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APOGEE PEAK OF FLIGHT NEWSLETTER

Electronic Staging of Composite Propellant Rocket Motors

Splash Software: A New Release!

Snipet: Free Shrox Plan

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"New Software Helps You Meet The FAA Regulations For Sub-Orbital or Other Extreme Altitude Launches"

Splash™ is a new six degree-of-freedom launch simulation software designed to find the landing location of your rocket.

why do you need it?

Extreme high-altitude launches require more than just a high-power-rocketry waiver. When you approach the FAA, they will tell you that you need a "launch license." And you can't get that license unless you present paperwork that is compliant with Federal Regulations.

One biggie, as far as the Feds are concerned, is they need to see a plot showing where the stages of the rocket will land or splash down. To them, that is the difference between a hpr waiver and a sub-orbital trajectory; the rocket may not land within the boundary of the launch site. The rocket just flies too high, and the winds aloft can easily push the rocket tens of miles (or further) downrange.

That is where the new Splash™ software becomes indispensable. It creates the plots (called splash patterns) that the FAA will want to see as part of your proposal for your launch license.

Constructing these "splash pattern" plots is not easy due to various uncertainties that can occur during the launch, or due to changing wind conditions.

What Splash™ does is to inject 18 constantly shifting variables into the launch simulation, and then predicts how these will affect the landing location of the rocket. It is Splash's™ ability to insert these "uncertainties" into the scenario that makes it different from any other simulation software.

For example, any margin of error in any of these parameters will change the flight trajectory of your high altitude rocket and where it may land:

- ♦ Mass Of The Rocket
- ♦ Moment Of Inertia
- ♦ Product of Inertia
- ♦ Center Of Gravity Location
- ♦ Axial Force Coefficient
- ♦ Normal Force Coefficient
- ♦ Center of Pressure Location
- ♦ Fin Cant Angle
- ♦ Total Impulse Of The Motor
- ♦ Propellant Mass
- ♦ Thrust Axis
- ♦ Wind Direction
- ♦ Wind Velocity
- ♦ Launch Rail Azimuth Angle
- ♦ Launch Rail Elevation Angle
- ♦ Ignition Failure Likelihood
- ♦ CATO Of The Rocket Motor Likelihood
- ♦ Deployment Failure Likelihood
- ♦ Chute Failure Likelihood

Splash™ takes all eighteen of these variables into account at the same time! Based on these uncertainties, it create a likely landing zone where the rocket will touch down. Yes, you can even put something into orbit.

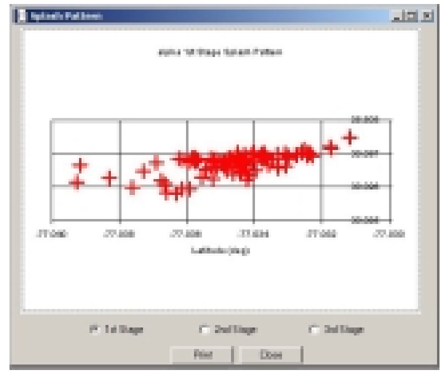
The figure on the right is a plot listing 250 potential impact points of a particular rocket. The distribution of the impact points illustrates not just a nominal impact point, but provides a level of confidence to the likelihood of an impact in any given region. Such data is indispensable in prelaunch safety analysis and is also of use in determining possible locations for wayward rockets. It is this capability that sets Splash apart.

As you can see from the plot, Splash™ displays the results in Latitude/Longitude format. There are two reasons this benefits you. First, you can overlay the grid right onto a map and quickly find out what structures lie in the landing zone. And second, you can take a GPS handheld receiver out the launch site, and walk toward the general landing zone. Splash helps you find your rocket quicker.

Other features of Splash™ include:

- ♦ Wind effects (weather cocking).
- ♦ Earth modeled as a rotating oblate spheroid. Yes, the earth rotates under the flying rocket!
- ♦ Gravitational effects that vary with altitude and latitude.
- ♦ Models the atmosphere up to 632 km above sea level (ASL).
- ♦ Clustering of up to 5 motors per vehicle stage.
- ♦ Up to 3 stages per vehicle.
- ♦ Ability to export flight data to a spread sheet program for further study.

Splash™ is a full 6-Degree-of-Freedom (6 DOF) simulation program. What this means is that it computes all six coordinates of the rocket during the entire flight: downrange distance (X), cross wind distance (Y), altitude (Z), pitch, yaw, and roll. By comparison, RockSim is 3 DOF: X, Z, and pitch. This is what allows Splash™ to create a true profile of the rocket's flight, and why it is so valuable



in high altitude flights. It is really impossible to predict where the rocket will land if you don't know how it is oriented throughout the entire flight.

Do you still need RockSim if you buy Splash?

I do recommend you own both, because Splash™ is not a rocket design program. It only runs launch simulations.

Splash™ needs some specific data about the physical characteristics of the rocket, like size, weight, and fin area. While you can compute these parameters separately, they are easily displayed using RockSim. So you'll save time running your Splash™ simulations if you own RockSim.

It's Not For Everyone

For most model rocket and hpr flights, the capability of the Splash™ software is massive overkill. If your rocket is not going to exceed 20,000 feet, it is likely that it will land within the confines of your launch area. In that case, the RockSim software is what you need.

Finally, because of the accuracy of Splash™ software and that it could potentially be used by terrorists to lob bombs across vast distances, at this time <u>we can only offer it to citizens of the United States of America.</u> Please be aware that you may be contacted by a representative of the US Government concerning your intentions for using the software.

Electronic Staging of Composite Propellant Rocket Motors

By Tim Van Milligan

There have been many people asking me recently how do you go about staging composite propellant motors. Most of these requests are coming from teachers that have students participating in the Team America Rocketry Challenge.

Unlike black powder propellant motors, staging composites is not very simple. Direct staging doesn't work, because there are no booster motors that use composite propellant. The reason why is explained in the article at: http://www.apogeerockets.com/education/newsletter49.asp

Basically, that leaves only electronic ignition as the only viable option for igniting the upper stage in a rocket lofted by a composite motor. This unfortunately is complex, and needs some explanation, which is why I'm writing this article. This article will just touch the surface of the subject. If you want actual schematics to build your own, you'll need to do some searching on your own.

Basic Staging Using Electronic Ignition

With electronic ignition of the upper stage, you are going to have to carry a payload in the rocket that controls the firing of the upper stage motor. That means, your rocket will need three components: a power source, an igniter, and something else (a little black box) that controls when the staging occurs.

The Power Source

For the power source, most people use a battery. The other option is a capacitor that is charged prior to the rocket lifting off. The size of the power supply really depends on the type of electronic igniters that are used. The more current the igniter needs, the heavier the power cell will need to be.

The Igniter

When selecting igniters for the upper stage motor, ideally you want a device that takes very "very" little current to start the fire going. A typical Estes solar igniter can be used, but most people that are proficient in staging with electronics prefer something more reliable and that draws less power.

The igniter that draws the least amount of current is the old style camera flash bulbs. When the bulb flashes, the surface gets hot enough to light a wick. For maximum reliability, the bulb is taped in direct contact with the wick. The wick then burns up into the nozzle of the upper stage motor, setting it off.

This method works good for black powder propellant motors that are in the upper stage, but not so good for composite propellant motors in the top stage. The reason is that the wick takes some time to burn up into the core of a composite motor. Usually you want instantaneous ignition. With a black powder motor, the length of the wick is pretty short, and the time lag for staging is minimized. However, for composite motors, the length of the core inside the motor means the wick has to be long - so it takes a long time for the wick to burn all the way up into the motor.

The other disadvantage of the wick method is that the best type of wick to use: thermalite, requires a Low Explosives User's Permit (LEUP) from the government to be able to legally buy and store it. That makes it difficult for younger modelers to use.

If you can't get thermalite, the other alternative is to make your own wick, or to experiment with readily available wick called: green fuse. Unfortunately, these wicks can have inconsistent burn rates, which can cause problems if you really need a precise time for staging the rocket.

For those that want to make your own igniters, there is a very good web site that describes all the various compounds that are available from various suppliers. That web site is: http://www.lunar.org/docs/talks/Massey9810/IgniterTalk.html

The Mysterious "Black Box"

Once you've decided on the power source and the igniter for the upper stage, the last component is the "black box." Why we call is a black box is because it could be anything. But basically, this component determines "when" the igniter fires.

With electronics, you have a number of options that can be used determine when the electric current begins to flow to the igniter. They can be: mercury switch (a type of deceleration switch device), acceleration switch, timers (both electronic or mechanical), radio control systems, or flight computers.

Mercury Switch Systems

The first systems people have used are mercury switches. Basically, when the rocket starts to decelerate after the booster stage burns out, the switch activates and then allows electric current to flow to the igniter of the upper stage.

For this to work, the mercury switch has to be oriented in

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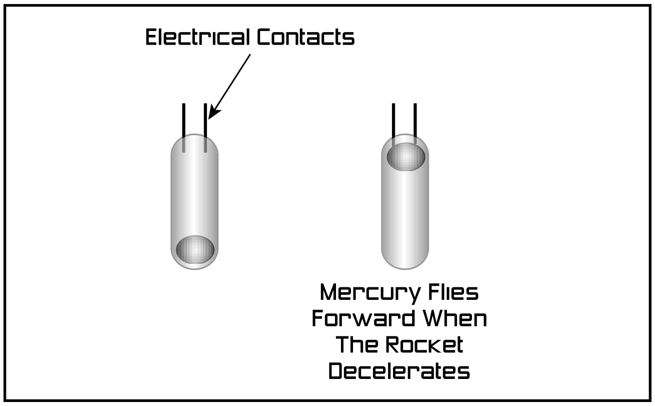

The mercury switch senses when the rocket begins to slow down.

the rocket so that the contacts are at the top. The liquid mercury will then touch both contacts when the rocket begins to decelerate.

The big advantages to the mercury switch are that the unit is every light weight, and it is also the least complex of any of the black boxes.

However, there are some major disadvantages to the system. First, the switch is only closed for a short period of time. You may know from experience that many igniters require electrical current for a fairly long duration of time.

The other major disadvantage of the mercury switch is the safety problems. And it has a couple of big safety problems. First, the switch is activated any time the rocket decelerates. And it doesn't take much. So even picking up the rocket and tilting the model sideways can cause the switch to activate. This is scary. Even with additional safety switches installed in the circuit, problems can happen.

The other safety problem that can occur is staging at the wrong moment in the flight. The model may not be orient properly when the switch closes, and could send the top stage going horizontal instead of vertical. For example, here's a situation that is totally possible.

Let's say the booster stage "chuffs" on ignition...

For those of you that don't know what a chuff is, let me explain. It is a momentary ignition of the motor, and then it immediately self-extinguishes. It sounds like a loud cough - hence the name: chuff. It happens only with composite propellant motors, and can occur for any number of reasons; the igniter wasn't fully inserted into the core of the motor, or the igniter was wimpy and didn't generate enough heat and pressure inside the motor to sustain the burn. But for whatever reason, the motor doesn't fully ignite and shuts off.

I've seen some pretty violent chuffs. I've even seen the rocket lift nearly off the end of the launch rod.

So it is possible for the mercury switch to sense a deceleration immediately after a chuff, and ignite the upper stage -- while the rocket is still on the launch rod. At that point, if the upper stage doesn't have launch lugs (which is entirely possible), it could send the rocket going in a horizontal direction.

The point that I want to make is that if you plan on using a mercury switch for staging, you have to be very very careful. It can be done, but it requires a lot of extra safeguards.

The Acceleration Switch

Adept Electronics sells a special acceleration switch, that minimizes some of the problems associated with the mercury switch. Basically, it is a hinged metal rod that makes contact with a micro-switch.

As long as the rocket is accelerating, the switch is open. When the rocket begins to decelerate, the switch closes. So it is sorta like the mercury switch.

However, it has some differences. The tension on the hinged metal rod can be controlled, so it is difficult to just jar it to close the circuit.

From what I recall, Adept puts some additional circuitry in the device to make sure it is sensing a real launch, and not just the rocket being jarred by a chuff or being tipped over. For example, the switch must sense a long duration acceleration (say a full second or two) before it allows the rocket to ignite the upper stage.

The built-in safety feature is worth the investment in the device. According to the Adept web site, the acceleration switch is patented. But they don't list the patent number, so if you make your own acceleration switch you may have to worry

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Source: Adapt's Web Site

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about the legal implications.

The disadvantage of the device is that it is heavier and bulkier than the mercury switch. It is also a bit more complex (the more components on a circuit, the greater the chance for something to go bad. It is better used on bigger rockets, but with a little ingenuity, I'm sure it is possible to use it on the Team America Rocketry Challenge rockets.

Timers

Both mechanical and electronic timers work in a similar way. They start counting as soon as the rocket leaves the launch rod. At the correct time in the flight, they allow current to flow to the igniter in the upper stage.

The advantage of a timer device is that they are cheap. And electrical timers can be made very small and lightweight.

Note: Because electrical timers are so inexpensive and reliable, I'd recommend staying away from mechanical timers (like wind-up devices).

The disadvantage of a timer is that it has to be preset prior to launching the rocket. For example, say the booster motor burns for two seconds. You want the upper stage to ignite right at burn-out of the lower stage. So you'd have to set the timer to ignite the motor for two seconds into the flight. But is isn't always that easy...

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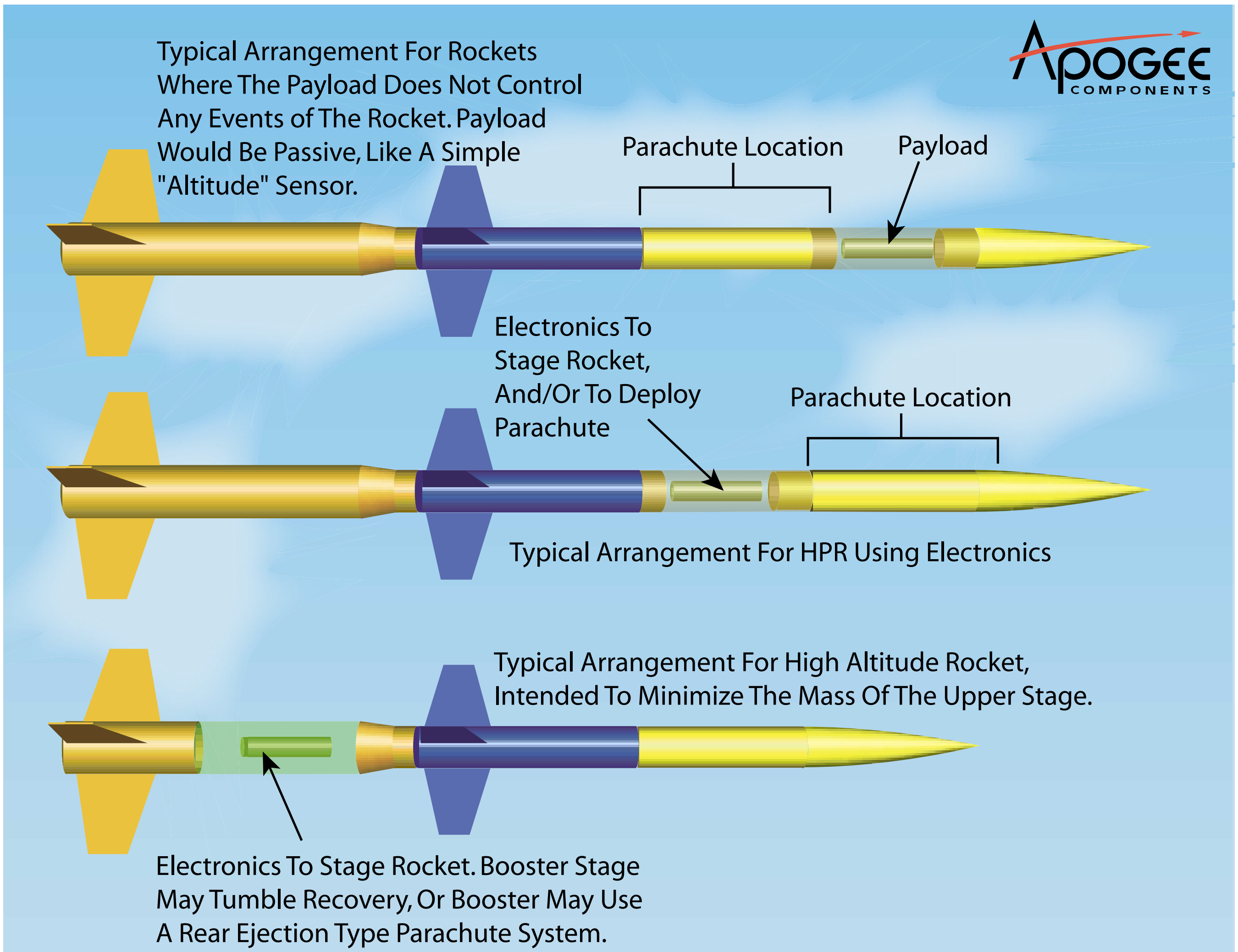

Common Payload Locations Used In Rocketry

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If the upper stage is a composite propellant motor, often they take a few moments to build up pressure and come up to full thrust. So you have to start the ignition of the motor a little bit early. What I'm saying is that there is a little bit of playing around that needs to be done when using a timer.

I recommend reading the article at:
http://www.info-central.org/propulsion_staging.shtml

There are some disadvantages to timers. The big one is that once the timer is started, you can't shut it off. This might be a safety concern. For example, say the two stage rocket lifts off the pad (the timer starts), and while the first stage is firing, a fin breaks off. The rocket immediately goes unstable. Can you see it in your mind? You have no way of knowing which direction the rocket is going to be pointed when the upper stage motor ignites. The most likely direction — according to Murphy's Law — is straight down and toward the crowd.

Another bad situation might be that the booster motor CATOs at ignition. The force of the explosion could send the upper stage skyward, where it ignites. So again, you have to be careful when using timers.

How do timers activate?

There many ways to start timers going. I'm sure I'll miss some in this short list, so please don't consider this a complete list.

The first one that pops into my mind is a pull pin. As the rocket sits on the pad, a pin (like a phono-jack) makes connection in the socket in the base of the rocket. As the rocket lifts off, the jack is yanked out, and the timer starts counting. Sometimes, the pin is on a string, so that the rocket has to move a sufficient distance up the launch rod before it is yanked out of the rocket.

Another method is a micro (slide) switch that rides along the launch rod. As long as the rod presses against the switch, the timer doesn't start. But as soon as the rocket leaves the rod, the switch closes and the timer activates.

In a similar fashion to the micro switch, I've also seen optical switches that use a LED to shine against the launch rod. When the rocket leaves the rod, the timer begins counting.

Radio control systems

It is possible to use radio control systems to control the staging of a rocket. In this case, you have a transmitter on the ground that you control. Inside the rocket, a receiver is mounted that only activates once you throw the switch on the transmitter.

There are some disadvantage of these systems. First, they are expensive. Second, the receiver is going to be a bit heavier compared to a timer or a mercury switch device. A third problem might be radio interference from other transmitters in the area. It has been know that someone else on the same radio frequency might accidentally set off the motor of your rocket.

The advantage of this system is that you have a little bit of control if things go horribly wrong with the flight during the booster phase. If the booster goes unstable, you don't have to ignite the upper stage. That is a little safer than having it come down under full thrust.

Flight computers

Flight computers are the most complex of any two-stage ignition system. They are more expensive, and can also be heavier, bulkier, and require the most electrical power. But they also give more control (hence safety) to the launch of the rocket.

The flight computer is a small payload that goes into the rocket. The computer wants information about the launch, so it will always have sensors hooked up to it. The most common sensors are electronic accelerometers and barometers. You can also hook up other sensors to it, like pull pins, acceleration switch, or optical switches.

The flight computer is a brain inside the rocket. What it does is to look at the information fed into it by the sensors, and determine when (or if) the second stage should be ignited.

For example, say the sensor hooked into the computer is a accelerometer. The computer will look at the acceleration of the rocket and determine if the force it sees is a true lift-off of the rocket, or simply a chuff or cato. If it is a chuff, it doesn't allow the upper motor to ignite. Only when the situation looks right will it allow the upper stage to ignite.

With a barometer as the sensor, the computer might look for a predetermined altitude. For example, it might not allow the upper stage motor to ignite unless it hits at least 500 feet up in the air. That would rule out a chuff or a cato on the launch rod.

A flight computer allows a lot of versatility in the launch, particularly if it has more than one type of sensor. For example, if it has both an accelerometer and a barometric sensor, it could control multiple things in the flight. These things are called "events," and can include things like staging, and deploying multiple parachutes at various altitudes. This is how dual-deployment systems operate.

If you have a big rocket, the way to go is the flight computer. They can be programmed to do a number of events dur-

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ing the launch, and offer a lot of safety features.

There is my basic review of electronic staging. I hope it helps. For more information, you can go to the web sites of the manufacturers that make the electronic devices. I've also listed a bibliography of some of the articles I've found useful.

Suppliers:

http://www.diac.com/~adept/products.htm - Product descriptions from Adept electronics.

http://www.missileworks.com/PET2.htm - Missile Works sells a programmable event timer.

http://www.perfectflite.com/ - Timers and flight computers.

http://www.gwiz-partners.com/html/products.html - Sells a flight computer.

Web Articles:

http://www.info-central.org/propulsion_staging.shtml - An article that describes staging composite motors.

http://www.faqs.org/faqs/model-rockets/ignition-tips - A basic article on the different types of electronic methods of igniting multi-stage rockets.

Magazine and Newsletter Articles:

"Technical Notes On Mercury Switch Staging" by William H. Dye. American SpaceModeling, December 1984.

"Electronic Staging" by Tom DesJardins. NOVARR Free Press, Jan 78.

"An Improved Capacitive Discharge Ignition System" by Moose Lavigne. American SpaceModeling, March 1987.

"Flash Bulb Ignition Mysteries Unraveled," by John Pursley. American SpaceModeling, May 1989.

"Electronics for Staging," by Paul Campbell. High Power Rocketry, September/October 1993.

"Electronic Staging of Rockets," by Matt Steele and John Fleischer. Tripolitan, June 1991.

http://www.nar.org/NARTS/cat.html#Basic_TR - This is the NAR's Techincal Service. Look for publication: *"Multi-Staging Advanced Rockets."* Product number: NCTRA2

About the Author:

Tim Van Milligan is the owner of Apogee Components (http://www.apogeerockets.com) and the new rocketry education web site: http://www.apogeerockets.com/education. He is also the author of the books: *Model Rocket Design and Construction, 69 Simple Science Fair Projects with Model Rockets: Aeronautics* and publisher of the FREE e-zine newsletter about model rockets. You can subscribe to this e-zine at the Apogee Components web site, or sending any message to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject of the message. This article may be reprinted as long as this paragraph is also included.

Archives of this Newsletter

All the articles that have appeared in this newsletter are archived at http://www.apogeerockets.com/education/newsletter_archive.asp

Download the RockSim Plans for This Rocket Today!

The data file you need is at: http://www.ApogeeRockets.com/shrox/snipet.html

Parts List:

1 - Nose cone. Apogee p/n 19400 - PNC-24A
1 - Body tube. Apogee p/n 10099 - 24mm dia X 13.50 inches long.
2 - Centering Ring. Apogee p/n 13031 - CR 18/24.
1 - Motor tube. Apogee p/n 10085 - 18mm dia X 2.75 inches long.
1 - Motor block. Apogee p/n 13029 - CR 13/18
1 - Parachute 12 inch dia. or equivalent.
1 - Shock cord. Apogee p/n29505 - 100lb test Kevlar® X 30 inches long)
1 - Shock cord mount.
1 - Launch lug. Apogee p/n 13051 1/8 inch X 1 inch long.
Fin Material - Basswood or Balsa wood, 1/8 inch thick.
Clay Nose Weight - 8.5 grams (.3 oz)