Confidential
Technical Report

TARC Tactics

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Useful information to give you an edge in the TARC-2006 competition.

By Tim Van Milligan

This year's TARC contest is more difficult than last year. It is a combination of three different objectives that you have to accomplish with just a single flight. You have to be good at all three if you want a chance to win.

1. Fly to as close to 800 feet as possible.
2. Land the rocket after a flight duration of 45 seconds.
3. Land without cracking the egg.

Number three in that list is obviously the most important. You crack the egg, and you automatically lose. DON'T CRACK THE EGG!

Meeting the first criteria of launching to 800 feet looks to be easy. However, if you meet this challenge, accomplishing the second one will be very difficult. Why? Because 800 feet is pretty high and you have to get the egg capsule down in a hurry to land within 45 seconds. Your egg must come down extremely fast.

Therefore everything comes down this important challenge: the key to winning is getting the egg to survive while landing at a very high speed.

If you do a little bit of math, which you probably already have done, you have discovered that the egg capsule needs to descend at an average speed of approximately 17.7 feet/sec. (800 feet divided by 45 seconds). That is very, very fast! If your egg hits the ground at this speed it is going to crack; and then you've lost.

My own typical rule of thumb is to have an ordinary rocket land at a speed of approximately 8 to 12 feet/second. And that is if the rocket is rugged and can take a hard landing. If it is carrying an egg, it should come down even slower so it doesn't crack it.

Actually, it is worse than 17.7 feet per second. You're rocket has to spend some time going upward, so you won't have 45 seconds to descend. I'd say you'll probably have 9 seconds for ascent, which leaves 36 seconds for the rocket to come down. So now your average descent speed is going to rise to 22.2 feet/second. SPLAT!

Egg Drop Experiment

Do you remember those science experiments in Junior High? You know — where you built egg-cradles so you could throw an egg out of the window and have it land without cracking the egg? That is the type of challenge you'll have to excel at for TARC-2006.

This whole contest comes down to an "egg-dropping" challenge. If you're good at dropping eggs out of windows without them cracking, you'll do well in TARC competition.

With this in mind, I predict that you'll have to concentrate most of your time and energy on building an apparatus that can cradle an egg so that it can survive when it hits the ground at a fairly high speed. Since this is such a big chunk of the contest, I'll give you some additional ideas later on in this article.

How To Win: Option Two

Actually, there is another option. And I'm sure you're thinking about it. You can have the rocket descend fast with a small chute for most of the trajectory, and then switch to a big parachute once the rocket is close to the ground. That way, when it finally touches down, it would be at a nice slow speed.

In rocketry, this is called "Dual Deployment Recovery." If you do an internet search on that exact phrase, you'll come up with additional information about the concept. You can also find information at: http://www.apogeerockets.com/Modern_hpr.asp .

You'll be happy to know that the RockSim software has capabilities to handle dual deployment. So using it will simplify your task for choosing the right size parachutes.

The key to getting dual deployment to work properly is to use some sort of electrical (or mechanical) timer to control when the big parachute is deployed. At a preset time in the flight, the big parachute is ejected out of the rocket and allowed to blossom, slowing down the descending egg capsule.

In theory, this should work. But there are trade-offs involved. There is obviously some added complexity. When you have additional complexity, you have more chances for things to go wrong in the flight.

In the typical rocketry dual-deployment scheme, there is a separate container inside the rocket that holds the big parachute. When the "electronics" indicate that it is time to eject, a small pyrotechnic charge is fired, which pushes the parachute out of the container.

Unfortunately, in the TARC competition, you will NOT be allowed to use black-powder to eject the big parachute (check the rules). This complicates the dual-deployment method, because now it is not so simple to get the parachute out of the rocket.

I can think of two methods to get around this problem. The first is some sort of mechanical device that doesn't rely on pyrotechnics to eject the parachute from the compartment within the rocket.

There is something called a "Parachute Dethermalizer" that might be useful. It works by releasing lines of a parachute to make it fall faster. You can find plans for this type of device included on the bonus CD-ROM. In this event, you'd have to

rig up something to release the big parachute, instead of releasing the suspension line strings.

There was recently an article in *Sport Rocketry Magazine* (July/August 2005), that had a device called a non-pryo ejection system. While this device is a bit complicated and heavy, it could also be used for dual deployment.

If you do come up with a new mechanical device, please let me know. I could personally use it on several of my own projects. I won't share it with anyone until after the contest is over, so your competitors won't know about it until you unveil it at the final event.

The other option is to use what is called a "burn string." This is used in rocketry all the time. An example of this is on the Apogee Components' Heli-Roc model kit (http://www.apogeerockets.com/Heli_Roc_Kit.asp). This is a helicopter-recovery model, where the blades are held down against the side of the rocket by a tiny thread. When the ejection charge in the motor fires, the thread is burned in two, which frees the blades. A tiny rubber band then pulls them to the open position.

In your rocket, you would combine the burn-string system with an electrical timer. You could wrap the parachute (or otherwise contain it in the compartment) by the thread. Do you get an idea where this is heading?

You would use the "electrical" timer to fire off an igniter. If the igniter is held tightly against the string, the heat should be able to burn through the thread. Once the thread is burned, it releases the parachute, allowing it to unfurl.

Is this legal for the competition? Yes. You're not using black powder to eject. You're just using a single igniter; which is the exact same type of igniter that you use to ignite the rocket engine. According to the contest rules, you ARE allowed to use this if you choose. Of course, they may change the rules, so stay current on them.

Which Way Is Better?

As you might expect, you and your team will have to weigh the pros and cons of each method. I personally lean toward simplicity. That reduces the number of things that can go wrong. So designing the capsule to cradle the egg for a hard landing would have an edge in my mind.

And even if you use dual-deployment techniques, you will still have to put some thought and energy into protecting the egg. If you can do that for a high speed landing, your margin of safety is further increased should you decide to go with dual-deployment parachute strategies.

Electronics does add complexity and increases the chances of something going wrong. For example: you might have a drained battery that fails to fire off the igniter. Or the burn string might fail to split when the igniter does fire. Or the string burns through, and somehow gets caught or snagged on something in the rocket. I've seen all these things happen, many on my own rockets. So weigh the alternatives before you decide which way to proceed.

Find Your Parachute Size

You don't have to decide right now which strategy you'll be using. But you should take some time to investigate what size parachutes you'll need.

Each parachute has its own descent characteristics. You need to figure out what size chute will give you the desired descent speed. For example, if you need the capsule to land at 15 feet per second, what size parachute should you use?

For a rough estimate, you can use the RockSim software. It has a parachute descent calculator built into it. Basically, you'll adjust the weight of the rocket to match the amount of payload coming down, and see what size parachute will be needed to match that descent velocity.

There is a how-to video on the bonus CD-ROM that shows how to use RockSim to size the parachute you'd need. But you'll still need to do drop tests. Each parachute has its own characteristic (coefficient of drag), which is hard to predict. The only way to find it is by doing drop tests. RockSim will get you in the ballpark, but you'll still need drop tests to confirm the results.

Once you get the size of the parachute, the next thing to do is start working on the egg capsule.

Design the Capsule for High Speed Landings

Whether you use simple "small-chute" recovery or "dual-deployment" strategies, eventually the egg capsule is going to land on the ground. You WILL need a capsule that offers some protection, even if it is just a little bit. If you can successfully design a capsule that protects the egg even at very high impact speeds, you'll have an advantage. That would mean you have the option of using either of the two recovery techniques – either a single parachute, or dual-deployment.

If through your experiments you find that you aren't able to design a capsule that can protect the egg when it impacts the ground at high speeds, then you're only option is to use some sort of dual-deployment technique. This means extra work for your team compared to using a single parachute to bring the model down.

Either way, you must find the maximum speed your capsule can tolerate. Once you know that, you then design the rest of your rocket around that particular parachute size.

Crumple Zones

One major technique used in egg-drop contests is to design an apparatus that crumples when it lands. This is the same technique automobile manufacturers use when designing cars to protect people from injury in auto accidents. The car is designed to crumple and twist so the people inside don't get hurt.

Why crumple? Great question. It comes down to energy dissipation. The rocket, when it is at 800 feet in the air has a lot of Potential Energy. This is converted to Kinetic Energy as it falls. The faster it falls, the greater the energy released when it smashes into the ground. If you don't have any kind of capsule, 100% of that energy is transferred to the egg. And it makes a big splat.

You need to dissipate that energy before it can be transferred to the egg. Crumpling is one way to do this.

Here is an example. Take a tree stick and break it in two. You had to use energy to break the stick. Do you understand? It takes energy to crumple and break things like sticks.

In this event, you must use up all the energy by designing a capsule that crumples before it has a chance to be transferred to the delicate egg. In effect, you're doing

the exact same thing as car manufacturers.

Why not use a lot of cushioning? Well, cushioning is similar to crumpling. Except the energy it can absorb is small compared to snapping a piece of wood in half. So you would have to use a whole lot of cushioning. It would be so large and bulky, that you'll have a huge, bulbous rocket.

Your rocket will be smaller and lighter if it utilizes crumpling instead of cushioning alone. Is this an advantage? It can be.

Smaller/lighter rockets use smaller (i.e. cheaper) rocket motors. They also need smaller parachutes to descend. Ask yourself: "What is more reliable: ejecting a small chute out of a rocket, or ejecting a big one?"

Depending on the size of the tube holding the parachute, it is a lot easier to eject and deploy a smaller chute than a bigger one. It doesn't plug the tube as tightly, so they come out a lot easier and faster. And since it comes out faster, they are less likely to get burned, melted or charred by the ejection charge. A melted parachute is very common in rocketry, because the modeler's flying skills are very poor. They don't know how to properly prep a large chute to be ejected from a small tube. In this case, a smaller chute can be a huge advantage.

Here are 10 other tips to help you win:

1. I've found through watching other rockets impact into the ground that a pointy nose cone is better and more survivable. Why? Because as the tip of the nose pokes into the ground, it pushes the dirt to the side. That takes energy to do, which means the rocket slows down faster.

Since pointy is better, stay away from the Apogee egg-capsule nose cone. While I'd love to sell it to you and make money, I'm telling you up front that it won't be good for this event. It isn't pointy, and it will smash your egg if it lands fast (which is what this event is all about).

And if you do use a pointy nose capsule, doesn't it make sense that it must land tip first? Of course!

So what are you going to do to insure that it does land tip down? Another question to ask is "what causes the nose cone to land on its side, or at an angle?" I'll give you the answer to this question: the PARACHUTE.

If your parachute sways around as it falls, it is likely that the nose will not be pointed straight down when it impacts the ground. If that happens, "splat" will be the word all the onlookers will say in harmony.

When you design your egg capsule to crumple, you want it to land so that the crumple-zone is that part that hits first. This makes sense, doesn't it? So you have to make sure the parachute doesn't sway the capsule around as it descends.

How do you do that? You cut a hole in the top of the chute. This is called a spill hole. Most people think that they are used to make the chute fall faster. But actually, their primary purpose is to stabilize the chute and keep it from swaying. So you can use this to your advantage to keep the nose from oscillating around as it falls.

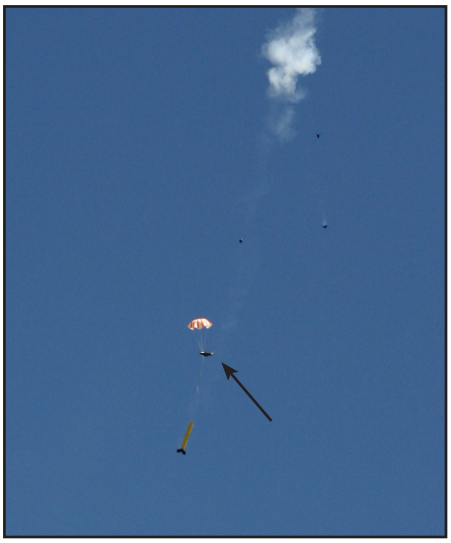
2. Weight is not an issue, because the 1500 gram lift-off limit is huge for just one egg. In other words, don't worry about the vehicle being heavy. You can always put a larger rocket engine in it. However, more weight will make your rocket more expensive, because larger engines cost a lot more than smaller ones. If you're on a tight budget, excessive weight will be your enemy.

3. You might want to consider separating the nose cone from rest of rocket, so the egg capsule comes down separate from the engine section. Why? If everything came down together, you may have the rocket oscillating wildly as it descends. This will make it fall at an inconsistent velocity. On one launch it may fall fast, and on the next, it may fall slower.

Also, if you plan on swapping the nose cone out between flights, you do have to worry about the durability of the bottom section of the rocket. You don't know how many times people have failed to inspect their rockets between flights. They think the shock cord mount is in the same condition after it just got scorched by the ejection charge of the rocket engine. So on the next flight, they are surprised to see that the bottom section is free-falling to the ground. It has separated from the capsule of the rocket because it was weakened by the previous flight. If a portion of your rocket comes down without a recovery device, and it isn't tumbling slowly, you will get disqualified, even if the egg capsule does come down safely.

If the rocket separates into two sections, there is less stress on the parachutes and the shock cords, which can help you prevent durability problems. But you have to weigh this against the complexity of the rocket. Two parachutes means there are more chances for things to go wrong.

Also, as mentioned previously, if you are going the crumple-zone route, you want the capsule to land pointy end down. I can tell you that there is a more likely chance that the chute will oscillate if the engine section is also dangling from the same chute. So having the bottom portion of the rocket descend by itself will allow you to get the capsule portion to descend in the correct orientation for landing.



See how the capsule portion is coming down horizontally in this image?

4. Consistency, consistency, consistency.

Like all the previous Team America Rocketry Challenge contests, you have to be consistent from one flight to the next. You will need to practice, practice, practice. You can't expect to win if the final model you launch is significantly different from the one you flew in the qualification round.

If you go with the "crumple" nose cone method, you will end up having to build dozens and dozens of nose cones so you can be sure that the egg can be protected in a high speed landing. If you aren't willing to spend a lot of time and effort practicing, you will lose. Because the rocket is going to fall so fast, there is no room for error.

5. The rocket must fly straight, even if it is windy. Since the weather is the one thing you can't control, you have to make sure your design will go straight up, no matter what the wind conditions. Making wind adjustments at the last minute is very tricky. If it doesn't go straight, it won't be nearly as easy to predict how high it will fly. And this only compounds things. If it doesn't hit the 800 feet, it will fall to the ground faster, and then you'll gain too many points for time aloft. You have to be consistent on hitting 800 feet in any wind conditions, or it will throw off the duration aloft portion of the contest.

It is much easier to plan ahead for wind, and design the rocket so it will fly straighter no matter what the wind is doing. How do you do this? Great question.

For one thing, you want to use "high-thrust" rocket motors. These will get the rocket flying faster, which makes it harder for the wind to turn the rocket. For example, an E30 is a high thrust motor, while an E6 is a low thrust motor. Use the highest average thrust that you can find to get the job done. You want to punch that rocket into the air as fast as possible.

Another way to counteract the effects of wind is to spin the rocket. This can be accomplished in a number of ways, such as canted fins, or camber-airfoil fins. I'm surprised at how few people actually spin their rockets to counteract the wind. But it works great.

Spinning does add drag to the rocket, and makes it harder to predict the altitude until you actually go out and test the design. But once you backtrack the Cd for the flight, you can easily input that number into the RockSim simulation software and predict the altitude of the next flight even more accurately.

Of these two flights, which do you think will consistantly fly to the same altitude? What can you do to insure a straight trajectory?

There are some designs, like rockets that use tube fins and ring tails that are less susceptible to wind than models with ordinary flat fins. These rockets seem to fly straighter in high wind, which would be useful if you don't know what the wind will be like on the launch day.

In summary, planning ahead for any type of wind isn't difficult. You just have to think outside the box.

6. Use nylon cloth parachutes. You're going to need strength and durability. These rockets will need to deploy at high speeds, and they will fall fast. A plastic parachute will be lighter, but the decreased durability will mean it could fail somewhere in the flight. It is worth the cost to use a better parachute.

7. Use just one single motor in the rocket. There isn't much reason to use clustered-together motors, or multi-stage rockets in this event. Why? Because there are no extra points for complex rockets, so keep things simple and use just one motor. The more motors you use, the more complex things get and the greater the chances for things to go wrong.

8. Unless you have a lot of money to burn, DON'T fly the altimeter until you are sure you can recover the egg without cracking it. The more times you fly the altimeter, the greater the chances of it being smashed to pieces.

How do you measure the altitude of the rocket without using the altimeter? Great question. You can do it the old fashioned way by using tracking scopes. This is highly accurate, and a great learning experience too. This contest is an educational event too, so this would be a great way to learn more about trigonometry and altitude determination.

You'll find more information in the Apogee Peak-of-Flight e-zine newsletter #92 and #93.

9. Quality doesn't win you extra points; but it does win contests.

What does that mean? If your building skills are poor, you're going to build poorly constructed models. This affects consistency from one flight to the next. So your final flight will be completely different from the qualification flight that got you to the finals.

On the other hand, when you build quality models (precisely built, with excellent surface finish), you'll see consistent and predictable results from one flight to the next. That is what you want, right? You want your final flight to be just like your qualification flight.

How do you learn proper building skills that lead to quality models?

Do you learn by reading about it in a book or on the internet? Unfortunately, no. If that were the case, every team would qualify.

Think about that for a second. Every team has the same access to the free stuff written on the internet. But why do most rockets look and fly like junk? I'll tell you right now, it isn't the quality of the stuff written on the internet. The information is good. It is written by some honest-to-goodness "knowledgeable" folks, with years of experience. I've written some of the material myself.

The problem is that the information doesn't make it the last couple of inches from the reader's eyeballs to the processing center in their brain. Somehow, there is a short circuit in the system.

If you can't learn proper building techniques by reading about it, how do you learn them? Simple: by listening and watching an expert builder do it first. You didn't learn to tie your shoes by reading about it in a book, did you? Of course not. You watched someone that knew how to tie shoes, and then they mentored you on how to do it.

In the same way, you learn building techniques by watching an expert modeler do it.

Where do you find an expert modeler? Most new rocketeers look to their friends for advice. But when they do this, they make a fatal assumption: they think their friends are experts. When in fact, those people are also doing things the wrong way; except no one told them they were doing it wrong.

There is no certificate in the hobby that says someone is or isn't a rocket building expert. So everyone that gets one model to have a successful flight thinks of themselves as an expert. In fact, they were just "lucky."

If you are still reading this section, I assume that you have put your ego to the side, and are willing to hear what I have to say. The so-called rocketry experts have already jumped to the next section, and have bypassed this information. So you do have an advantage over them, as the models they build will be inferior and inconsistent from one flight to the next.

There are two tools that will help you do well in the TARC-2006 contest. The first you know about: the RockSim software. The second is the Apogee Components' video books that walk you through the techniques in how to build rockets the right way. If you view these video books, you'll possess building skills that only 10 percent of all rocketeers know about. That gives you an edge over your competition. You can find them at: http://www.apogeerockets.com/video_book_collection.asp

I'm certain most readers of this report will gloss over this section. After all, who is going to tell you to build crappy models? Everyone will tell you to build quality models, so it makes sense to skim over the section on "building quality models." Those that do will be at a disadvantage. Their egos are in the way of them succeeding. Too bad for them. But hurray for you — IF (big "if") — you actually go out and get the video books and watch them. Unless you take the step and get them, you are no better off than the people that skimmed over this information. Are you willing to invest in yourself, and do what it takes to win? Or are you just going through the motions and trying to get this project over with the least amount of work possible?

10. Pick the brains of your team's mentor. They probably have a lot of flying experience and can be a great source of information. When talking to them, the key question to ask is "Why?" When they make a recommendation to you, find out the reasons "why" they picked that one over some other solution. This will allow you to evaluate and compare different strategies. You'll be surprised at how right they are.

Conclusion

The TARC-2006 competition is going to be difficult. What I believe is the key to success is building a capsule that can protect the egg at a high speed touchdown. This opens up a host of possibilities in regards to engine selection and flight strategies.

If you can't accomplish a high speed landing, then you'll have to switch to a dual-deployment scheme to bring the capsule down safely. This adds complexity and increases the chances for things to go wrong. I believe that it will also be difficult to do with any consistency from one flight to the next. For that to happen, conditions have to be nearly perfect.

The goal of this report was to explain some of the different options available to you in this competition. Many of them are obvious as you read through the rules. Eventually, you'd come to the same conclusion as I've given here; like using a single motor as opposed to a cluster of motors. But I wanted to point them out, just in case you may not have thought of them.

I hope you take this event seriously, and get started as soon as possible designing and test flying your rockets. The more practice you get in, the more consistent your flights will be. This greatly improves the chances of winning the top prize.

When you do win, please send me a note. We'd love to see a RockSim user win.