PEAK OF FLIGHT NEWSLETTER

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IN THIS ISSUE

EJECTING TWO PARACHUTES FOR RECOVERY OF TWO SEPARATE ROCKET PARTS

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PEAK OF FLIGHT

Ejecting Two Parachutes

By Tim Van Milligan

A common question that we've been getting recently is about separating a rocket into two parts, where each part has its own parachute. I suspect that the people asking about the technique don't trust that two parachutes will properly deploy.

In this article, I'll go over the reasons you may want to have the rocket come down in two separate pieces, and then the many different methods that I've personally used to eject the two parachutes cleanly and make sure that they fully inflate.

FIGURE 1: A ROCKET THAT HAS BEEN SPLIT INTO TWO SECTIONS, EACH DESCENDING WITH THEIR OWN PARACHUTES

Why split a rocket in two parts for descent?

This question started popping up from TARC rockets in past contests that required the rocket come down in two pieces. Every year the TARC rules change to make the event more challenging and to prevent teams from dusting off old designs and not making any significant attempt at starting from scratch. Making the rocket come down in two parts makes the event only slightly more difficult, because you'd have to make sure that both parachutes deployed fully and each piece came down safely. If one piece would not fully inflate, the mission would be disqualified as a failure.

Other than for contest events like TARC, what would be other situations where you might want to separate the rocket into two pieces? After all, there is a huge downside of separating the rocket in two — you have to recover multiple pieces after it lands on the ground. For those of us in rocketry for a long time, we already know how difficult it is to collect one rocket after a launch. Walking around searching for a second piece is an additional chore. I don't know of anyone that enjoys searching for a lost part of a rocket. We'd rather be launching rockets, not recovering them.

The other disadvantage of separating a rocket into two pieces, as mentioned above, is that you have two chances of recovery device failure. Any second recovery device in the rocket complicates the odds of a successful deployment. That just goes without saying.

But there are times when you might want to consider splitting the rocket into two separate pieces for recovery. They are:

1. To reduce the internal volume needed to be pressurized.

If the rocket is long, there is a lot of internal volume inside that needs to be pressurized by the ejection charge to push the parachutes out. By splitting the rocket in two shorter pieces, this decreases the internal volume that needs to be pressurized in order for successful deployment to occur.

Normally, the base of the coupler (glued into the upper part of the rocket) is capped off with a bulkhead, so that the internal volume is cut in half.

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Continued on page 3

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Ejecting Two Parachutes

Continued from page 2

Of course, you don't have to have the two pieces become detached and come down separately. You can put a shock cord between them to keep them together.

2. To protect a delicate payload in the nose.

There are some payloads, like fragile raw eggs, that you want to isolate from the rest of the rocket, so that they come down on their own parachute. This could mean that there is less of a chance that the payload could be damaged on landing.

FIGURE 2: THE DELICATE ESCAPE TOWER ON THE SATURN KITS IS PROTECTED BY HAVING IT HUNG BY A HARNESS. THIS IS SO THAT ITS TIP WON'T HIT THE GROUND FIRST.

In this category, you might have several failure modes that you might consider that could occur if the payload was connected by a shock cord to the body tube section.

A first situation is when the payload is swinging back and forth like a pendulum under the canopy. It isn't so bad while the rocket is in the air, the problem occurs at the instant of touchdown. The issue is that the payload hanging under the canopy has both a vertical velocity and a horizontal velocity. The vertical velocity is known -- which means you planned for it by selecting the proper size of the parachute before the flight. That vertical speed is slow enough that the payload could land on the ground and it doesn't cause damage to the payload. But the swinging of the payload's horizontal velocity could be significantly higher.

I have had numerous fragile payloads (eggs) smack the ground hard on their sides because they were swaying wildly just before touchdown. I've also had them drape over a fence or tree limb and smack the payload against that tree trunk or fence post hard enough that they damage the payload. Splat!

An advantage of having the rocket come down in two pieces is that you can get more stability for the payload section because the other half of the rocket isn't also swaying around under the parachute and causing the whole system to oscillate. An example of this is the Quest Magnum Sport Loader egg-lofting kit (https://www.apogeerockets.com/Rocket-Kits/Skill-Level-3-Model-Rocket-Kits/Magnum-Sport-Loader).

You can also then cut a spill hole in the chute for the payload, which further stabilizes the parachute and helps it reduce oscillation, keeping the horizontal speed to a minimum.

Continued on page 4

Electronics Hardware Installation Kit

Think of the convenience of getting everything to professionally install your dual-deployment or other electronic payload into a e-bay of your rocket!

Includes: nylon standoffs, screws & nuts, wire, push-switch, drill & tap, ejection charge cannisters, barrier strips, wire ties, and step-by-step DVD instructions.

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Ejecting Two Parachutes

Continued from page 3

A second problem of connecting the payload (such as the nose cone) to the body of the rocket is that the two pieces interact with each other during descent. The swaying of one piece will also cause the other piece to sway back-and-forth. It is a "system" after all, and in a system, everything is affected by just one part.

Therefore, if both pieces sway back and forth on their respective suspension lines, they could whack into each other as they are coming down. How often have you retrieved a rocket and you notice that the nose cone has a new swipe of paint on it - the same color as that of the body tube? This is proof that the two pieces whacked each other on the way down while under parachute.

It was for these two conditions that I decided to separate the Saturn V (https://www.apogeerockets.com/Rocket-Kits/Skill-Level-5-Model-Rocket-Kits/Saturn-V-1-70th-Scale) and the Saturn 1B (https://www.apogeerockets.com/Rocket-Kits/Skill-Level-5-Model-Rocket-Kits/Saturn-1B-1-70th-Scale) models into two parts so that they both could survive the landing intact and with minimal damage. That little escape tower on the scale models is very delicate and I wanted to protect it as much as possible. Coming down on two separate parachutes was really the only way to achieve this (see Figures 2 and 3).

FIGURE 3: WHEN YOU HAVE A HIGHLY DETAILED ROCKET, YOU DON'T WANT THE UPPER PORTION TO WHACK THE LOWER PART AND RUIN THE PAINT FINISH OR KNOCK OFF RAISED DETAILS.

The third issue is when you use a rubber shock cord between the two parts. In this case there is a chance for shock-cord snapback. In this situation, the nose cone shoots off the tube at ejection and fully stretches the rubber shock cord. The rubber cord then starts retracting quickly, and the base of the nose could smash hard into the front of the body tube. This has been termed by some people as "the Estes dent" because it leaves the front of the body tube with a significant deformation that ruins a nice paint job on the model. It is fortunately fairly rare, but it does happen.

By having the sections of the rocket completely separate, there is zero chance of having an Estes dent on the front of your body tube.

3. To create a stable platform

We discussed this above, but what if your payload needed a no-wobble platform? For example, you may want to attempt aerial photography from the rocket as it is descending under the parachute. The less swaying there is of the parachute, the less blur there will be in the photographs.

Again, having the rocket come down in two parts gives you more control on the descent of each parachute, and things can be made more stable.

Another example of this is if you wanted to make a rocket that landed upright when it touched down on the ground. The more the lander hangs vertically under the

Continued on page 5

Ejecting Two Parachutes

Continued from page 4

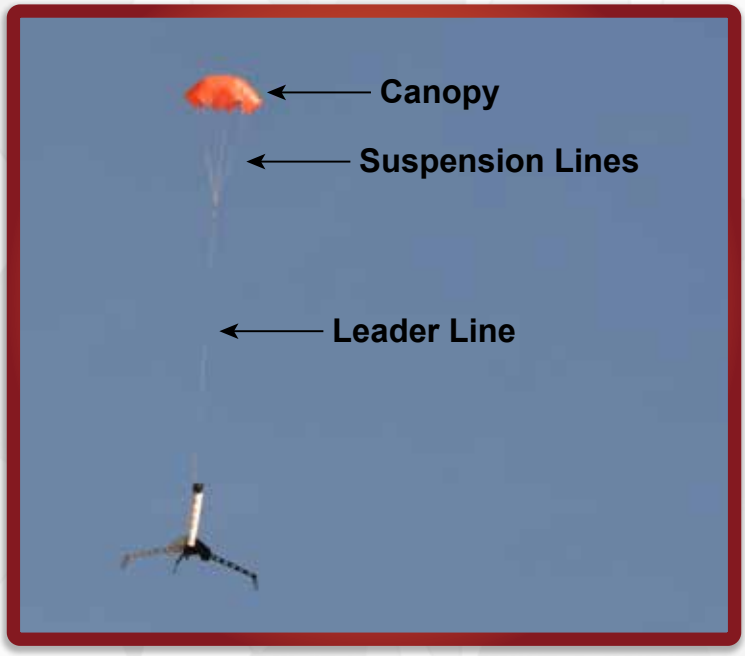

FIGURE 4: FOR A LANDER, YOU WANT A STABLE DESCENT TO GIVE THE ROCKET A BETTER CHANCE OF STAYING UPRIGHT ON TOUCHDOWN.

parachute at the instant of touchdown, the more likely it is to stay vertical after touchdown.

This is exactly the reason I designed the Star Lift Mega Lander (https://www.apogeerockets.com/Rocket-Kits/Skill-Level-5-Model-Rocket-Kits/Star-Lift-Mega-Lander) to separate into two pieces. I wanted to make sure that the lander portion had the best chance of remaining upright once it touched down on the ground. And it worked great! That rocket always seems to stick the landings.

4. To create consistent decent rates

Another case where you may want the pieces of the rocket to completely separate is to get a more consistent descent time.

This usually isn't a problem, but there may be some situations, like a timed rocket duration contest, where you have to land at a specific time. If you can get rid of the portion of the rocket that causes the most swaying (the fin section), then your payload will come down straighter and at a more consistent rate. It is the swaying back-and-forth that causes a lot of variation in the descent time of the model.

5. You don't have a big enough chute

Have you been in the situation where you have a really heavy rocket, but you didn't have a chute that is big enough to safely bring back the whole rocket in a single piece? I have.

Instead of using one big (and typically expensive chute), you could break the rocket up into two sections, each with their own smaller parachute—which of course, you do have available.

Can you reliably eject two parachutes?

I think this is the big question that people have about using two parachutes in the same body tube. Is there a reliable way to make sure that both parachutes are ejected from the body tube?

There are two ways of thinking about what is happening at deployment. The first way is that the pressure inside the tube shoots the nose cone off, and the parachute is "pulled"

Continued on page 6

Ejecting Two Parachutes

Continued from page 5

out of the tube, since it is connected to the base of the nose cone.

The other way of thinking about the situation is the ejection charge creates a pressure wave inside the tube and that pushes the parachute, which then pushes the nose cone out of the tube.

I think both are legitimate ways of looking at the same situation. But pulling the parachute out is the most common. And I lean that way myself. I'd rather design a rocket to have the nose shooting out, pull everything out, rather than relying on the pressure wave pushing the parachute out.

I have seen situations where the parachute is NOT fully ejected from the body tube because the fit on the nose cone is too loose, which lets pressure escape around the shoulder. Or the mass of the nose cone is too low, and it doesn't have enough inertia to tug the parachute fully out of the tube.

Also going through the back of my mind are those situations where I compacted the recovery wadding too tight in the tube that the pressure wave wasn't strong enough to push everything out of the rocket. Yes, I too have smashed rockets by improper preparation…

Two parachutes, for two separate pieces inside the tube compound the situation. Since one of the parachutes isn't going to be pulled out, you have to rely on the pressure wave to push everything out of the rocket. It is for this specific reason that I think there is a lot concern on how to put everything together in the rocket and still get reliable deployment of both parachutes. Particularly for that second parachute that doesn't get pulled out by the upper part of the rocket.

In my experience, to a great extent, the bigger the diameter of the tube that the parachutes are stored in, the easier it is to get them to pop out.

In the Saturn 1B rocket (https://www.apogeerockets.com/Rocket-Kits/Skill-Level-5-Model-Rocket-Kits/Saturn-1B-1-70th-Scale), the tube is approximately 4 inches in diameter. There is room inside the tube to place the parachutes side-by-side. In this case, there is friction between the chutes from the sides. So if one parachute is pulled out by the nose cone coming off, the friction force of its parachute pulls the other one out at the same time.

Therefore, the first possible solution is to pack the two parachutes side-by-side inside the tube. This seems to work pretty reliably in getting deployment of both chutes. But it is a special case where there is just enough friction where they both can slide easily as a unit together in the tube.

If the fit is too tight, they are going to wedge each other even tighter in the tube and neither will deploy. If the fit is too loose, then the chute attached to the upper part of the rocket could be pulled out without also pulling out the lower section's parachute.

Being too loose is the case of the Saturn V rocket - which is 5.6 inches in diameter. There is so much room

Continued on page 7

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Ejecting Two Parachutes

Continued from page 6

inside the tube that there is no friction between the parachutes if they are packed side-by-side. They are completely independent of each other.

However, in the case of our Saturn V kit, the parachute compartment is very short. This is on purpose for two reasons. First, I put a stuffer tube inside the main tube in order to reduce the volume that the ejection charge needs to pressurize in order to blow the nose section off. The space where the parachutes are packed into, while very big in diameter, is also pretty short. And it is very close to the wide opening of the tube (see Figure 5).

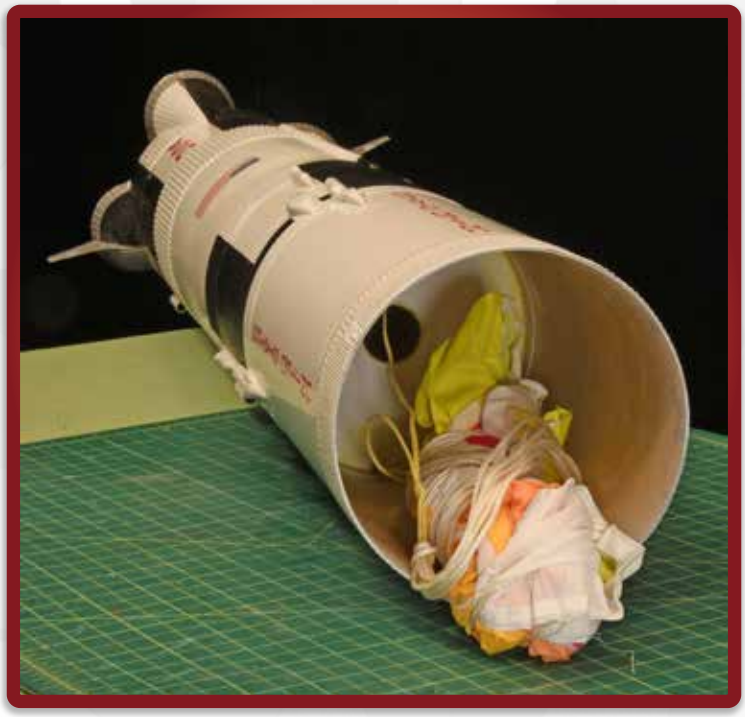

FIGURE 5: THE TUBE ON THE APOGEE 1/70TH SCALE SATURN V IS SO BIG THAT EVEN THE MASSIVE 58-INCH DIAMETER PARACHUTE SHOWN IS FLOPPY INSIDE OF IT.

What happens in this situation is that the upper part of the rocket is blown off by the ejection charge, and pulls its own parachute out of the tube. The other parachute for the main tube is neither pulled out by the upper section, nor is is blown out by the pressure wave of the ejection charge. Since it is so close to the mouth of the tube and there is nothing holding it in, it just sort of falls out on its own.

It really relies on the rocket tube to start tumbling in order for this to work properly though. The Saturn V rocket is not highly stable to begin with. It has very small fins, and takes a lot of nose mass to move the CG far enough forward to make it fly stable in the first place. At ejection, that nose weight goes away since it is part of the upper section, and the large tube section is now shorter and even more unstable. Because of this it begins to tumble, and that sort of tosses its parachute out the wide mouth of the tube by centrifugal force.

That short parachute stowage area is important here. Because if it was deep inside the tube, that chute would have a difficult time rolling out on its own.

Also, if the lower section were a stable model (in that it would follow a predictable trajectory on its own) and didn't tumble, that parachute could easily stay in the mouth of the tube and not be ejected at all.

This is a legitimate concern, you really shouldn't rely on this method to deploy the parachute unless you set up the conditions correctly. Fortunately, there is a much more reliable way to eject the parachute of the booster section of the rocket. We'll discuss it later.

Stacking Parachutes

The other idea that people have used, particularly in smaller diameter models, is to stack the parachutes on top of each other with the upper section's parachute being on the bottom (closest to the ejection charge of the rocket motor). What happens in this case is that the nose blows off and pulls its parachute out. But since the lower section's

Continued on page 8

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Ejecting Two Parachutes

Continued from page 7

parachute is sandwiched between it and the base of the nose, that chute gets pushed out by the chute attached to the nose.

This does work for the most part. And for small kits like the Quest Magnum Sport Loader, it is probably just fine.

But there is a significant possibility of the chutes tangling around each other. The reason is that the shroud lines (or a leader line) of the upper section's parachute has to pass off to the side of the lower section's parachute. In effect, you have a line that is just itching to get tangled.

If the chutes do become tangled, the rocket is going to tumble to the ground. That could be OK if the model is lightweight and falls slowly enough while tumbling. But you're likely to break a fin off the model because it is coming down faster than expected.

Piston Ejection Systems

If you're going to stack the parachutes one on top of the other, it is better to put the upper section's parachute on the top, and use a piston system to push everything out of the tube.

In this ejection method, there is no pulling the parachutes out. You're using a sliding plug (called the "piston") to push everything out.

For small diameter rockets, Apogee sells styrofoam piston plugs (https://www.apogeerockets.com/Building_Supplies/Parachutes_Recovery_Equipment/Disposable_Wadding) that will work just fine for this. As mentioned, they slide through the tube to push everything out. Typically they are used in competition model rockets where packing a super large parachute in a small tube is common. Big chute in a small tube is often difficult to eject out properly. This would be similar to having two parachutes in the tube.

They often sound like a potato gun going off, because of the loud pop they make as they eject the parachutes from the tube. They are very reliable in getting everything out of the tube, and for small rockets, we highly recommend them.

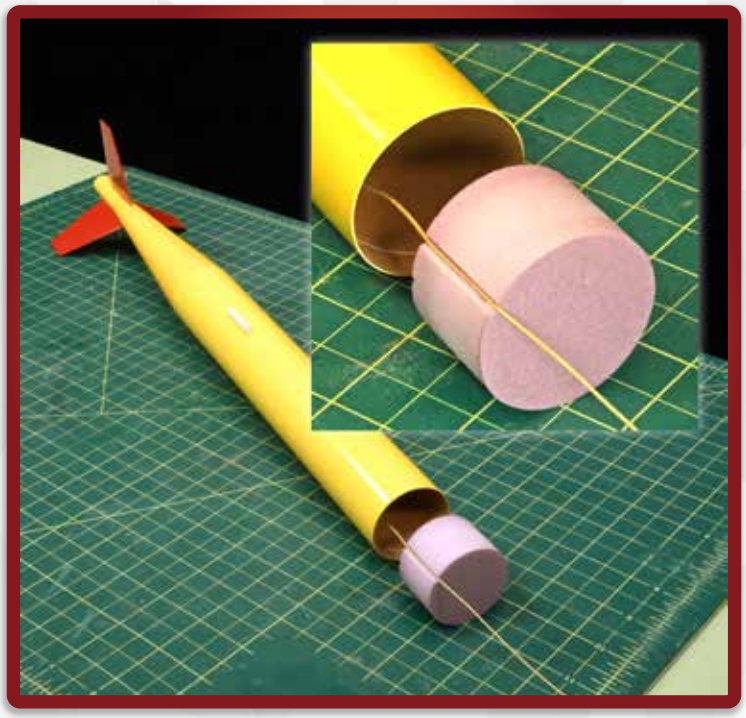

FIGURE 6: REUSABLE STYROFOAM EJECTION PISTONS WILL FORCEFULLY EJECT ANYTHING IN FRONT OF IT. NOTICE THE V-NOTCH CUT DOWN ONE SIDE (INSET) SO IT CAN SLIDE OVER THE KEVLAR SHOCK CORD.

Continued on page 9

Ejecting Two Parachutes

Continued from page 8

The question people have about the ejection plugs is how do you get the shock cord in the tube to pass around the outside. For this we recommend using a round kevlar shock cord for the rocket, and then cutting a slot (v-notch) down the length of the styrofoam plug as shown in Figure 6. The shock cord then stays in the slot as the piston passes by it out of the tube.

On larger diameter tubes the piston is typically custom made, although some kits do contain a piston ejection system, such as the Aerotech Sumo (https://www.apogeerockets.com/Rocket-Kits/Skill-Level-3-Model-Rocket-Kits/Sumo).

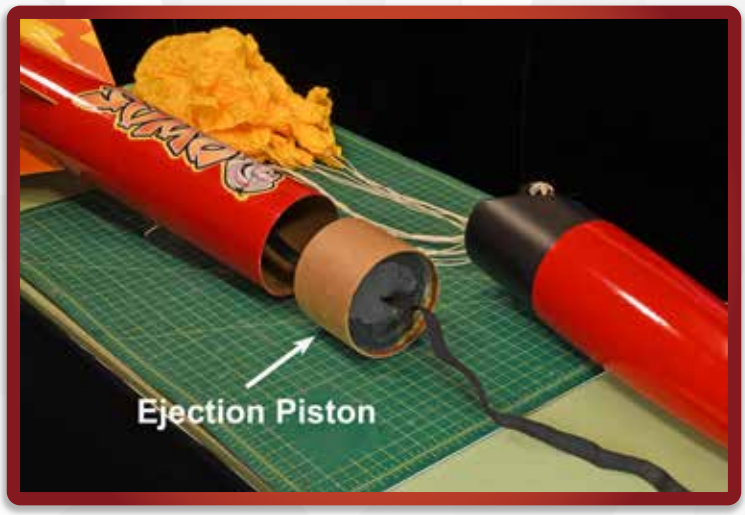

FIGURE 7: AN EJECTION PISTON WILL PUSH EVERYTHING OUT OF THE ROCKET.

As shown in Figure 7, they work identically to the smaller styrofoam pistons, with the exception being the shock cord is attached to the underside of the forward bulkhead in the piston. So the lower part of the shock cord is blasted by the ejection charge, and therefore should be made from a heat resistant material like Kevlar®.

There is a downside of larger diameter pistons. The residue from the ejection charge can coat the inside of the body tube and build up over time. This build-up of residue can cause the piston to seize up in the tube and not eject the parachutes from the rocket. So if you use a larger diameter piston, be sure to test the fit and function of the piston in the tube between launches - it should slide freely and easily through the tube.

It is recommended that the piston be taken fully out of the tube so that the kevlar line can also be inspected after each launch. Therefore be sure to design the piston so that it fully ejects out of the rocket so you can clean out the tube it slides in, and do the inspections after each launch.

The smaller styrofoam pistons seem to be self-cleaning. That is, when you install a new plug in the tube, it scrubs the inside of the tube clean and prevents it from seizing up at ejection. They are also reusable. They come out of the tube so fast that they don't melt. You'll often find them on the ground, looking like they've never been used.

Using Deployment Bags

For larger diameter rockets (anything bigger than a BT-60 size tube, which is 1.64 inches in diameter), I recommend using parachute deployment bags when you are separating your rocket into two pieces.

Continued on page 10

Ejecting Two Parachutes

Continued from page 9

The purpose of a deployment bag is to control the unfurling and opening of the parachute out of the rocket.

The bag is exactly what it sounds like - a pouch that holds the parachute until you want it to be deployed. We at Apogee sell deployment bags (https://www.apogeerockets.com/Building-Supplies/Recovery-Equipment/Parachute-Deployment-Bags) made from Nomex®. We have the flame resistant Nomex ones because they also eliminate the need for wadding. But if you're putting wadding in the rocket, you can use something cheap like a small plastic sandwich bag like shown in Figure 8.

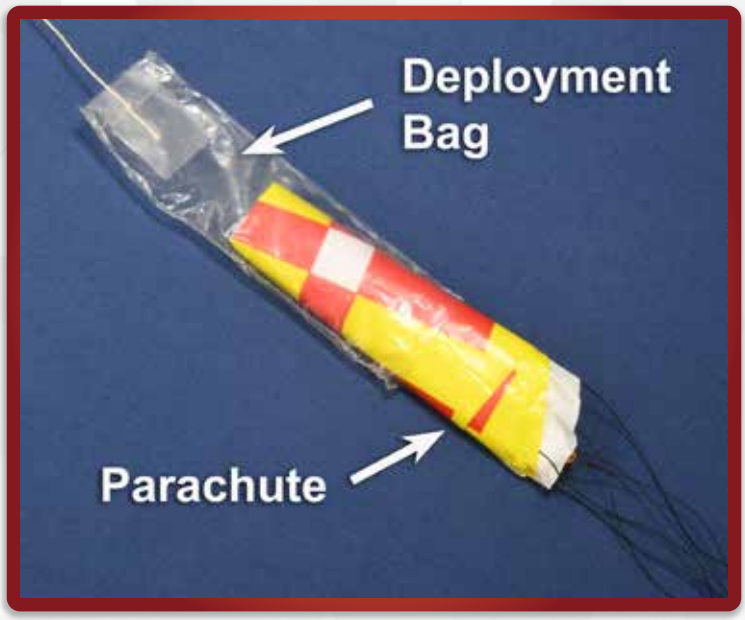

FIGURE 8: A SIMPLE DEPLOYMENT BAG MADE FROM CHEAP PLASTIC.

Ideally, the bag should be small, so that the parachute when folded up is snug inside the bag. We want it snug so that the parachute stays inside until the leader line and the suspension lines slip out and are fully extended. Additionally, you want it to be a "small" size because you don't want the bag to tangle with the upper parachute lines once it has opened.

The bag is open on one of the four sides. Attached to the opposite side of the open end is a leader line (regular stout string works fine - https://www.apogeerockets.com/Building_Supplies/Parachutes_Recovery_Equipment/Shock_Cord/Heavy_Cotton_String). You can attach the leader line to the plastic bag just using a strip of tape. Just make sure the line stays attached and won't come loose from the bag if you tug on it. If that leader line comes undone during flight, the parachute for the lower section will remain in the bag, and nothing is going to slow it down as it smashes into the ground. Make sure to tug on it as part of your pre-launch checklist to make sure the bag remains attached to the upper section of the rocket.

The free end of the leader line is attached to the base of the upper section of the rocket. You can attach the line to the same place where you attach the parachute of the upper section as shown in Figure 9.

Inside the bag, you're going to stow the parachute for the "lower section" of the rocket. When you pack the parachute, don't wrap the suspension lines around the parachute like you'd do for a regular small parachute. Instead, lay them zig-zag fashion towards the apex of the canopy. The idea here is that we want the lines to slide out of the bag while the canopy of the chute stays inside the bag (see Figure 10).

Continued on page 11

Ejecting Two Parachutes

Continued from page 10

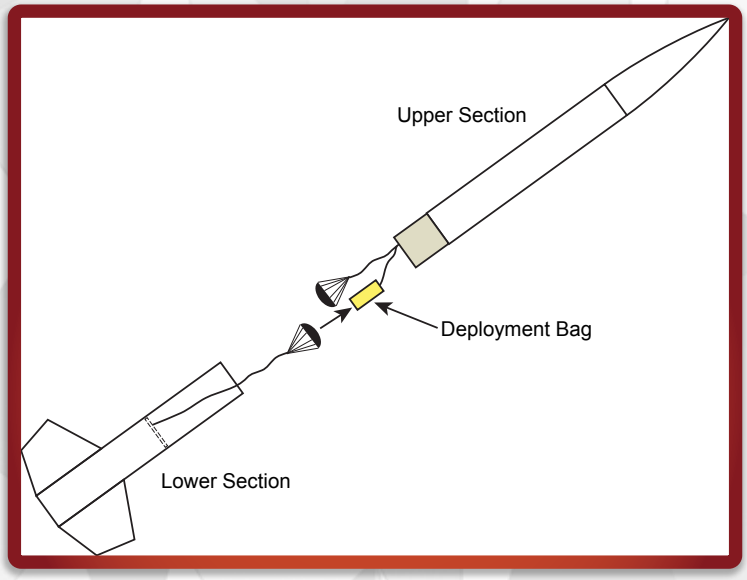

FIGURE 9: A SIMPLE DIAGRAM SHOWING THE DEPLOYMENT BAG ATTACHED TO THE UPPER SECTION AND HOW IT WILL PULL THE LOWER SECTION'S PARACHUTE OUT OF THE TUBE.

At this point you have the chute for the lower section inside the deployment bag, and the deployment bag attached to the upper section of the rocket by a leader line.

Now fold up the upper section's parachute, and this time do wrap the suspension lines of it around the canopy. By wrapping the lines around the parachute, you'll be delaying the opening of this parachute because it first has to unroll in order to stretch out all the suspension lines. This is what we want— just to slow it down from deploying a small amount.

The recovery wadding (or chute protector) will go in first. Then the two chutes can be stowed in the compartment in the fin-can section of the rocket. The lower section's parachute (inside the deployment bag) will go on the bottom, and the rolled up parachute attached to the upper section will go on top.

During the flight, when the ejection charge fires, it kicks off the nose cone. Both parachutes are "pulled" out this time. Remember, the lower section's chute, because it is in the bag attached to the bottom of the upper section is also pulled out.

Once it is out of the rocket, the suspension lines pull out from the bag. Once they are fully extended, the canopy is also pulled out. Now the lower section's parachute will instantly inflate.

The upper section then begins to unfurl the lines wrapped around its parachute, and then it begins to inflate. The deployment bag, still attached to the upper section, just flaps around in the breeze. If the leader line connecting

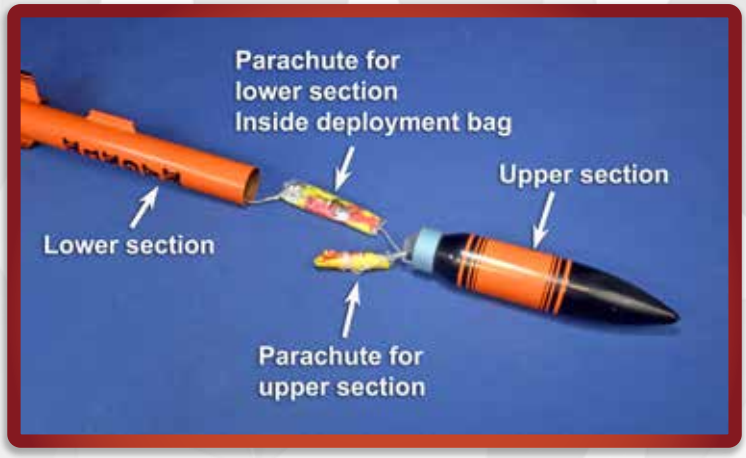

FIGURE 10: A ROCKET SET UP FOR SEPARATION USING A DEPLOYMENT BAG. NOTE THAT THE SUSPENSION LINES ARE NOT WRAPPED AROUND THE PARACHUTE WHILE INSIDE THE DEPLOYMENT BAG.

Continued on page 12

Ejecting Two Parachutes

Continued from page 11

the bag to the base of the upper section is short enough, it shouldn't interfere at all with the parachute of the upper section. You might also want to put a leader line on the upper parachute, so that its suspension lines are well clear of the empty deployment bag that will flap around in the breeze while the nose section descends.

If you want, you could use a second deployment bag attached to the lower section, which holds the upper section's parachute. So now the two deployment bags slide past each other as they are both pulled out of the rocket. This is the method I used on my own personal L3 project, which you can read about here (https://www.apogeerockets.com/downloads/Lifeproof_rocket.pdf).

It may seem complicated the way I described it, but in practice, it is not really that bad.

Other Common Questions

Do you need a leader line? As shown in Figure 4, sometimes you want to add a leader line between the payload and the suspension lines. The purpose of this leader line is to get the apex of the lines to be further away from the payload. Shown in Figure 4, if the suspension lines were attached deep inside the tube, it would be hard to even attach the parachute to the rocket. So a leader line is added to get the parachute attachment point out of the tube.

The leader line doesn't really help make the rocket descend more vertically. Nor does it stop the swaying of the payload. Not that I've been able to tell anyway. If the wind is blowing, and the side area of the payload is large, the wind is going to blow the model sideways. An example would be like having large fins on the bottom - which you might think of as a large sail on the bottom of the rocket. The wind will catch that and try to rotate it so that the drag resistance is minimized. The photos in this article just happen to be taken on calm days, so the rockets came down fairly straight to begin with.

Keeping the payload from swaying under the parachute has a lot to do with minimizing the side area of the payload, and also the canopy shape (such as having a large spill hole in the fabric). That is maybe a topic for a different article. But for parachutes that don't oscillate much, see Peak-of-Flight Newsletter issues #497 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter497) and #492 (https://www.apogeerockets.com/education/downloads/Newsletter492.pdf) and #485 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter485).

Conclusion

Separating a rocket into two parts for descent isn't often needed. But when you do, you need to set it up so that you make sure to fully eject the parachute for the lower section. It is a wonderful sight to see two parachutes drifting gracefully back down to the ground.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward an M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and also the author of the books: Model Rocket Design and Construction, 69 Simple Science Fair Projects with Model Rockets: Aeronautics and publisher of the "Peak-of-Flight" newsletter, a FREE e-zine newsletter about model rockets. You can email him by using the contact form at https://www.apogeerockets.com/Contact.

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