *American Spacemodeling*, Aug. 1985, Pursley, B&W photos; *National Geographic*, Feb. 1976, ASTP color photo; *Illus. Encyc. of Space Tech.*, Gatland, color photo, color drawing; *The Soviet Manned Space Program*, Clark, color photos; *The Rocket*, Baker, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo

Space Shuttle: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Sparrow-HV Arcas: *Rockets of the World*, Alway, dimensioned, color keyed drawing

Sparta-Wresat: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

Sputnik (A / SL-1, SL-2): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Model Rocketry*, July 1970, Stine, dimensioned drawing; *Cambridge Encyclopedia of Space*, Rycroft, partially dimensioned drawing; *Space Age*, William J. Walter, color photo (Sputnik 2); *Illus. Encyc. of Space Tech.*, Gatland, color drawing

SS-9: *Cambridge Encyclopedia of Space*, Rycroft, B&W photo

Super Loki Dart: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NARTS data pack, dimensioned drawings, B&W photos, color description

Taurus-Tomahawk: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

Terrapin: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Sounding Rockets*, Newell, partially dimensioned drawing, B&W photo

Terrier-Sandhawk: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo

Thor-Able: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *National Geographic*, Feb. 1959, Aug., 1960, color photos; *Space Frontiers*, Vol. 3 no. 4, partially dimensioned drawings, B&W photo, color description; *Apollo Expeditions to the Moon*, Cortright, color photo ; *McGraw-Hill Encyc. of Space*, B&W photo

Thor-Able Star: *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Thor-Agena A: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Tiny Tim: *Cambridge Encyclopedia of Space*, Rycroft, B&W photo

Titan I missile: *National Geographic*, Oct. 1959, May 1961, color photo; *McGraw-Hill Encyc. of Space*, color photos; *The X-Planes*, Miller, partially dimensioned drawing, (with Dyna-Soar); *Cambridge Encyclopedia of Space*, Rycroft, B&W photo

Titan II missile: *National Geographic*, Sept. 1965, color silo photo; *The History of Rocket Technology*, Emme, B&W photo

Titan IIIB: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Titan IIIC: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photo 74-HC-243 (ATS-6); *National Geographic*, Sept. 1965, color photo; *Illus. Encyc. of Space Tech.*, Gatland, B&W photo, color drawing; *McGraw-Hill Encyc. of Space*, color photos; *The Rocket*, Baker, B&W photo

Titan III D: *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Titan III E: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photo 75-HC-467 (Viking 1); Illus. *Encyc. of Space Tech.*, *Gatland*, color drawing; The *Rocket*, *Baker*, color photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo

Titan 34D: *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Titan IV: *Rockets of the World*, Alway, dimensioned, color keyed drawing; *Space Frontiers*, Vol. 2 No. 3, partially dimensioned drawing

Tomahawk cruise missile: *Model Rocketeer*, Sept. 1981, partially dimensioned drawing, B&W photo, color description

Tomahawk sounding rocket: see D-Region, IQSY

Topaze: *Journal of the British Interplanetary Society*, Vol. 40 (1987), pp. 51-66, Gire and Schibler, dimensioned drawing

Trailblazer I: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA TN D-2270, TN D-2189, dimensioned drawing, B&W photo; NASA photo 68-HC-063

Trailblazer II: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photos 68-HC-064, 68-HC-065, 72-HC-722; *Model Rocketeer*, Nov. 1980, dimensioned drawing, B&W photos, color description

Tsyklon (F-2 / SL-14): *Rockets of the World*, Alway, dimensioned, color keyed drawing; *Aviation Week & Space Tech.*, Jul. 25 and Aug. 1, 1988, undimensioned drawing, color photos; *Illus. Encyc. of Space Tech.*, Gatland, color drawing

V-2 (A-4): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, B&W phot; *Model Rocketeer*, June 1976, dimensioned drawing, B&W photos; *National Geographic*, Sept. 1946, B&W photos; *National Geographic*, Oct. 1950, color photos; *Sounding Rockets*, Newell, B&W photo; *Illus. Encyc. of Space Tech.*, Gatland, color photo; *The History of Rocket Technology*, Emme, partially dimensioned drawing, B&W photo; *Rocket Power and Space Flight*, Stine, B&W photos; *Rockets, Missiles, and Space Travel*, Ley, B&W photos; *Reminiscences of 30 Years of Space Research*, Friedman, color photos; *Blueprint for Space*, Ordway and Liebermann, B&W photo; *Space Age*, William J. Walter, B&W photo; *Blueprint for Space*, Ordway and Liebermann, color photo, Blossom

V-2-A (Soviet): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Illus. Encyc. of Space Tech.*, Gatland, color photo; *McGraw-Hill Encyc. of Space*, color photo; *The Rocket*, Baker, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, color & B&W photo

V-3-A (Soviet Vertikal 4): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, B&W photo

V-5-V (Soviet): *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, B&W photo

V-11-A (Soviet research Scud): *Rockets of the World*, Alway, dimensioned drawing

Vanguard: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; NASA photos 68-HC-248, 68-HC-249 color photos of TV-4, TV-5; *Space Frontiers*, Vol. 2 no. 5 thru Vol.3 no.1, dimensioned drawings, B&W photos, color descriptions; *Illus. Encyc. of Space Tech.*, Gatland, color photo, color drawing; *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Space Age*, William J. Walter, B&W photo

Veronique: *Rockets of the World*, Alway, dimensioned, color keyed drawing; *Sounding Rockets*, Newell, undimensioned drawing, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Journal of the British Interplanetary Society*, Vol. 40 (1987), pp. 51-66,Gire and Schibler, dimensioned drawing

Vesta: *Rockets of the World*, Alway, dimensioned, color keyed drawing; *McGraw-Hill Encyclopedia of Space*, color photo; *Journal of the British Interplanetary Society*, Vol. 40 (1987), pp. 51-66, Gire and Schibler, dimensioned drawing

Viking: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Model Rocketry*, Jan. 1969, Model plan, B&W photo, color description; *Space Frontiers*, Vol. 2 nos. 1 and 2, dimensioned drawings, B&W photos, color descriptions; *The History of Rocket Technology*, Emme, dimensioned drawing, B&W photo; *Rocket Power and Space Flight*, Stine, B&W photos, undimensioned drawings; *Rockets, Missiles, and Space Travel*, Ley, partially dimensioned drawings, B&W photo; *Cambridge Encyclopedia of Space*, Rycroft, B&W photo

Viper: NASA photo 63-Viper3-1, *Model Rocketeer*, August, 1973, dimensioned drawing, B&W photo, color description; NASA TN D-1279, Dimensioned drawing, B&W photo (air-launched).

Voskhod: *The Soviet Manned Space Program*, Clark, B&W photos; *McGraw-Hill Encyc. of Space*, color photo of shroud; *Cambridge Encyclopedia of Space*, Rycroft, B&W photo; *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Vostok: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Model Rocketry*, May 1970, Soviet drawings; *Model Rocketry*, July 1970, Stine, dimensioned drawing, B&W photos; *The Soviet Manned Space Program*, Clark, color photos; *McGraw-Hill Encyc. of Space*, color photos; *Cambridge Encyclopedia of Space*, Rycroft, color photo; *Illus. Encyc. of Space Tech.*, Gatland, color drawing

Wac Corporal: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *Sounding Rockets*, Newell, B&W photo; *The Rocket*, Baker, B&W photos; *Cambridge Encyclopedia of Space*, Rycroft, B&W photo

Wasp NASA photo 68-HC-066,color

Winkler HW-1, 2: *Rockets of the World*, Alway, dimensioned, color keyed drawing; *Cambridge Encyclopedia of Space*, Rycroft, B&W photo

X-17: *Rockets of the World*, Alway, dimensioned, color keyed drawing, B&W photo; *The X-Planes*, Miller, undimensioned drawing, B&W photo, color description; *ARS Journal*, August 1959, dimensioned drawing

Zenit: *Rockets of the World*, Alway, dimensioned, color keyed drawing; *Aviation Week & Space Tech.*, July 3, 1989, color photos

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THE ART OF SCALE MODEL ROCKETRY

Peter Alway

The Art of Scale Model Rocketry is a complete guide for building flying models of research rockets, missiles, and space boosters—from the library to the flying field.

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About the Author:

Peter Alway has been building and flying scale model rockets for 20 years, and flying them in competition since 1987. In 1993, one of his scale models took first place at NARAM, the annual national model rocket competition. He has worked in high-altitude cosmic ray research at the University of Michigan, and in laser fusion research at KMS Fusion in Ann Arbor. He has lectured in physics and astronomy at Eastern Michigan University. He is the author of *Scale Model Rocketry* (now out of print), and *Rockets of the World*, a reference book detailing 133 rockets from 14 countries.

Cover Photo: The author's Saturn I in 1/69 scale (Photo by Daniel Alway)

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