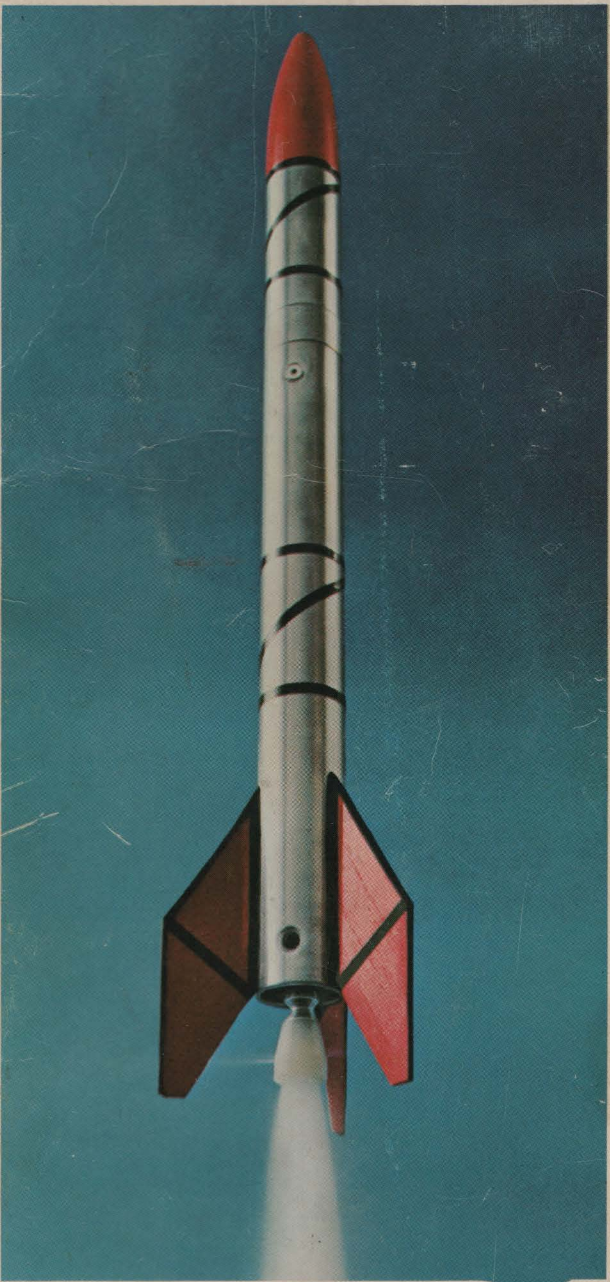
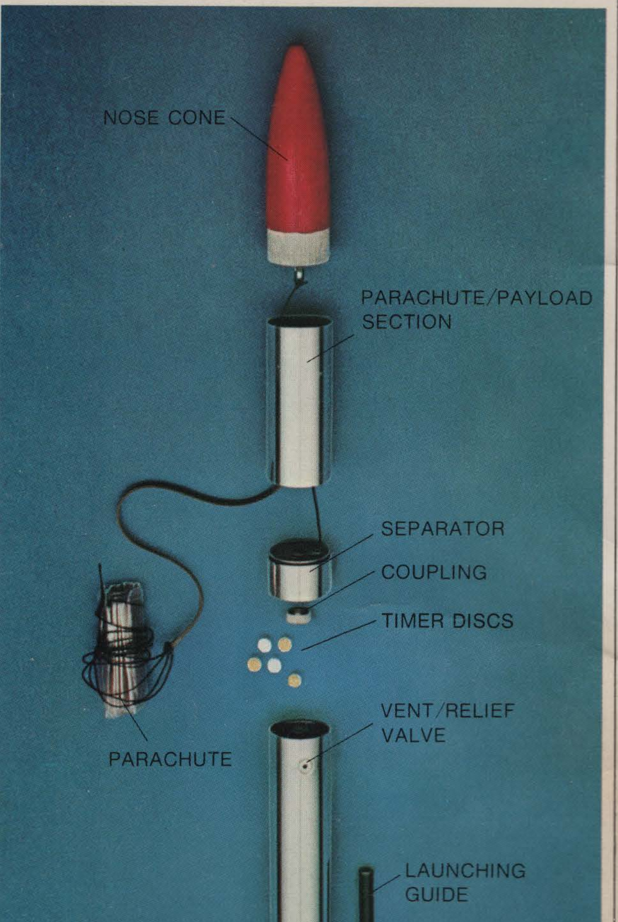
ROCKETS
AND ACCESSORIES



VASHON INDUSTRIES, INCORPORATED



THE VALKYRIE-2 ROCKET

LIQUID PROPELLANT

VALKYRIE

ROCKETS

AEROSPACE - DESIGNED
FLYING MODELS
FROM VASHON INDUSTRIES

Durable polished **aluminum** engines and parts

Real working **valves, separator** and **parachute**

Build your own **scale** models

Blast off to **1,000 feet** or more!

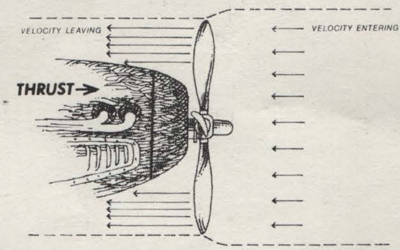
Available to all modelers **everywhere**

U.S. and Foreign Patents Pending

HOW ROCKETS WORK

A little over 10 years ago the first artificial satellite was rocketed into orbit; since then hundreds of satellites and spacecraft have been launched carrying scientific experiments, TV cameras, animals, men. Soon man will land on the moon, and return to earth—all by rocket power.

Why will rockets be used for this travel of the future? There is one very good reason: other forms of propulsion are not capable of performing in space. A propeller won't work because there is no air in space for it to blow. Jet engines won't work because they need to breathe air to combust the fuel. We obviously can't walk, swim, drive or fly because there is nothing to walk, swim, drive or fly *in* (or *on*).



Airplane engines deliver thrust forwards by accelerating the surrounding air backwards.

Propellers and Jets

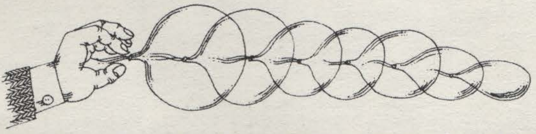
Think a minute about a spinning propeller. It blows a large stream of fast moving air toward the rear of the airplane, causing it to move forward. This illustrates Issac Newton's famous law, "Every action has an equal and opposite reaction" — the action, the force causing the air to rush rearward, has an equal and opposite reaction, an equal force causing the airplane to move forward.

Where does the propeller get the air it thrusts rearward? From the mass of air in front of the airplane, of course. The propeller actually accelerates the air so that the velocity of air leaving the propeller blade is greater than the velocity of the unaffected air in front of the propeller.

A jet engine works in a similar manner. It compresses, heats and exhausts a high velocity jet of air which the engine receives through its intake. The increase in velocity of the airstream from intake to exhaust caused by the jet engine results in a reaction thrust that drives the plane forward.

The reaction thrust generated by propellers and jet engines results from an increase in momentum that the propeller or jet engine imparts to the air stream. Its momentum is defined as the product of the mass of the air stream times the velocity of the air. Its change of momentum is equal to the thrust exerted.

In other words, forward thrust is dependent upon how much the propeller or jet engine accelerates the passing air. However, as the airplane flies faster, the air meeting the propeller or entering the jet engine will eventually flow nearly as fast as the air leaving it; consequently, the change in air velocity — and the thrust—becomes smaller and smaller until the plane will fly no faster. Because thrust goes to zero as the aircraft speed approaches the velocity of the exhaust air, the plane can fly no faster than its own engine exhaust velocity. This is a fundamental way in which rocket engines differ; this phenomenon is *not* true with a rocket engine.



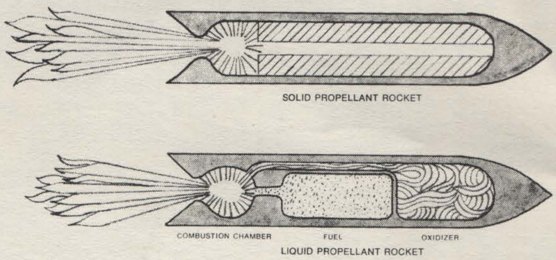
A balloon illustrates the rocket principle by jetting out a stream of air which it has carried along inside as "fuel."

ROCKET ENGINES

A rocket engine is also a reaction engine, but it exhausts a gas which it generates *right in the rocket engine from its own propellent.* This gas is accelerated in a high velocity jet stream of exhaust and the resulting reaction is forward thrust. In other words, a mass of gas is generated within the rocket motor itself and accelerated out of the motor. This results in a large change in velocity of the gas and consequently its momentum is increased. The increase in momentum is equal to the thrust exerted by the rocket. The rocket does not receive air from the front as propellers and jets do, but carries everything it needs along with it. This is why it can function in either space or atmosphere. This is also why the rocket can travel much faster than its own exhaust gases. Since all of the gases generated come from inside and leave with a high velocity relative to the rocket, the thrust of the rocket is independent of its speed.

TYPES OF ROCKETS

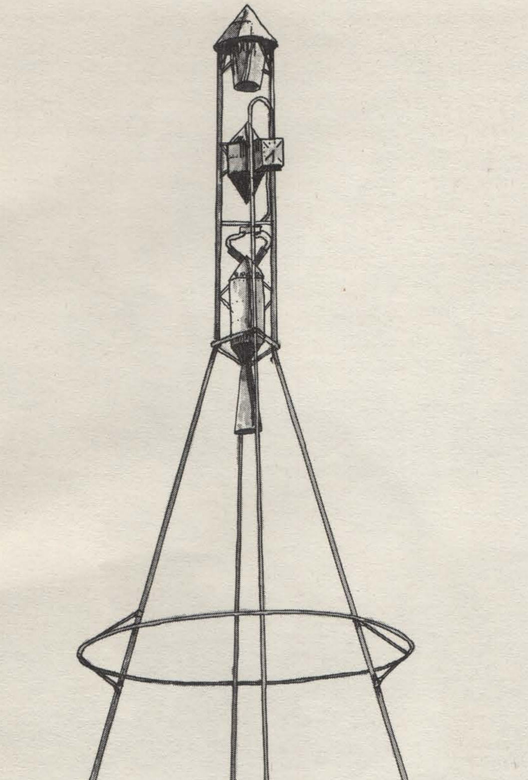
The earliest rockets used solid propellants—gun-powder or similar combustible solids. Chinese fireworks rockets, most small military rockets, and some large modern rockets also use solid propellants. Goddard's first rocket used a liquid propellant as do most of the larger rockets of today, including the Atlas, Titan, Saturn, the Redstone, Jupiter and old German V-2, the Russian Vostok and the new, advanced Centaur and Apollo. Liquid propellants are loaded into large tanks in the rocket. During operation they flow to the engine, where they burn and exhaust out the nozzle as high velocity gas.



Solid propellant rocket fuel is formed into a "grain," which is mounted in the combustion chamber. Liquid propellant rockets carry their fuel in tanks usually formed by the rocket body itself.

Most liquid rocket propellants, like their predecessors the solid propellants, are highly flammable, dangerous chemicals which must be handled carefully by professionals. Unfortunately this has precluded amateurs from experiencing the excitement of their own countdown and the thrill of a successful launch — unless they get it second hand from the TV screen. And few but professionals have had the opportunity to learn first hand the science and workings of this modern technology. Model rocket propellants were considered to be dangerous fireworks in many states . . . *until Vashon Industries developed the Valkyrie!*

The Valkyrie Rocket is similar to the full sized rockets; however, it uses safe propellants. It has been designed and developed by Vashon Industries, Inc. to fill the need for a safe, educational, high performance rocket for modelers and other non-professionals.



Dr. Robert Goddard, father of liquid propellant rocketry in the United States, stands by one of his earliest rockets prior to launch. In spite of many difficulties the rocket finally flew — to an altitude of 90 feet.

THE VALKYRIE ROCKET

The Valkyrie Rocket is actually firing as co-developer Al Forsythe holds firmly against the thrust. Note the exhaust plume and side jets. You can test your Valkyrie the same way — even indoors. Just be ready to hold on!

The Valkyrie Rocket is Safe

The Valkyrie was developed by a group of professional rocket engineers who felt there was a need for a model rocket that was authentic, educational and fun, and yet entirely safe for modelers and other non-professionals. The rocket design they sought would be similar in many respects to the actual liquid propellant rockets used by NASA and the military service and would adequately demonstrate the principle of rocket propulsion in complete safety.

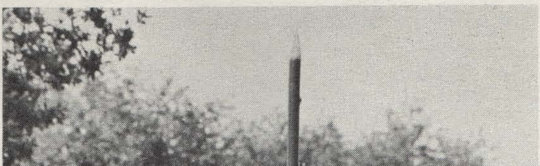
Conventional solid and liquid propellants are too hazardous for model rocket boosters; to achieve complete safety, it was apparent that combustion or chemical processes associated with the rapid release of heat must be avoided. Conventional propellants always produce heat as a result of combustion or decomposition. Consequently, there is always a potential fire or explosion hazard present in their use. (Rocket engineers recognize this danger and avoid, as far as possible, being near loaded rockets when they are stored, tested or used.)

The solution was found in the use of RP-100* propellant. *The RP-100 propellant used in the Valkyrie Rocket does not release heat, is not flammable, and is non-toxic.* The Valkyrie cannot start a fire, nor can it explode. This is why the Valkyrie rocket engine can be held in the hand while "firing," and, if firmly anchored, can even be operated indoors!

The Valkyrie Rocket is Realistic

With such a safe, low energy propellant can realistic model rockets be built? Can high altitude flights be made? To get an idea of the realism of the Valkyrie 2 Rocket, just take another look at the photo on the front cover!

The Valkyrie-2 Rocket is 16 inches long and 1 inch in diameter. At "lift-off" most of its weight is in propellant, just like the full-size



A model U.S. Army missile made from a Valkyrie Kit blasts off, Leaving a billowing trail of exhaust. The V-2 engine delivers over two pounds of thrust, giving the rocket 4 g's acceleration at lift-off and over 10 g's at burn-out.

**Trade name Difluorodichloromethane*

Atlas, Titan or Saturn rockets. At liftoff the Valkyrie Rocket starts off relatively slowly at about 4 "G's" and its acceleration at burn-out is about 10 "G's", just like full sized NASA and military rockets. *The key to the operational realism of the Valkyrie Rocket is its low energy propellant.* If a solid propellant model rocket of the same size were designed to consist predominately of propellant, like its full size counterpart, it would go too high and far too fast to be used by modelers. And such a large concentration of solid propellant would be very dangerous.

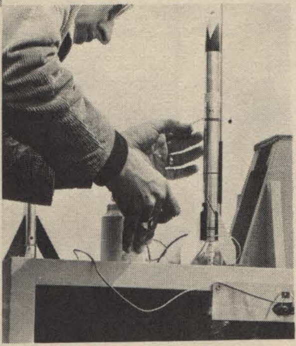
As to performance, the combination of low energy propellant, and the true-to-scale high mass fraction, enables the Valkyrie to reach altitudes of up to 1,000 feet. The Valkyrie Rockets can also be staged to carry larger payloads or to achieve greater altitudes.

Just as it is done at Cape Kennedy, the RP-100 propellant is loaded into a tank, part of the Valkyrie Rocket body, just before launch. Since the fuel is non explosive or flammable, the Valkyrie can safely use aerospace-type high strength metals for its tank just like the full size rockets do. The propellant tank of the Valkyrie rocket has fill and vent valves for loading its propellant, providing added realism and safety.

Other features of the Valkyrie Rocket are its large, true-to-scale rocket engine nozzle, and its payload separator and timer. The large nozzle along with the nozzle plug and "ignitor" wire form an electro-mechanical propellant valve. This reusable valve lets you fire the rocket again and again, either remotely with battery power or manually by pulling a safety pin. The separator and timer deploy the recovery parachute at the proper altitude. The timer works on a pneumatic delay principle, and allows separation of the parachute tube a fixed time after it has sensed motor burn-out.

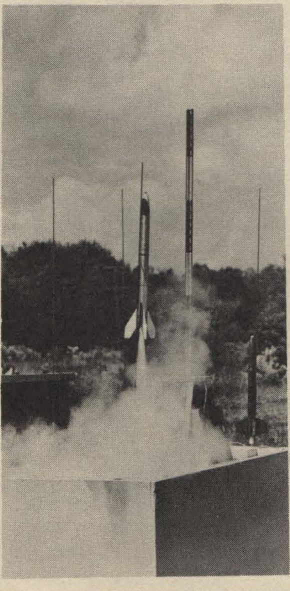
The engineers of Vashon Industries, Inc. now offer you the Valkyrie Rocket—a sophisticated, high performance aerospace product for modelers.

In addition to designing and making fins prelaunch preparations include ground testing of the separator and timer mechanisms for release of the parachute.



When all systems are "go" the Valkyrie is loaded with propellant on the pad through an umbilical fueling hose. The engine is vented during loading from a relief valve at the forward end.

CATALOG NO.3



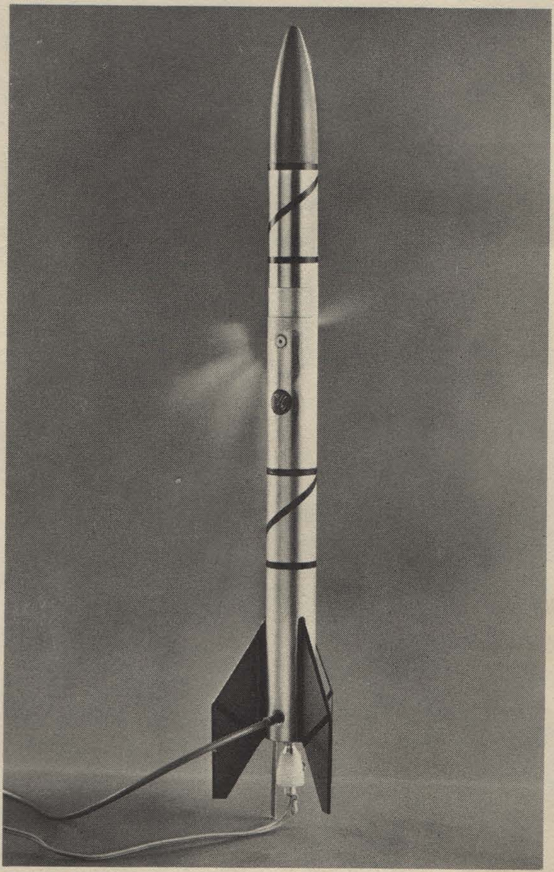
At "t" equals zero the rocket lifts off on a plume of exhaust. About six seconds later the parachute will deploy and bring the entire rocket back for another launch.

VASHON INDUSTRIES, INC.
Box 309, Vashon, Washington 98070

ROCKET KITS

VALKYRIE-2 ROCKET **KIT-801**

The best way to get started in liquid propellant rocketry—the Valkyrie-2 Rocket Kit provides everything you'll need to assemble a flying rocket, including launching pad, propellant loading equipment, and RP-100 liquid rocket propellant. This is the basic, single stage Valkyrie Rocket with maximum altitude capability over 1,000 feet and payload carrying capacity of nearly ¼ pound. Best of all, this same rocket engine can be used in the future as a booster for multistage rockets, or in clusters for big payloads—you can use this versatile multipurpose rocket in many ways, over and over.



Specifications

Maximum Altitude (0 drag)	over 1,000 feet
Thrust	2 pounds
Total Impulse	2.25 pound seconds
Diameter	1.0 inches
Length overall	16 inches
Dry Weight	2 ounces
Propellant Load	4 ounces

KIT-801 **$15.95**

COMPLETE BASIC KIT — All rocket parts, electric firing assembly, launcher, loading equipment, and propellant. Ready to assemble and launch!

KIT-901 **$13.95**

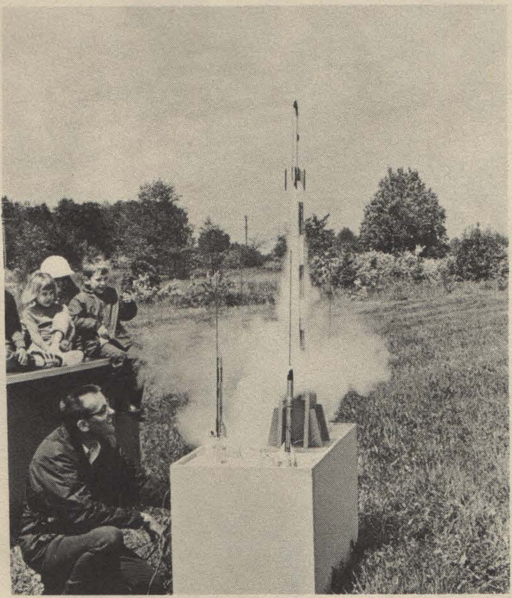
Same as Kit-801, less propellant . . .

available at your local Hobby Shop.

BIG V-2 ENGINE — All polished aluminum. Launch it as a sounding rocket; use it as a booster or a model plane strap-on; even power a model car or rocket sled.

Electrically fired, remotely with a battery.

Features the new, ECHO SATELLITE material for parachutes.



Complete kit includes rocket engine, timer, separator, parachute tube, and parachute, nose cone, fins, loading valve and hose, electric firing assembly, launch stand, one can of propellant, accessories, and instructions. (Battery not included.)

CATALOG NO.

KIT-801 (Mail order only, including propellant) **$15.95**

KIT-901 (Propellant not included) **$13.95**

VALKYRIE-1 ROCKET **KIT-902 $11.95**

An inexpensive way to add to your rocket fleet, here's a complete rocket at a low, low price.

Good for launches to 500 feet!

Features the all aluminum V-1 engine and manual firing.

This kit can also be made into a strap-on or a second stage for other Valkyrie rockets and includes a V-1 engine, separator, timer, nose cone, fins, parachute, parachute tube, launcher and propellant loading equipment.

CATALOG NO. KIT-902 (Propellant not included)

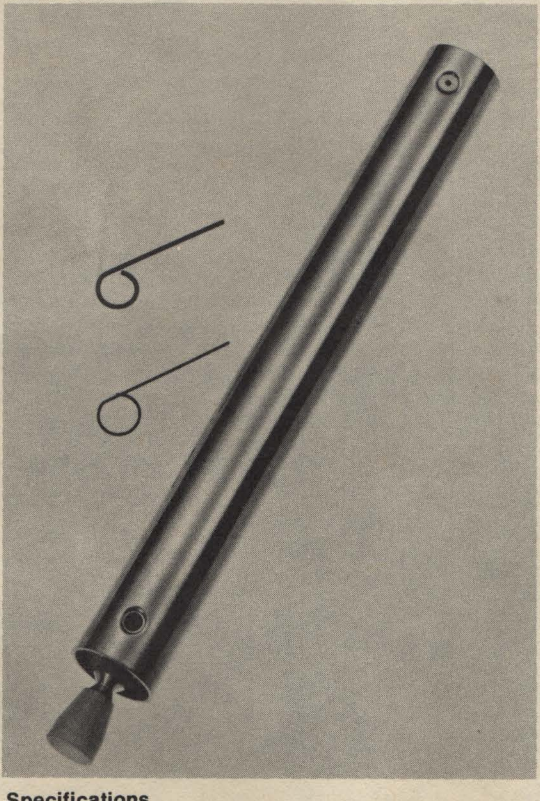
at your local Hobby Shop. $11.95

A VALKYRIE-1 ROCKET

ROCKET ENGINES

The Valkyrie rocket engines listed below are identical to those included in Valkyrie kits. They use RP-100 propellant and can be electrically or manually fired with the appropriate firing assembly. The engines are interchangeable with all Valkyrie accessories. Make a fleet of rockets with just one set of launching and recovery equipment!

V-2 ENGINE — ENG-801

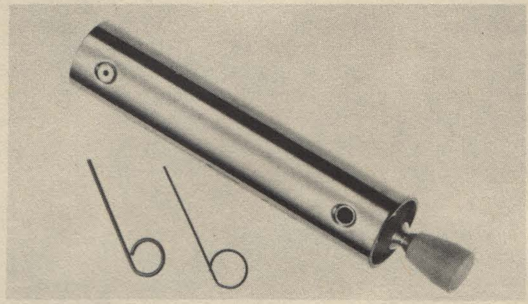


Specifications

Thrust	2 pounds
Total Impulse	2.25 pound seconds
Diameter	1.0 inches
Dry Weight	1.14 ounces
Length	9.4 inches
Propellant Capacity	4 ounces

Make your Valkyrie kit a big performer with this V-2 engine. Can also be used as strap-ons for more ambitious rocket designs. (A separator and a firing assembly are required for use.) Engine comes with nozzle extension, vent pin, and safety pin.
CATALOG NO. ENG-801 **$5.75**

V-1 ENGINE **ENG-802**

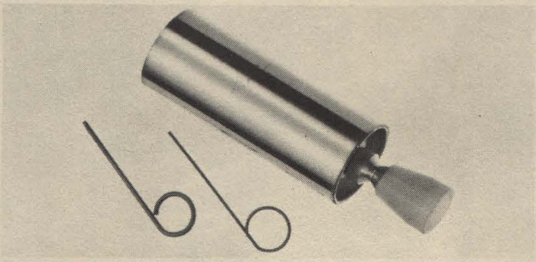


Specifications

Thrust ....2 pounds
Total Impulse ....1.125 pound seconds
Diameter ....1 inch
Length ....5.4 inches
Dry Weight .... .765 ounces
Propellant Capacity ....2 ounces

A shorter version of the V-2 engine, the V-1 has the same thrust, but half the total impulse. Twice as many shots per fuel can! Also good for strap-on boosters, second stage rockets, model airplane jatos, and model cars. Convenient size, but plenty of push. (A separator and a firing assembly are required for use.) Engine comes with nozzle extension, vent pin, and safety pin.
CATALOG NO. ENG-802 **$4.95**

V-½ ENGINE **ENG-803**



Specifications

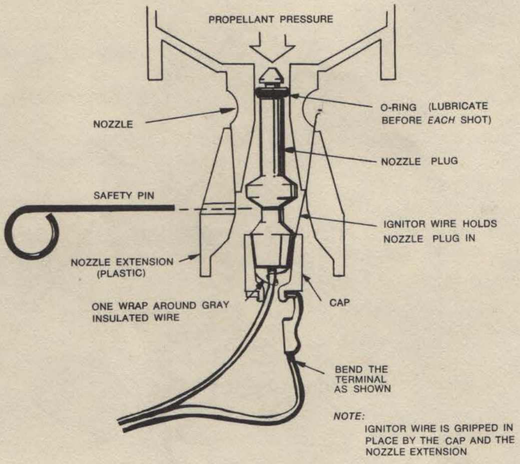
Thrust ....2 pounds
Total Impulse .... .56 pound seconds
Diameter ....1.0 inches
Length ....3.4 inches
Dry Weight .... .555 ounces
Propellant Capacity ....1 ounce

Muscle for mini-missiles—only 3.0 inch long engine body, but still 2 pounds thrust! Just right for a jato or small second stage. Use with a separator and make a drop-off jato — spent rocket drops off after boosting your plane into flight. Load and fire just like the V-1 or V-2. (A separator and a firing assembly are needed to fire it.) Comes with nozzle extension, vent pin, and safety pin.
CATALOG NO. ENG-803 **$4.25**

ELECTRICAL FIRING

Any Valkyrie rocket may be adapted to electrical firing merely by obtaining the electrical firing assembly (CATALOG NO. FIR-801).

The electrical firing assembly consists of a plug which fits in the rocket nozzle, and electrical connections and wiring which allow the rocket to be electrically initiated. The plug is held in against propellant pressure by a length of ignitor wire. This assembly also permits manual firing if desired.



When electrical current is applied, the ignitor wire melts, allowing the nozzle plug to be blown out. The ignitor wire is made of a very special material; it is not nichrome or any other common metal. No other wire will substitute.

To assemble:

1. Oil the O-ring before *every* shot.
2. Take off the plastic nozzle extension and pass it over the nozzle plug, big end first, and up onto the wire. Bend the terminal back as shown to allow it to slide back onto the wire.
3. Wrap the ignitor wire around the gray lead wire, and press the cap firmly onto the nozzle plug to grip the ignitor wire to the plug. Be careful not to kink or bend the wire. It is fragile.
4. Push the plug into the nozzle. *It should slip in easily;* oil again if it doesn't. The ignitor wire should be outside the nozzle.
5. Orient the nozzle extension so the ignitor wire will not be damaged when you insert the safety pin. Press the nozzle extension firmly onto the nozzle to grip the ignitor wire to the rocket.
6. Insert the safety pin before pressurizing or filling the rocket.

THE SEPARATOR

The separator grips the parachute tube by means of two spring-like fingers which press against the inside of the tube when the separator is pressurized.

SEPARATOR AND TIMER TEST

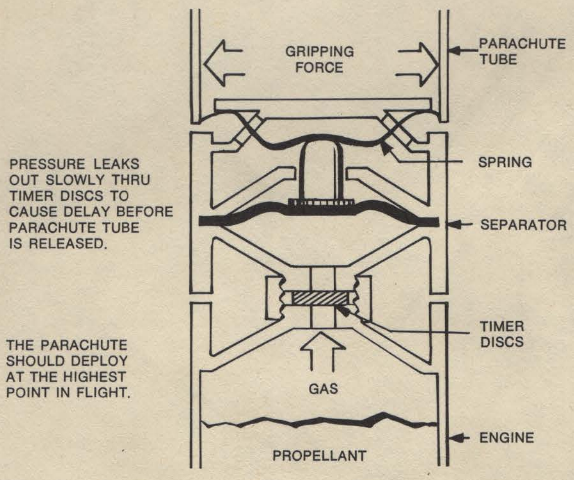
Before setting up to launch, it is an excellent idea to "ground test" the separator and timer discs. To do this, completely assemble the rocket. Install a nozzle plug and a safety pin in the nozzle, then hold the parachute tube on and pressurize the rocket with a very short (½ sec.) burst of propellant. The parachute tube should lock on.

Now firmly hold the rocket horizontally about 2 inches above a surface and quickly vent off all the pressure by pulling the safety pin. It should take about 5 seconds after the pressure is gone for the parachute tube to release and drop off. If it takes longer, remove a disc or change to faster ones as required.

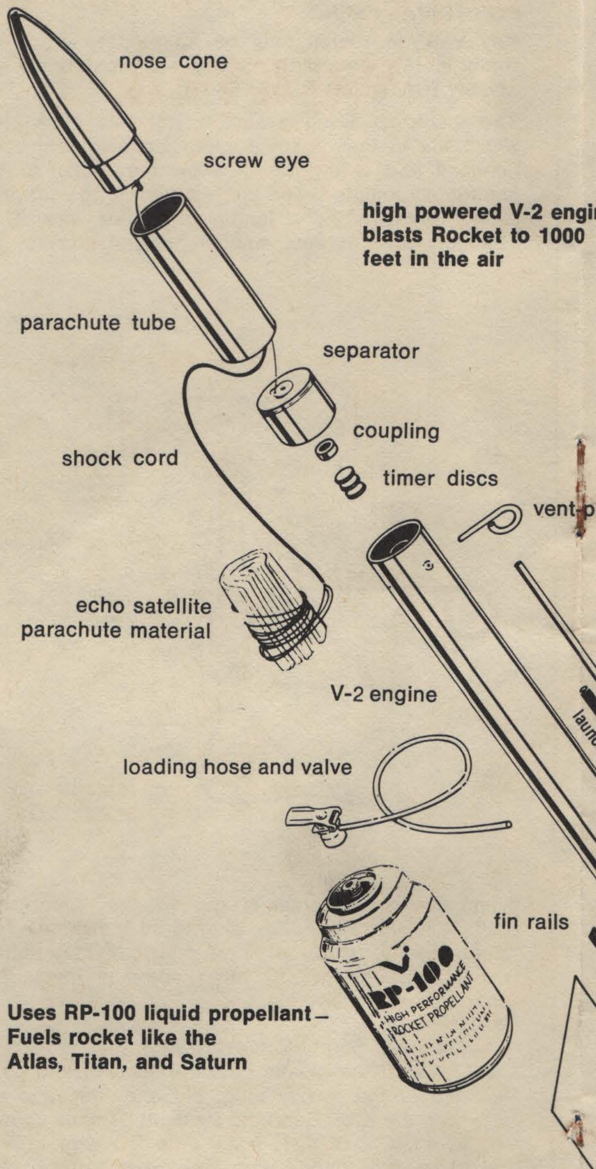
If it drops off too quickly, add another yellow disc and test it again.

NOTE: Timer discs do *not* have to be replaced every time you launch. Once you have the right combination, leave them in.

SEPARATOR **SEP-801**



CATALOG NO. **SEP-801** **$3.50**



Ask your local Dealer for "Kit-901"

ONLY $13.95

Includes everything you need to launch your rocket, except propellant

VALKYRIE·2

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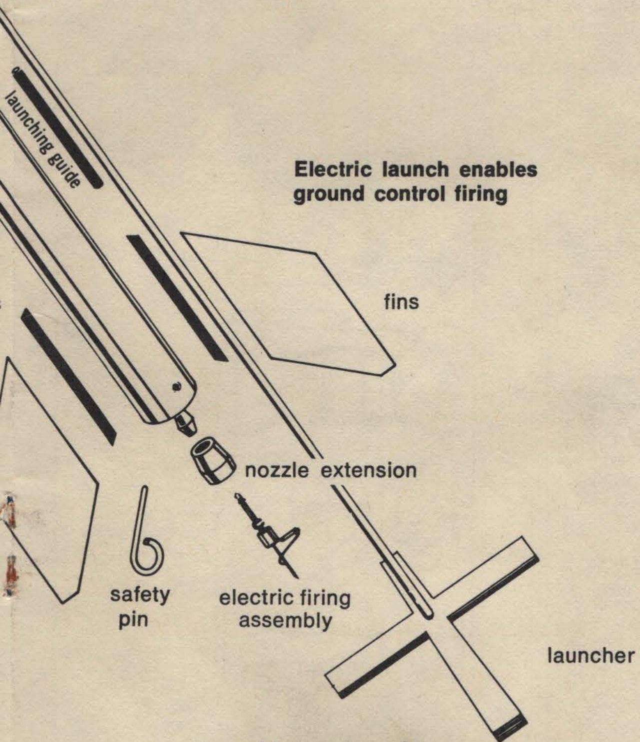
00

Polished high strength aluminum construction.

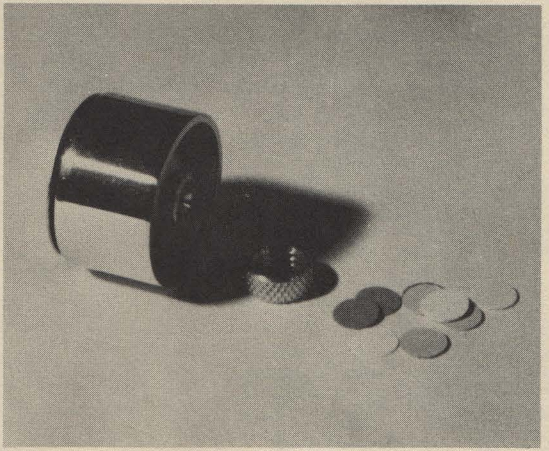
t-pin

Electric launch enables ground control firing



Launching pad provides accurate vertical flight.

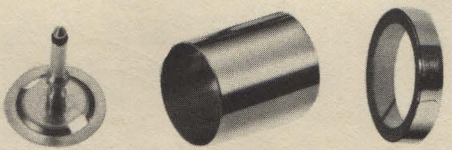
PARACHUTE SEPARATOR SEP-801



The separator mounts on top of any Valkyrie Rocket engine, and releases the parachute section by timing from engine burnout, or releases jato engines at burn-out. Many other uses. It incorporates an adjustable timer which can delay release from 0 to 15 seconds after the rocket burns out. Change the time yourself to suit your needs. It fits any of the Valkyrie rocket engines. When connected to a loaded engine, the separator will grip and hold a parachute or payload section tube firmly during flight but release it at the proper time. Remember to order a spare coupling too, for attaching to the engine. Includes separator, coupler and assorted timing discs.

CATALOG NO. **SEP-801** **$3.50**

STAGING ADAPTER KIT **available soon**



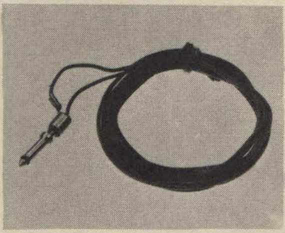
These parts can be used to convert your parachute separator into a staging separator. Mounted on top of any Valkyrie engine it automatically fires a second stage engine at first stage burn-out. It can also incorporate a time delay if you want. Add real sophistication to your rocket!

Kit includes an interstage adapter section, adapter plug, and special aluminum tape for attaching the adapter section to the second stage engine.

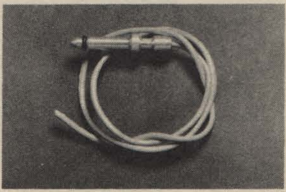
Adapter Kit, CATALOG NO. ADK-801

Staging separator complete with separator, adapter section, adapter plug and tape.

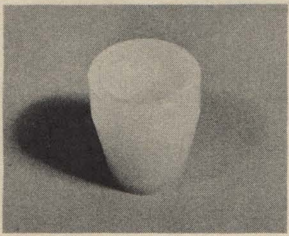
CATALOG NO. SEP-802



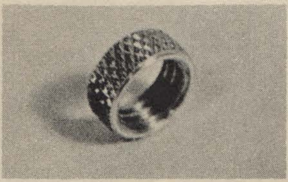
FIRING ASSEMBLY
Nozzle plug, nozzle plug cap, remote firing wire, for electrical firing.
CAT. NO. FIR-801 **$1.75**



MANUAL FIRING ASSEMBLY
For manual firing
CAT. NO. FIR-802 **75¢**

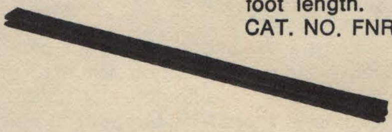


NOZZLE EXTENSION
Nylon nozzle extension — fits any Valkyrie engine.
CAT. NO. NOZ-801 **25¢**

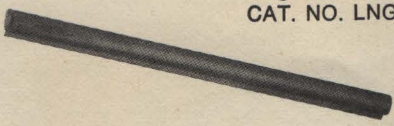


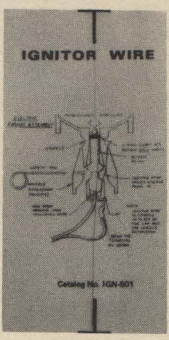
COUPLING
Connects separator to rocket engines.
CAT. NO. CPL-801 **15¢**

FIN RAIL
For attaching fins. One foot length.
CAT. NO. FNR-801 **25¢**

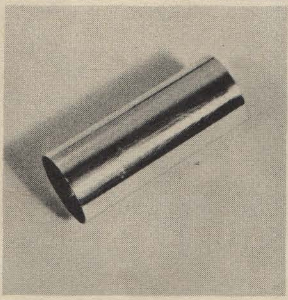


LAUNCHING GUIDE
Fits easily over launcher rod (1/8" dia.). 4 inch length.
CAT. NO. LNG-801 **15¢**

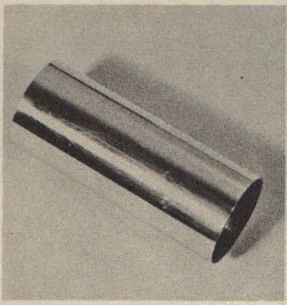




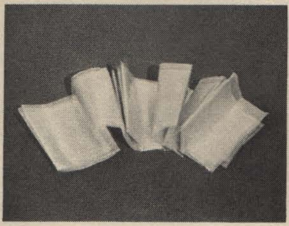
IGNITOR WIRE
Wire that retains nozzle plug, releases on firing signal. Get some spares! Comes in 6 inch lengths.
CAT. NO. IGN-801 **35¢**



PARACHUTE TUBE
3.0 inch long thin wall aluminum tube for stowing parachute or payload. Fits separator and nose cone.
CAT. NO. PRT-801 **55¢**

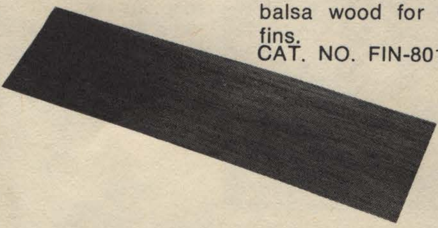


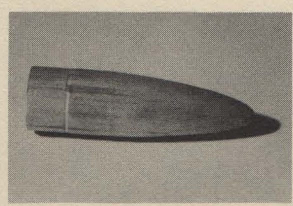
PARACHUTE TUBE
Same as above, except 4.5 inches long. More space for payloads.
CAT. NO. PRT-802 **75¢**



PARACHUTE
One foot square of shiny aluminized Mylar — the ULTIMATE parachute material. Extremely thin (.00025") yet tough and strong. ECHO satellites were made of this.
CAT. NO. PAR-801 **35¢**

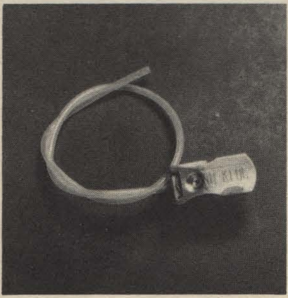
FIN STOCK
3"x12" sheet of 1/16" balsa wood for making fins.
CAT. NO. FIN-801 **15¢**





NOSE CONE
Shaped balsa nose cone, ready for sanding and finishing.

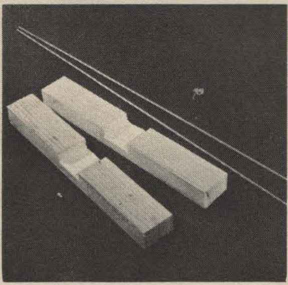
CAT. NO. NSC-801 **45¢**



LOADING VALVE ASSEMBLY
Includes loading valve and hose.
CAT. NO. LDV-901 **50¢**

RP-100 PROPELLANT
15 oz. can of high performance RP-100 propellant. Safe, odorless, nonflammable, non-explosive.

CAT. NO. PRP-801 **$2.00**



LAUNCHER
Handy two-piece launcher rod and base.

CAT. NO. LCH-801 **85¢**

RECOVERY KIT
The complete parachute recovery system, including nose cone, parachute tube, parachute, shock cord, and screw eye.
CAT. NO. RCV-801 **$1.50**

WHAT TO ORDER

A. To *manually* fire an engine (for cars, sleds, etc.) you'll need:

An Engine	ENG-801, -802, or -803
A Separator	SEP-801
A Firing Assembly	FIR-802
A Loading Valve	LDV-901
Propellant	PRP-801

B. To *electrically* fire an engine you'll need all the parts listed in A, above, plus:

Ignitor Wire	IGN-801
Firing Assembly	FIR-801 instead of FIR-802

C. If you have loading and launching equipment available, and just want a rocket, then order:

An Engine	ENG-801 or -802
A Separator	SEP-801
A Recovery Kit	RCV-801
A Firing Assembly	FIR-802
Launching Guide	LNG-801
Fins	FIN-801
Fin Rail	FNR-801
Cement	CEM-801

For electrical firing, order in addition:

Firing Assembly	FIR-801
Ignitor Wire	IGN-801

D. To launch the rocket listed in C you'll also need —

A Launcher	LCH-801
A Loading Valve	LDV-901
Propellant	PRP-801

E. Everything listed in C and D above that you'll need to electrically launch a rocket is included in KIT-801. KIT-801 is the basic starter kit on which you can add additional engines, strap-ons, multi-stage, and so on at modest additional cost later on.

In other words, to electrically launch a rocket from scratch, order:

A Valkyrie-2 Kit	KIT-801

VALKYRIE SAFETY PRECAUTIONS

1. Fly your rocket where it won't endanger aircraft.
2. Check out your recovery device before use.
3. Load your rocket only with RP-100 propellant.
4. Never shoot your rocket at anybody or anything.
5. Never carry or store a loaded rocket.
6. Always use a launcher.
7. Always launch your rocket vertically.
8. Load and use your rocket under adult supervision.

NOTE: The user must exercise care in the use of Vashon Industries products and strictly comply with the precautions stated above and instructions provided. The user assumes all risk of use or handling. Vashon Industries does not guarantee merchantability, makes no warranty of any kind, express or implied, and assumes no liability beyond the replacement of parts which, in the judgment of Vashon Industries, are defective.

ORDERING INFORMATION

Handy order blanks and a pre-addressed envelope are provided for your convenience. Just fill in your name and address, and the number of rockets, kits, and parts you desire, along with catalog numbers and prices. Include a check or money order for the full amount and mail. (Washington residents remember to add 4.5% of sales tax.) Do not mail cash. *All shipments are mailed postpaid.*

Prices are subject to change without notice

SEE YOUR LOCAL DEALER,
or write to:

VASHON INDUSTRIES, INC.
Box 309, Vashon, Washington 98070

ROCKET PERFORMANCE

Two characteristics are of fundamental importance in rocket performance: (1) specific impulse, (2) vehicle mass ratio (ratio of total loaded weight to empty or "burn-out" weight). The combination of these two characteristics determine how high and how fast a rocket will fly (neglecting aerodynamic drag and gravity effects). Professional rocket designers try to maximize the values of these two parameters. *Specific impulse* is largely a function of how "energetic" the rocket propellant is; the more energetic, the higher the specific impulse. But, the more energetic a rocket propellant is, the more hazardous it is to use. This is why Vashon Industries' designers used a *low energy* or low specific impulse propellant to make sure your Valkyrie is a *completely safe* model rocket.

To compensate for the low energy propellant, they gave the Valkyrie a *high mass ratio* so that it could reach high altitudes and perform just like the big ones.

Blast-off! The boy with the delighted grin has just pushed the firing button on a remote electrical firing console. This rocket is being launched from a rail made from three pieces of fin rail (FNR-801) *cemented to a rod. Another piece glued to the rocket interlocks and slips easily in this rail, making a perfect advanced launcher.*

By scaling a big rocket down to model rocket size, and using a low energy propellant, Vashon engineers achieved realistic performance as well as appearance. For example:

- Full size liquid rockets typically weigh 3 to 10 times more when loaded with propellant than when empty—The loaded weight of the Valkyrie Rocket is *also* predominantly made up of propellant weight.
- The ratio of total loaded weight to burnout weight (mass ratio) is very important in full size rockets—just as it is with the Valkyrie Rocket.

When the total vehicle weight divided by the empty or burnout weight has a value of 2.718, the vehicle is theoretically capable of traveling as fast as its own exhaust gases (under drag free zero "g" conditions—such as outer space). If the ratio of total vehicle weight to burnout weight is greater than 2.718, then vehicle velocity can be greater than exhaust gas velocity:

$$V_b = C \log_e \frac{M_o}{M_f} \text{ for horizontal flight}$$

$$V_b = C \log_e \frac{M_o}{M_f} - gt_b \text{ for vertical flight}$$

where V_b = rocket velocity, ft/sec

C = exhaust velocity, ft/sec

M_o = loaded rocket weight, pounds

M_f = empty rocket weight, pounds

g = acceleration due to gravity, (32.2 ft/second squared)

t_b = engine burn time, seconds

How is exhaust velocity determined? Exhaust velocity is equal to specific impulse (I_{sp}) times the acceleration due to gravity ("g"), or:

$$C = 32.2 \times I_{sp}, \text{ in ft/sec.}$$

The specific impulse of a propellant is a very commonly used name for the value of the thrust which can be generated by a rocket propellant divided by the number of pounds per second of propellant consumed in generating the thrust. The specific impulse of rocket propellants used by NASA and the military ranges from 200 to over 300 lbs. of thrust per pound per second of propellant flow rate. For example, if a rocket propellant can deliver a specific impulse of 250 seconds, and if 25,000 pounds of thrust is desired, then 25,000 ÷ 250 or 100 pounds of propellant must be consumed in the rocket motor each second. The exhaust velocity (the speed at which the gases leave the rocket motor) is about 8050 ft/sec. If the rocket motor were used in a space vehicle which contained enough fuel to give it a mass ratio of 2.718, the vehicle would achieve a speed of 8050 feet per second or 5,500 miles per hour in space.

Of course, this velocity is far too high for model rocketry. Although the Valkyrie can achieve mass ratios higher than 2.718, its maximum velocity is considerably less due to the lower specific impulse of its propellant.

The RP-100 Propellant

RP-100 is a liquified gas. This means that the propellant is a liquid when it is stored under its own vapor pressure. When pressure is released, however, a portion of the liquid changes into a gas (or vaporizes) and the mixture becomes very cold. As it warms up from heat flowing into it from its surroundings, the remaining liquid vaporizes. When used with the Valkyrie Rocket, the liquified gas is loaded into the rocket tank. From there it is forced through the nozzle by its own vapor pressure. In the nozzle some of the propellant vaporizes due to the lower pressure in the nozzle throat. The gases formed expand and help drive the mixture of gas and liquid out of the nozzle at high velocity. This action generates the thrust that propels the Valkyrie Rocket. Once outside the nozzle, the surrounding air rapidly vaporizes the remainder of the liquid propellant.

The specific impulse of RP-100 is normally about 9.0 seconds. Because the specific impulse will vary up and down with temperature, store your RP-100 at room temperature before use. To obtain maximum effect from the Valkyrie, place your hands on the rocket body after loading to warm it slightly before launching.

Calculating Your Rocket's Performance

Your Valkyrie-2 Rocket is designed to have a maximum mass ratio of 2.81. This corresponds to a .25 pound propellant weight and a .138 pound burnout weight. The Valkyrie Rocket can carry less propellant if you wish, and various payload weights. You will need a scale to weigh your rocket before and after loading to accurately calculate how high and how fast it will go. This is because changing propellant weight or payload weight will change the mass ratio of the rocket. The following equations and tables can be used to calculate how high and how fast your Valkyrie-2 will go when loaded with propellant in accordance with directions and for various "extra" payload weights.

The path that a rocket follows is called a *trajectory*. The equations which follow are simplified drag free trajectory equations. A vertical flight of the Valkyrie Rocket is made up basically of three phases:

1. *Powered flight*—engine thrusting
2. *Coast*—engine out and coasting to apogee or maximum altitude
3. *Recovery*—parachute deployed and settling back to earth

The first two phases are of interest here. The first phase, or powered flight is the most complicated. It is necessary to know how high the rocket is at engine burnout, and how fast the rocket is going so that we can calculate what will happen during the coast phase.

Altitude at Burnout

For vertical, drag-free flight, the altitude at burnout is given by:

$$H_b = \frac{I_{sp}^2 \; g W_o}{F R} \left[R - 1 - \log_e R - \frac{W_o}{2FR}(R-1)^2 \right]$$

In this equation:

H_b = Altitude at burnout, in feet

I_{sp} = Specific impulse (approximately 9.0 seconds for RP-100 propellant)

g = Acceleration due to gravity, or 32.2 ft/sec^2

W_o = Total weight of the loaded rocket, in pounds

F = Thrust of the rocket, in pounds

$R =$ Mass ratio, or total weight of the loaded rocket divided by the weight at burnout (empty weight)

$\log_e R =$ Natural logarithm of R, to the base e. You can determine this from the table on page 15.

Velocity at Burnout

For vertical, drag-free flight, the velocity at burnout is given by:

$$V_b = I_{sp}\, g \left[\log_e R \;-\; \frac{W_o}{F} \left(\frac{R-1}{R} \right) \right]$$

where

$V_b =$ Velocity at burnout, in feet per second, and the remaining symbols are the same as for calculating altitude at burnout.

Having determined the altitude and velocity at burnout, the next step is to calculate how much higher the rocket will coast. This is given simply by $\frac{V_b^2}{2g}$, for drag-free flight.

Maximum Altitude

The maximum altitude for vertical, drag-free flight is:

$$H_{max} = H_b + \frac{V_b^2}{2g}$$

where

$H_{max} =$ Maximum altitude, in feet

$H_b =$ Altitude at burnout, in feet

$V_b =$ Velocity at burnout, in feet per sec.

$g = 32.2$ ft/sec^2

As we have pointed out, these equations do not take into account the effect of aerodynamic drag. Air drag will tend to slow the rocket and keep it from going as high as these equations would indicate. The effect of drag is more difficult to calculate, and depends on the shape and size of the nose cone and fins, as well as many other factors. It is normally done with a computer, or by step-by-step calculations.

It's easier to estimate the actual maximum altitude by assuming that the altitude at burnout is about equal to the altitude lost due to drag.

Maximum Actual Altitude -- Approximate

The altitude your rocket will attain can be estimated from

$$H_{max} = \frac{V_b^2}{2g}$$

where

V_b = Velocity at burnout in feet per second, as calculated above.

$g = 32.2\ ft/sec^2$

This assumes that the altitude at burnout is offset by the altitude lost due to air drag.

These equations are more complicated than the impulse equations that can be used accurately with solid propellant model rockets, where weight of propellant is a small fraction of total weight. But for Valkyrie Rockets which are largely propellant at lift-off, the impulse equations cannot be accurately used. It is necessary to take into account the change in weight during powered flight, just as professional rocket engineers do.

VALKYRIE-2 PERFORMANCE WITH VARIOUS PAYLOADS

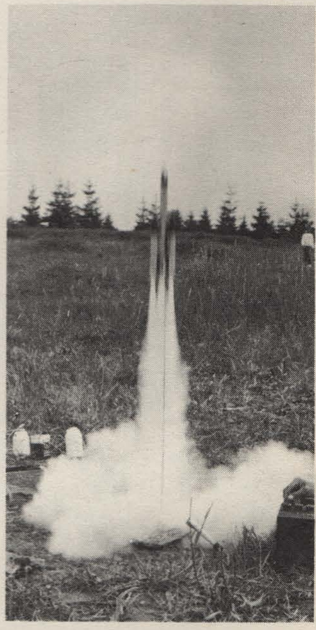
	DRAG FREE VERTICAL TRAJECTORY						
Payload Weight (ounces)	0	.5	1	1.5	2	2.5	3
Weight at Lift Off (lbs)	.338	.419	.450	.482	.513	.544	.576
Weight at Burnout (lbs)	.138	.169	.200	.232	.263	.294	.326
Mass ratio	2.81	2.48	2.25	2.08	1.95	1.85	1.77
Altitude at Burnout (ft)	120	106	95	84	77	70	62
Motor Burn Time (sec)	1.125	1.125	1.125	1.125	1.125	1.125	1.125
Velocity at Burnout (ft/sec)	273	227	199	176	157	142	129
Vertical Coast Distance (ft)	1,157	800	615	481	383	313	258
Acceleration at Lift Off (g)	4.0	3.8	3.4	3.15	2.9	2.7	2.5
Acceleration at Burnout (g)	13.5	10.8	9.0	7.63	6.6	5.8	5.1
Time to max. Altitude (sec)	9.3	8.2	7.3	6.6	6.0	5.5	5.1
Maximum Total Altitude(ft)	1,277	906	710	565	460	383	320

Note: One U.S. cent weighs approximately .11 ounces

NATURAL LOGARITHM TABLE

R	$\log_e R$	R	$\log_e R$	R	$\log_e R$	R	$\log_e R$
1.01	.010	1.51	.412	2.01	.698	2.51	.920
1.02	.020	1.52	.419	2.02	.703	2.52	.924
1.03	.030	1.53	.425	2.03	.708	2.53	.928
1.04	.039	1.54	.432	2.04	.713	2.54	.932
1.05	.049	1.55	.438	2.05	.718	2.55	.936
1.06	.058	1.56	.445	2.06	.723	2.56	.940
1.07	.068	1.57	.451	2.07	.728	2.57	.944
1.08	.077	1.58	.457	2.08	.732	2.58	.948
1.09	.086	1.59	.464	2.09	.737	2.59	.952
1.10	.095	1.60	.470	2.10	.742	2.60	.956
1.11	.104	1.61	.476	2.11	.747	2.61	.959
1.12	.113	1.62	.482	2.12	.751	2.62	.963
1.13	.122	1.63	.489	2.13	.756	2.63	.967
1.14	.131	1.64	.495	2.14	.761	2.64	.971
1.15	.140	1.65	.501	2.15	.765	2.65	.975
1.16	.148	1.66	.507	2.16	.770	2.66	.978
1.17	.157	1.67	.513	2.17	.775	2.67	.982
1.18	.166	1.68	.519	2.18	.779	2.68	.986
1.19	.174	1.69	.525	2.19	.784	2.69	.990
1.20	.182	1.70	.531	2.20	.788	2.70	.993
1.21	.191	1.71	.536	2.21	.793	2.71	.997
1.22	.199	1.72	.542	2.22	.798	2.72	1.001
1.23	.207	1.73	.548	2.23	.802	2.73	1.004
1.24	.215	1.74	.534	2.24	.806	2.74	1.008
1.25	.223	1.75	.560	2.25	.811	2.75	1.012
1.26	.231	1.76	.565	2.26	.815	2.76	1.015
1.27	.239	1.77	.571	2.27	.820	2.77	1.019
1.28	.247	1.78	.577	2.28	.824	2.78	1.022
1.29	.255	1.79	.582	2.29	.829	2.79	1.026
1.30	.262	1.80	.588	2.30	.833	2.80	1.030
1.31	.270	1.81	.593	2.31	.837	2.81	1.033
1.32	.278	1.82	.599	2.32	.842	2.82	1.037
1.33	.285	1.83	.604	2.33	.846	2.83	1.040
1.34	.293	1.84	.610	2.34	.850	2.84	1.044
1.35	.300	1.85	.615	2.35	.854	2.85	1.047
1.36	.307	1.86	.621	2.36	.859	2.86	1.051
1.37	.315	1.87	.626	2.37	.863	2.87	1.054
1.38	.322	1.88	.631	2.38	.867	2.88	1.058
1.39	.329	1.89	.637	2.39	.871	2.89	1.061
1.40	.336	1.90	.642	2.40	.875	2.90	1.065
1.41	.344	1.91	.647	2.41	.880	2.91	1.068
1.42	.351	1.92	.652	2.42	.884	2.92	1.072
1.43	.358	1.93	.658	2.43	.888	2.93	1.075
1.44	.365	1.94	.663	2.44	.892	2.94	1.078
1.45	.372	1.95	.668	2.45	.896	2.95	1.082
1.46	.378	1.96	.673	2.46	.900	2.96	1.085
1.47	.385	1.97	.678	2.47	.904	2.97	1.089
1.48	.392	1.98	.683	2.48	.908	2.98	1.092
1.49	.399	1.99	.688	2.49	.912	2.99	1.095
1.50	.405	2.00	.693	2.50	.916	3.00	1.099

Two V-1 engines are used as strap-ons to provide a big boost to a Valkyrie-2 rocket. All these engines fire at lift-off; at burn-out the two strap-on engines drop off while the central "Sustainer" rocket continues to spectacular altitudes.



MULTI-STAGE

All this can be accomplished with parts now available. For further details send for
CAT. NO. INS-805

CATALOG NO. KIT-801 (Mail order only)

When you open your VALKYRIE-2 KIT you'll be entering a new world — the world of *safe,* liquid propellant model rocketry! The Kit has everything you need to start building your own space program. The Valkyrie-2 is an aerospace product for modelers from:

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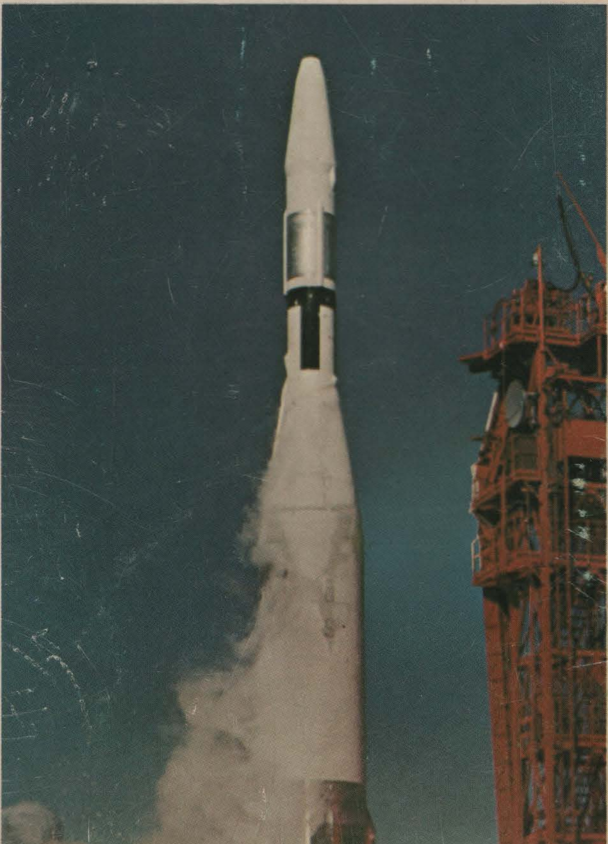
Box 309, Vashon, Washington 98070



NASA Ranger IV spacecraft on its way to the Moon on a U.S. Air Force Atlas-Agena Rocket Photo credit—NASA