The Purdue Rocketeer's Guide to the Galaxy:

How to Earn Certifications with PSP

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Update Log

Update Draft and Date	Author of Revision	Revised Material
Draft A - 1/1/2024	Erika Denker	- Entire HPR document written and published for general PSP use
Initial Release A1 - 1/8/2024	Grant Williams	- Changed document name to minimize chance of offense - Reworded introduction to better remove religious nomenclature
Release A2 - 2/7/2024	Grant Williams	- Added PSP Pre-Launch Checklist

Introduction to the PSP HPR Guide

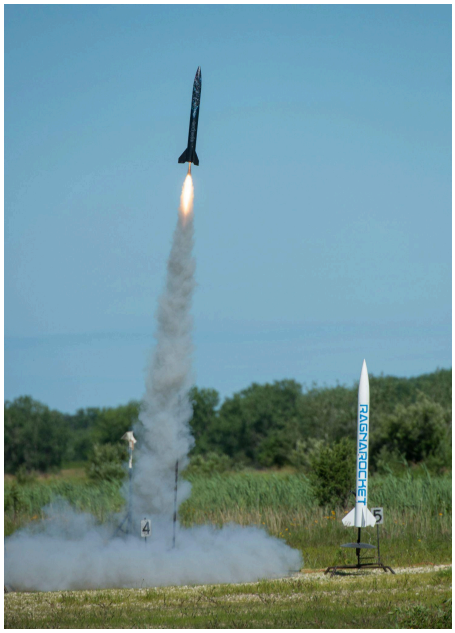
Welcome to the Purdue Space Program High Power Rocketry Guide! This is meant to serve as a resource for PSP members to pursue their high power rocketry certifications. In this document you'll find plenty of information about how PSP handles Level One certs, as well as resources for upper level certifications. If you're working towards your Level One within the club, odds are a lot of this guide will be explained to you in person or taken care of by PSP HPR leadership. However, please feel free to consult this guide at any step along the process.

As you look beyond your Level One certification towards Level Two or Level Three, there will be some advice and links provided to get you started, but the club doesn't currently support any build days or purchases towards Level Two or Level Three certifications.

If you have any questions about the contents of this guide, please reach out to EJ Denker or any other member of PSP's executive team.

Happy launching!

~ EJ Denker



What is High Power Rocketry?

High Power Rocketry (HPR) is the next step beyond model rocketry, using rocket motors that literally give you more bang for your buck. The legislation controlling HPR was written by the National Fire Protection Association; the public is expected to follow the Code for High Power Rocketry (NFPA 1127) so no harm comes to any people, places, or things[1]. After all, HPR is essentially permissible directional explosives, so it makes sense that there are some rules. In this section, we will discuss what you need to join the high power rocketry community and gain additional leveled certifications to launch bigger rockets safely.

HPR Motor Classifications

Solid rocket motors are classified by the total impulse they produce in units of Newton-seconds (Ns). Therefore, HPR motors belong to a class of motor with higher impulse than hobby rocketry and that is why they are so controlled.

Motors are classified by letter, with A being the smallest impulse. For every letter that you advance, the total impulse of the motor doubles. Therefore, if a B class motor produces 5 Newton-seconds of total impulse, a C class motor can be expected to produce 10 Newton-seconds.

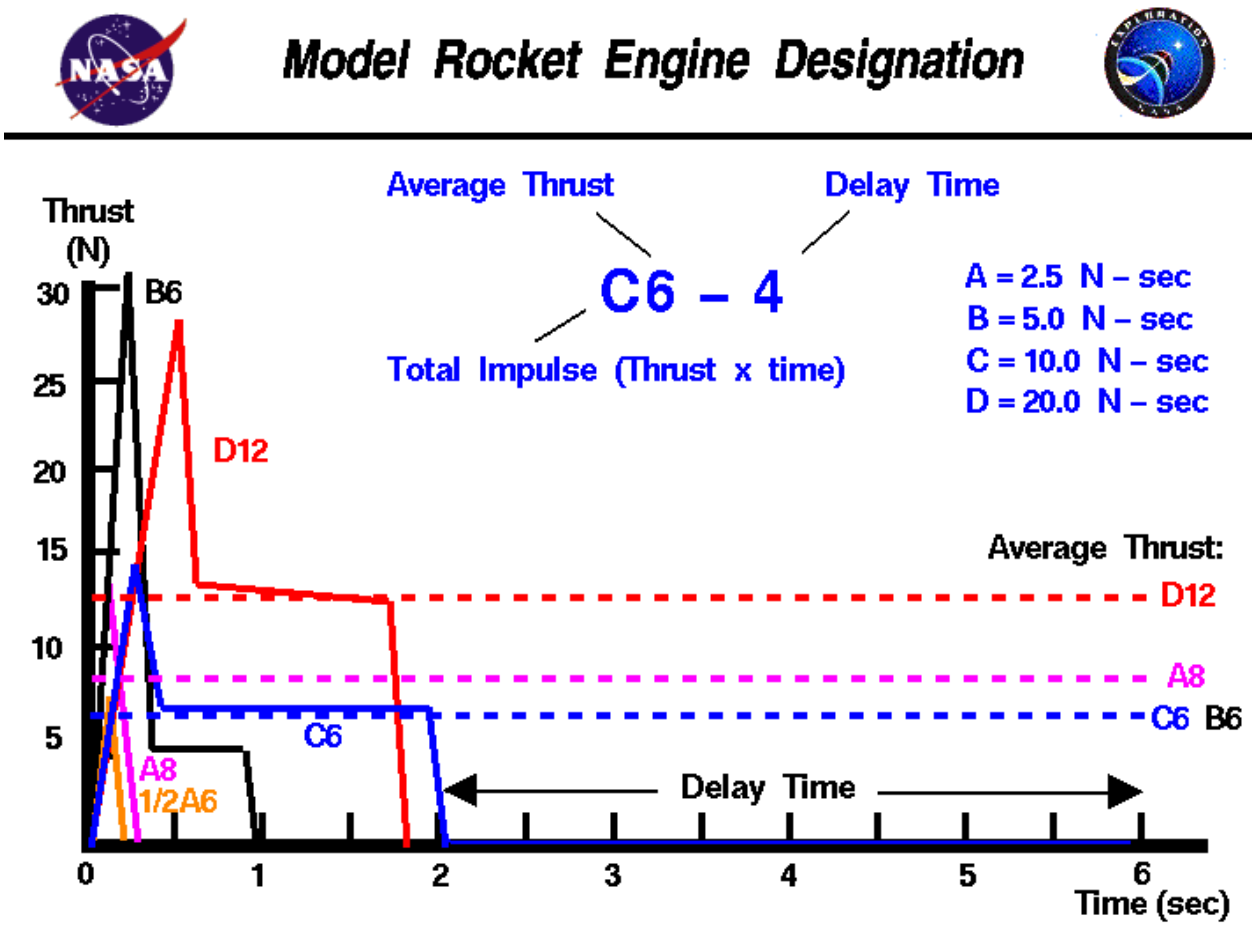
The following table shows the expected total impulse for all hobby class motors[2]:

Classification	Impulse Range	Impulse Limit	Category
Model Rocket	1/8A	0.3125	Micro
	1/4A	0.625	Low Power
	1/2A	1.25	
	A	2.5	
	B	5	
	C	10	
	D	20	
	E	40	Mid Power
	F	80	
	G	160	
High Power	H	320	Level 1
	I	640	
	J	1280	Level 2
	K	2560	
	L	5120	
	M	10240	Level 3
	N	20480	
	O	40960	

[1] https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1127
[2] https://www.nar.org/standards-and-testing-committee/standard-motor-codes/

As shown in the above table, HPR covers motors from class H to class O, divided further into three leveled categories. You need certifications to launch any of these class rockets, but A through G class motors can be bought and flown by anyone without certifications.

However, not all motors within a class are the same. Each motor comes with a motor code, which looks something like this[3]:



There are three components to the motor code on a rocket when you purchase it:

1. Letter - the class to which the motor belongs
2. First number - the average force (aka thrust) that the rocket will deliver over the course of the launch. The above image shows the thrust curve over time for a variety of rockets; observe that the C6-4 rocket's average thrust curve falls at 6 N on the vertical axis.
3. Second number - the delay time between the primary burn of the motor and the firing of the ejection charge. This ejection charge is what releases your recovery system, so the delay time is equal to the amount of time your rocket is in the air without propulsion but before your parachutes deploy.
4. Some motors have a letter after the delay. This indicates the propellant type (or color) of the motor when it fires. It doesn't affect the flight itself, it's extra knowledge.

[3] https://www.grc.nasa.gov/www/k-12/rocket/rktenglab.html

Fun fact: Generally, the aerospace community refers to solid rocket propulsion systems as “motors” and liquid rocket propulsion systems as “engines”. Therefore, HPR only employs rocket motors, not rocket engines. This distinction is related to the fact that liquid systems typically require pumps and cycles like car engines.

Governing Organizations

There are two international organizations that understand these rules thoroughly and support public rocketry initiatives. The National Association of Rocketry (NAR)[4] and Tripoli Rocketry Association (Tripoli or TRA)[5] offer memberships so you can launch high power rockets under their governance. By becoming a member of either of these groups, you join a network that will help ensure you follow the government regulations. In PSP, we encourage memberships with Tripoli. However, it isn’t a problem if you join NAR instead; most launch sites support launches from either organization.

Getting Involved with Tripoli

Here is a step-by-step guide to get a membership with Tripoli Rocketry Association. Memberships cost the member $20 per year. *Remember, you cannot get any HPR certifications without a membership from either Tripoli or NAR.*

1. Go to Tripoli’s website, which is https://www.tripoli.org.
2. Click on the “Membership Information” tab in the hot bar towards the top of the web page.
3. Scroll down and click the button labeled “Click to Join Tripoli Instantly!”
4. Select the “Student” Membership Type and click “Next”.
5. Click on one of the “I Agree” options after reading through the Terms of Use and Privacy.
6. Fill in all of the information indicated as required by the red dots.
7. Click “Next” through the next couple tabs. We don’t have a Prefecture.
8. Create a User Name and Password. WRITE THESE DOWN! Click “Next”.
9. Click “I Agree” to the Member Sign Up. Click “Next”.
10. Confirm your information and click “Submit Application”.

After this, Tripoli should walk you through the process of paying for your membership. It may take a couple days, but you should eventually get an email certifying that you are a member of the Tripoli Rocketry Association and that you can download your digital member ID card. Make sure to save this card, and welcome to Tripoli!

[4] https://www.nar.org/
[5] https://www.tripoli.org/

HPR Certifications

In order to launch higher impulse rocket motors, Tripoli requires their members to pass certification tests[6]. These tests get more rigorous as you climb to higher HPR levels, but at their basis they all require a single person to build and fly a rocket with a motor from the level you are trying to certify for with successful recovery. The following sections go into more detail about each level Tripoli offers and the requirements to be certified. An important note: *as long as you keep your membership dues up to date, your HPR certifications remain current.* Otherwise, your certifications will no longer be valid.

If you lose your certifications or haven't earned any yet, you are technically a Level 0 member of the organization.

Basics of Level One (L1) Certification

Earning your L1 HPR Certification allows you to fly up to 640 Newton-second motors, or class I motors[7]. At its basis, you are required to fly a rocket that you built with either an H or I class motor onboard, and it must recover intact. It must have a standard or conventional airframe design with a marked center of pressure. The recovery system must also employ the use of a parachute as opposed to other recovery methods. The flight must also be under the direction of a certifying member of Tripoli who then performs your post-flight inspection.

Basics of Level Two (L2) Certification

Earning your L2 HPR Certification allows you to fly up to 5120 Newton-second motors, or class L motors[8]. Unlike the L1 certification, the flyer has to pass a written examination before being allowed to certify. There are quizzes and practice exams on the Tripoli website.

Similarly to the L1 certification, you are required to fly a rocket that you built with a J, K, or L class motor onboard, and it must recover intact. It must have a standard or conventional airframe design with a marked center of pressure. The recovery system must also employ the use of a parachute as opposed to other recovery methods. The flight must also be under the direction of a certifying member of Tripoli who then performs your post-flight inspection.

Basics of Level Three (L3) Certification

Earning your L3 HPR Certification allows you to fly motors greater than 5120 Newton-seconds, or motors of at least M class[9]. L3 certifications are very difficult, but not impossible. They require working with TAP (Technical Advisory Panel) members and gaining 2 TAP members' approval on your design before starting any construction[10]. Unlike any prior certification, the flyer is required to launch and successfully recover an L2 rocket with an electronic recovery system before they are allowed to attempt an L3 certification. The flyer must also provide checklists and documents to TAP members that are not required for any previous

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[6] https://www.tripoli.org/content.aspx?page_id=22&club_id=795696&module_id=468541
[7] https://www.tripoli.org/content.aspx?page_id=22&club_id=795696&module_id=468544
[8] https://www.tripoli.org/content.aspx?page_id=22&club_id=795696&module_id=468687
[9] https://www.tripoli.org/content.aspx?page_id=22&club_id=795696&module_id=479470
[10] https://www.tripoli.org/content.aspx?page_id=22&club_id=795696&module_id=479472

certification. The recovery system must include at least two completely separate electronic systems as primary and backup means of deployment.

Similarly to prior certifications, you are required to fly a rocket that you built with an M, N, or O class motor onboard, and it must recover intact. It must have a standard or conventional airframe design with a marked center of pressure. The flight must also be under the direction of a certifying member of Tripoli who then performs your post-flight inspection.

It is recommended that you consult with the Tripoli website and L3-certified individuals if you're looking into gaining your own L3 certification. It's a complex and expensive process, but there are plenty of online resources out there to help.

What PSP Will Help You With

PSP as an organization is dedicated to increasing student knowledge of rocketry, and thus, we're incredibly interested in helping you earn HPR certifications! Although we can't promise you assistance with every step along the way, our organization has implemented procedures and events in place to ease people into HPR. We tend to focus on L1 certifications and provide the most support for members with those goals, but many of the below topics will have relevance and importance to higher level certifications as well.

Acquiring Your Rocket Kit

Every amateur rocketeer may dream of a custom built system, but *I strongly recommend flying your certification flights on a rocket built from a kit.* This is simply due to the fact that a kit has prior testing and is more likely to survive the flight, since a certification flight is your first exposure to flying a motor of a certain class and impulse, or in the case of L1, your first time flying high powered motors at all. These certifications are meant to be a learning experience; with great power comes great responsibility, and the governing organizations of HPR want to make sure they're putting power in the right hands.

That being said, diving into the world of HPR can be very overwhelming. What kit fits my needs? I know I need an L1 motor, but how do I get one? We've taken care of a lot of those steps for you.

The rocket kit that PSP purchases in bulk for members hoping to earn their L1 certification is called the LOC IV[11]. You can decorate it however you want, but this is what the general shape looks like:

LOC Precision makes these kits and they have a tried and true history (inside and outside of PSP) of reliably allowing rocketeers to earn L1 certifications. Because we purchase these in bulk, buying this kit through the club is usually a lot cheaper than buying a kit independently. That being said, we'd never stop you from buying any other kit on your own.

[11] https://locprecision.com/products/loc-iv

The process for acquiring one of the kits through PSP is simple:

1. Wait for the HPR representative to release a form asking about kit purchases. This typically happens once a semester, but is truly at the discretion of the HPR representative and the wider PSP executive board.
2. Fill in the form to sign up to get a kit.
3. Pay for the kit via TooCool, which is a Purdue website through which clubs can perform transactions under the supervision of Purdue administration.
    a. Log in with your student information.
    b. Search “purdue space” in the search bar.
    c. Click on Purdue Space Program’s TooCool page.
    d. Navigate to the link about L1 kit payments.
    e. Pay whatever the L1 kit costs that semester.

Once you’ve submitted your payments in TooCool, it’s a waiting game. Eventually, when the kits come in, the HPR representative will either let you know where to pick up your kit or bring kits to L1 build days.

An important note: we include motors in our kits, but if you order a kit elsewhere, you’ll have to order a motor separately from the kit.

L1 Build Days

An L1 build day is an event where anyone interested in assembling HPR rockets can come build them. These were created with the intention of allowing those who ordered kits to assemble them, but we also welcome others (and their other rockets) at these events!

Essentially, these events will be announced by your HPR representative whenever kits are in and space is free for the build day to be held. Materials like epoxy are provided, and in the specific case of the LOC IV, PSP members who have already built the kit are there to teach and assist with the builds. The LOC IV instructions can be pretty cryptic, so these people are going to be your number one source on how to make sure your kit will fly and survive the certification flight. If you can’t make it to one of these days, you’re more than welcome to build on your own, and I’ve provided our own PSP experience-guided instructions later in this guide.

Getting (or Storing) Your Motor

I’m going to write this in big red letters so you’ve been sufficiently warned:

IF YOU TRY TO KEEP A ROCKET MOTOR IN YOUR DORM OR APARTMENT, I WILL PERSONALLY DROP KICK YOU INTO THE MOON.

“But EJ, what do I do with my motor before launch?”

Well, if you order a kit through PSP, we won’t give it to you until you’re driving to your launch. If you go to a build day, we will give you everything you ordered without the motor.

"So then, where is my motor? How do I get it?"

Conveniently enough, we have a lovely giant propulsion lab complex called Zucrow Propulsion Laboratories with a lot of cabinets made for storing motors just like these. Even better, Zucrow likes our club (and also likes not having students caught with propellant in their dorms) and is willing to let us use those spaces. Even better, we have a contact at Zucrow who is one of our club advisors!

If you're looking to store a motor that you've purchased or pick up a motor you ordered through PSP, your contact is Chris Nilsen. You can message him through the PSP Slack, but he can also be reached at cnilsen@purdue.edu. He is more than willing to help students with motors and the like. If you're going to a launch day with a lot of other PSP members, odds are he'll mention something about picking up motors or ask who needs motors soon. If you don't want to reach out to him directly, your HPR representative is in touch with him.

Launch Days

Anyone can go to a launch, but launching at a launch day is a bit more complicated. Before going to a launch day with the intention to launch, make sure you've consulted the following checklist:

- ☐ Do you have a rocket that is launch-worthy?
- ☐ Do you have proof of membership in either Tripoli or NAR?
- ☐ Do you have your Universal Certification Form filled in and printed out[12]?

To get to a launch day, there are a couple options available. Any time that PSP organizes a trip to a launch site, there will be surveys, spreadsheets for carpooling, and announcements indicating that we're going as a club. Keep an eye on the main PSP communication channels and there should be plenty of notice in there.

It's also perfectly fine to go to a launch day without PSP. Rocketry clubs across the Midwest regularly hold launch events that anyone can attend; these are the events PSP goes to, but you can go on your own. One of our favorite local clubs is Indiana Rocketry, Inc.[13] which is located in Lafayette. They have a launch calendar on their website and will post the day before if a launch is scrubbed (cancelled). Occasionally we'll drive up to Bong Recreation Center in Wisconsin for bigger launches, so you can check for WOOSH Rocketry to hold launches at Bong on their Events page[14]. Bring cash–they require everyone who launches at WOOSH events to pay a launch fee of $10 for non-members.

Once at a launch day, you'll have to find the rocketry club members running the event. At all the launch days I've been to, they usually have a table and/or a tent where they sign rocketeers up to use the launch rails. If you're looking to launch, but especially to certify, these

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12 https://s3.amazonaws.com/ClubExpressClubFiles/795696/documents/Universal_Certification_Form_1405254603.pdf?AWSAccessKeyId=AKIA6MYUE6DNNNCCDT4J&Expires=1695684849&response-content-disposition=inline%3B%20filename%3DUniversal_Certification_Form.pdf&Signature=nQzEf%2FfmKR2c0wFTdk4Uc%2FTqLEc%3D

13 https://www.indianarocketry.org/

14 https://www.wooshrocketry.org/events-1.html

are the first people you'll have to talk to. Once you've properly prepared your rocket for launch, bring it to these people along with your membership information to ensure that you're set up to launch. These are also the people who will monitor your L2 written test if you're going for your L2 certification. Keep in mind: *all of these people are volunteers! Be nice!* We're all at these events because we want to launch rockets, and these people are very generously offering their time to help you do so.

How to Make the LOC IV Rocket Kit

Your Materials

The LOC IV 4” kit is one of the standard kits that the HPR community uses for L1 certifications. The kit itself comes with the parts needed to construct the rocket, but if you work with PSP and come to our build days, we’ll provide additional materials and a motor for you.

Parts that generally come with the LOC IV 4” kit:

- Body tubes - 2, one with fin slits
- Coupler
- Nose cone
- Fins - 3
- Motor tube (sometimes called the “engine mount”)
- Centering rings - 3
- Shock cord
- Parachute
- Various smaller pieces (I recommend leaving these sealed in a bag for as long as possible)
    - Eyebolts
    - Motor retainers
    - Carabiner
    - Rail buttons

Additional materials PSP provides with your purchase of a kit:

- Motor (we typically provide something in the H100 range)

Additional materials PSP provides at build days:

- Epoxy
- Sandpaper
- Popsicle sticks
- The expertise of already-certified PSP members

Assembling the Kit

Although assembling a kit like this can be daunting, many videos and instruction guides exist to help you in constructing your rocket. Here’s one instruction guide that we like and is current (when I wrote this):
https://cdn.shopify.com/s/files/1/0568/7489/3503/files/PK-48-Instructions.pdf?v=1623760037

The PDF is out of order but it communicates the basic steps needed to build the LOC IV. However, I will communicate some extra details or tips in the sections below.

Assembling and Attaching the Internal Structures

Your rocket is essentially the stack of your nose cone on top of your small body tube, with a coupler securing that body tube to the larger tube, which then accommodates your fins so the rocket can sit up straight. However, the motor that makes your rocket fly needs somewhere to live–this is your motor tube, which holds the motor in the center of the body tube, suspended by the centering rings.

To construct this apparatus, reference Steps 1 and 2 in the PDF. My recommendations are to triple-check that your centering rings fit between your center and aft rings, and to not apply epoxy on the sides of the centering rings where the fins get attached. It's not horrible if you accidentally epoxy those sides of the centering rings, but it may make it more difficult to slide the fins in later.

Another recommendation when working with the motor structure and inserting it into the body tube is to make sure that you do not epoxy the edges of the rings that will slide along the fin slots in the body tube. If this happens, you'll have to clean out those fin slots before the epoxy hardens, otherwise you won't be able to get your fins in.

Finally, make sure that your internal motor structure has completely hardened before attempting to put it in the body tube. The centering rings will need to be sanded before they fit on the motor tube or into the body tube, and sanding any surfaces that get epoxied will help establish grip, strengthening the epoxy's bond.

Attaching the Fins

This is one of my favorite parts of building a rocket. It feels very satisfying to make the epoxy look clean and precise in what is referred to as a "fin fillet". We use this term to identify the glue or epoxy used to secure the fins onto the rocket; it's got a special name because we apply the epoxy in a special way so it doesn't hinder the rocket in flight. There are pros and cons to adding fin fillets[15]:

Pros:

- Adding a fillet adds a lot of strength to the joint, and the extra epoxy shields the joint from rough landings. This is very necessary strength to add to your rocket as commonly rockets don't certify because their fins broke off.
- The airflow over the fin-body joint has a lot of drag. If we shape the fillet to reduce the severity of the corner, this reduces the drag and your rocket will fly more efficiently.
- It looks SO pretty. :)

Cons:

- Adding thick fillets that maximize the above pros also maximize the added weight to the rocket. And, not only is this weight going to slow you down, it's also at the very base of the rocket. This moves your center of gravity rearwards, which destabilizes your rocket. Thankfully, our kit is very stable and this isn't a giant concern.

[15] https://www.apogeerockets.com/education/downloads/Newsletter514.pdf

The quality of your fin fillets is a way many seasoned rocketeers judge the time and effort spent building a rocket, so it's important to do it right and do it well.

To get a clean fin fillet, I recommend following a few guidelines:

- Put some epoxy on the inside edge of your fin before sticking it through the body tube and attaching it to the motor tube. This will help your fin stay intact throughout flight, as well as stabilize it for putting on the fin fillets.
- Bring painter's tape so you only get epoxy on the parts of your rocket body that require fillets, as shown in the picture below[16]. This will help with the aerodynamics of your rocket.

- Use the rounded end of the popsicle stick to create a round in the fillets that you create. This channels the air less violently over the angle between the fin and the body. It should look something like the shape in the photo below[17].

- Don't let the epoxy dry completely before pulling the tape off–it's a viscous enough material that it shouldn't flow too badly and mess up your fillets. It's better to have a slightly messier fillet than get tape stuck under your epoxy.

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16 https://www.google.com/url?sa=i&url=https%3A%2F%2Fimprobableventures.org%2F2020%2F06%2F30%2Fhow-to-build-a-fiberglass-rocket-part-11-fin-fillets%2F&psig=AOvVaw0onBrqmwxx_7uDbLJe4a7A&ust=1703205249200000&source=images&cd=vfe&opi=89978449&ved=0CBQQjhxqFwoTCMC02pikn4MDFQAAAAAdAAAAABAD

17 https://leederville.net/rocket/wp-content/uploads/2015/05/SML_IMG_5912.jpg

Fitting the Nose Cone and Coupler

Your nose cone has slight ridges on the outside that create extra friction when it is inserted into the upper body tube. However, this can be too much friction; I recommend slightly sanding down the ridges a bit, but not too much. Your rocket should obey the Dairy Queen Blizzard rule[18]:

In other words, there should be enough friction to keep your nose cone in your body tube if you turn it upside down, but just enough to do that. Nothing more. This is because you can deploy your recovery system by popping off the nose cone; however, the newer kits have the upper and lower body tube so you can possibly deploy your recovery system between the body tube sections. This is also how you'd access your payload bay should you choose to have one.

The coupler should sit inside/between the upper and lower body tubes. Feel free to epoxy it to one or the other, but *not both*. Otherwise, you won't be able to separate your body tubes and that's not good. This is also a location where your rocket kit can separate during flight to deploy your recovery system if you have a payload bay. If you choose to install a bulkhead on your coupler tube, epoxy your coupler to the upper body tube and then epoxy the bulkhead into the exposed end of the coupler. The eyebolt should face towards the bottom of your rocket. *Note: if you have a payload bay and therefore a bulkhead, tape your nose cone to the upper body tube before launch.* This will keep your nose cone from getting lost! It doesn't need to pop off in these kinds of flights because the recovery system is deployed from the coupler.

Preparing Your Recovery System

Your shock cord should run from your uppermost centering ring (through the eyebolt) up to either your payload bay or your nose cone, depending on if you decide to install the bulkhead in the coupler or not. Where, then, does the parachute attach?

With your shock cord attached to the upper centering ring and either the bulkhead or the nose cone, find the point about two-thirds up the cord from the body of your rocket. You know you've found the right place if you can dangle your rocket pieces holding that spot on the cord

[18] https://i.insider.com/5919d534144293cb058b4ad8?width=922&format=jpeg

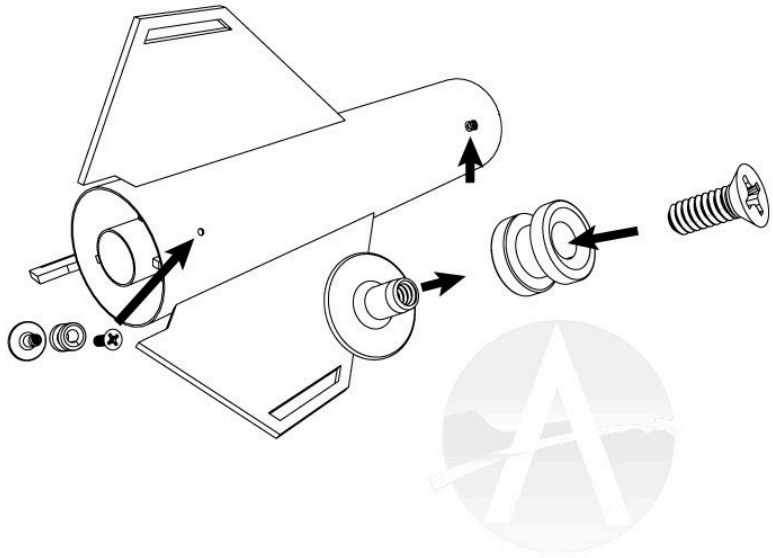
and the rocket pieces don't swing into each other. This means that when your rocket is suspended by the parachute during descent, the upper and lower portions of the rocket won't cause damage to each other.

Tie a simple knot in the shock cord at this location to create a small loop. This is where the carabiner goes so you can easily attach or detach your parachute from the rest of your rocket.

To fold your parachute, make sure none of the lines are tangled and carefully slide the loops onto the carabiner. Keeping the parachute in its roughly semicircular fold (it's just folded in half), start folding the edges towards the center. Do this two or three times until you have a narrow triangle. You can gently nestle the lines up into the fold of the narrow triangle and slide this into your body tube; this should help it deploy tangle-free and keep it stored until you prep your rocket for launch. You can fold the parachute the same way for launch! Just make sure you put dog barf in between the motor system and the recovery system so it doesn't get melted or burned.

Installing Rail Buttons

This is what allows your rocket to launch off the rail that most launch sites use. Ours look like and are installed similarly to the buttons in the picture below[19]:



Find the centerline between two of your fins and space your two rail buttons out on that centerline. Like the picture above, you're aiming for about a foot and a half between the rail buttons but keeping them towards the lower end of your rocket. This is what gives your rocket stability as it begins its ascent; the lower on the rocket these tend to be, the longer the rail is able to give your rocket stability. It may also be worth investigating how long your launch rail is at a launch site. For the LOC IV kits, they are small enough that this is not a concern, but bigger rockets might need longer launch rails.

[19] https://www.apogeerockets.com/bmz_cache/2/2dfeb7eb4677486fa9df8838b970f44e.image.700x700.jpg

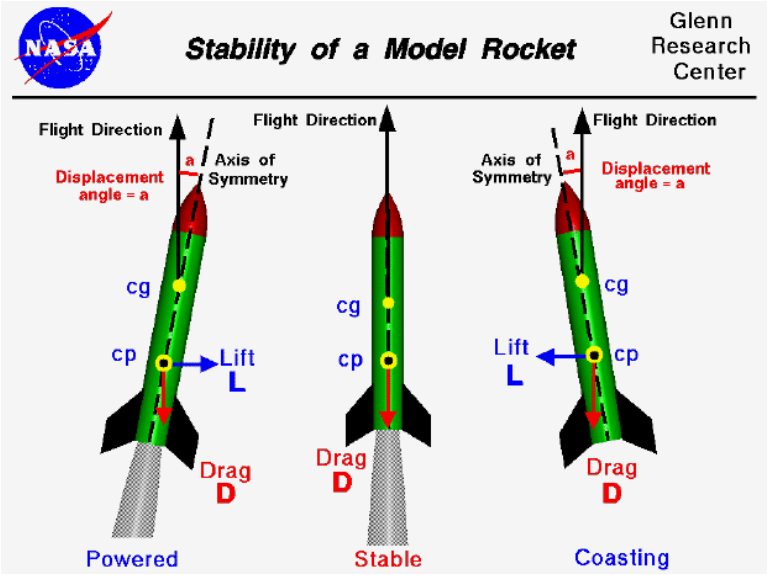
Marking Centers of Pressure and Gravity

A crucial part of getting a certification is marking your center of pressure and center of gravity on your rocket.

The *center of pressure* is the spot on your rocket through which the resultant lift and drag forces act[20]. You can manipulate the center of pressure on a model rocket through its geometry (changing the thickness of fins, nose cone shapes, etc.), but it is much easier to simply move the center of gravity[21]. You'll have to determine this by either asking other people who have built the kit before or using a simulation software like OpenRocket[22].

The *center of gravity*, therefore, is the point on the rocket around which the rocket would rotate during flight. A rocket does rotate a little bit during flight to accommodate wind and other factors. The center of gravity can be easily determined by balancing your rocket on your arm and seeing where the rocket balances itself. The center of gravity can be manipulated by adding weight to your rocket either in the nose cone (to move it upwards) or down near your centering rings inside the rocket body (to move it downwards).

Why do we care about where these are located? These factors basically control your rocket's stability. If your center of gravity is above your center of pressure, the forces from the center of pressure and the center of gravity cancel out (or "restore" the rocket). A good rule of thumb is that **your rocket is sufficiently stable if there is one to two rocket diameters between your higher center of gravity and lower center of pressure**. This is enough stability that your rocket will continue along the path you've sent it on, but also it isn't overtly stable. Too much stability (more than two rocket diameters) can cause your rocket to "weathercock" or turn right into the wind[23]. That means that, if the wind is severe enough, your rocket could end up flying horizontally or really anywhere but straight up.



[20] https://www.grc.nasa.gov/www/k-12/VirtualAero/BottleRocket/airplane/rktstab.html#:~:text=For%20a%20stable%20model%20rocket,of%20the%20center%20of%20gravity.

[21] https://www.nar.org/nar-products/rocket-stability/#:~:text=To%20move%20the%20center%20of,back%20on%20the%20body%20tube.

[22] https://openrocket.info/

[23] https://www.apogeerockets.com/education/downloads/Newsletter05.pdf

Launching Your Kit

Once you've put your kit together and painted it up all pretty, it's time to prepare your rocket for its upcoming launch. This should all take place at your launch site shortly before mounting your rocket to the launch rail.

WHAT'S A LAUNCH RAIL, EJ[24]?

A launch rail is the system used to hold your rocket and then direct it upwards for an optimal flight trajectory. Sometimes it's leaned a little bit into the wind to help your rocket get a headstart. Most of the launch rails I've seen at launch sites are a six foot tall 1010 aluminum t-slot extrusion. This is more than enough for our kits! This is also what your rail buttons slide onto to keep your rocket on the rail for the beginning of your launch. You don't need to provide this, the launch site will have this and an attached igniter to start your motor from far away.

Preparing Your Motor

Back in the HPR Motor Classifications section of this document, I discussed how to read rocket motor codes, like C6-3 or E28-4T. For this part of the process, we care about the number after the hyphen, or the delay time.

According to the Tripoli Safety Codes[25], if a commercial off-the-shelf motor is tampered with in any way, it changes from a Certified Motor to a Research Motor:

> **Research Motor:** A Rocket Motor, made by a Tripoli member or team of Tripoli members or a Certified Motor which has been intentionally modified by a Tripoli member of team of Tripoli members for their own use at a Tripoli launch.

This changes some of the guidelines that you have to follow for launch. Therefore, I recommend that you don't change your delay time for any certification flights. If you decide to modify your delay time with a drill at a launch site, please consult the Tripoli codes to make sure you're not doing anything illegal.

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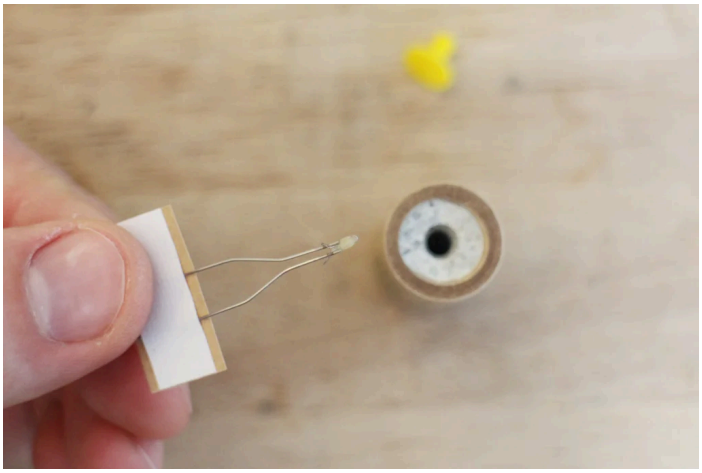
[24] https://www.apogeerockets.com/images/medium/apogee_products/13593-18mm-fly-away-rail-guide-04-MED.jpg
[25] https://www.tripoli.org/content.aspx?page_id=22&club_id=795696&module_id=520420

Installing Motors

You definitely did the responsible thing and got your motor from Zucrow right before launch and never stored it in your dorm, so how do you get it in your rocket?

1. Find a Phillips head screwdriver (or ask nicely around the launch site) and loosen the metal motor retainers at the bottom of the rocket.
2. Slide your motor into the motor tube from the bottom of the rocket. There's a lip on the bottom of the motor that shouldn't permit it to slide completely into the motor tube.
3. Tighten the motor retainers to hold the motor in place against the bottom end of the motor tube. Because of the motor's little lip, the motor won't slide up into your rocket, and because of the motor retainers, it won't slide out.
4. Find a rocket igniter and stick the pointy end into your motor. Insert it as far as you can so it touches the bottom of the cavity. Then you can tape the igniter to the rocket and bend the wires out of the way. Some motors may have a plug for you to keep the igniter in place instead of having to tape it. An igniter looks like this[26]:



5. The two wires extending out of your rocket motor will eventually be attached to the launch pad igniter to launch your rocket, so make sure they aren't twisting or touching or interfering with each other in any way:

[26] https://www.instructables.com/Model-Rockets-2/

What's Dog Barf?

Spoiler alert: it's not actually dog barf. It's commercially available cellulose housing insulation that won't burn, so we use it to protect your rocket's recovery system from burning up due to close proximity to your rocket's motor[27].

This stuff is sold in hardware stores as just cellulose insulation, but you can buy it in much smaller quantities from rocketry websites; for instance, I got the above picture from a listing at Rocketry Works.

To use dog barf effectively, you will add a couple handfuls after the motor is secured within the rocket body but before anything else is put into your rocket. Therefore, although your rip cord will already be secured inside your rocket, pull out as much of your recovery system as you can so you can put the dog barf underneath it. Don't pack it in, just add your fluffy handfuls. You should end up with a couple inches of dog barf between your motor and your recovery system.

[27] https://www.rocketryworks.com/dog-barf-recovery-wadding/#:~:text=Description.treated%20to%20be%20flame%20resistant.

Building a Rocket Independently

A note here: *I strongly recommend using a kit for your certification flights.* It doesn't have to be the LOC IV kit that PSP promotes, but it's important for you to get that certification flight under your belt and to do it correctly. While it's possible to get your L1 certification on any rocket, it's better to be safe than sorry for certification flights.

But once you've gotten your L1 certification, the rocketry world is open to you. You can start to launch pretty much whatever you want as long as it isn't a danger to those around the launch site. But what if you don't want to build a kit? What if you want to create your own rocket completely from scratch? How do you start going about designing a rocket? Here are a few resources to help you get started.

Basic HPR Design Principles

Any high powered rocket needs a motor, a structure to hold the motor in place, a recovery system, a body tube, a nose cone, and fins. There are plenty of commercial off-the-shelf (COTS) options for you to assemble a rocket of your own design, as well as resources on how to build things from scratch. Below, I'll provide some resources about each of the integral sections of a rocket. However, if you're looking for a more comprehensive guide, I really recommend this NASA guide. It breaks down the more technical design decisions one can make when building high power rockets, more so than I ever could with my background. It also covers a lot of the information I've covered in this guide with more general applications.

The best way to verify that your design is viable is to download OpenRocket at this site: https://openrocket.info/. It allows you to customize the components in a rocket and compare all of the parts used in your design. There are numerous tutorials on YouTube for how to use OpenRocket, but here's an introduction to get you started: https://www.youtube.com/watch?v=oqe0lTp1WH0&ab_channel=BYURocketry

Below is, as promised, resources broken up by rocket part. This is obviously an incomplete list and I encourage you to thoroughly research each area of your rocket to guarantee it will have a safe and successful flight!

Body tube:

- Hand laid fiberglass body tube
- Part 2 Tube removal
- Apogee Rockets High Power (Thick Wall) Tubes
- John Coker Rockets Body Tube

Nose cone:

- Which Nose Cone Shape Works Best?
- Add Nose Weight to Rocket Nose Cones
- High Power Nose Cones Apogee Components

Fins:

- Richard Nakka's Experimental Rocketry Site
- Newsletter 442 (Fin Shapes)
- Model Rocket Fins 101

Internal structures:

NAR Rocketry Basics
NASA SL ARW Rocket Structures

Motor selection:

Selecting Rocket Motors
NASA SL ARW Propulsion Systems

Recovery systems:

Newsletter 447 (Rocket Recovery Techniques)
NASA SL ARW Recovery Systems

Reloadable vs. Single Use Motors

Although the NASA SL ARW Propulsion Systems PDF linked under “motor selection” is quite comprehensive for design decisions involving motors, I wanted to take the time to point out a key point that is buried in the document. Motors are either reloadable or single use–for our L1 kits, we purchase single use motors. This is because single use motors come ready to fly and don’t require the installation of a casing in your rocket. For less than three launches off the same airframe, this is also a cheaper investment. Reloadable motors, on the other hand, have some assembly required. However, assembling yourself means that you can customize your options a bit more thoroughly. You can control your burn time as well as your delay time.

In general, a single use motor is more likely to fit your motor needs, but knowledge of what reloadable motors bring to the table may be valuable as you move towards more advanced rocketry practices.

Dual Deploy Configurations

Dual deploy configurations involve deploying a small parachute called a “drogue” at the rocket’s apogee before deploying the main chute closer to landing. The appeal of this recovery configuration as opposed to a single parachute is that the drogue will carry the rocket down faster than the main chute and cause less drift during the flight, but the main chute will still allow for a soft landing and safe recovery. This configuration is typically considered for higher altitude flights so you don’t have to walk miles to recover your rocket.

Beyond Level One

PSP may not officially offer any opportunities for L2 and L3 but that shouldn't stop you from dreaming big! As you start planning for opportunities beyond L1, use the following sections to get you started.

Looking at Level Two

NAR's How to Build Your Level 2 Certification Rocket
Level 2 Certification - Tripoli
- Contains links to written exam study guide and test parameters

Level 2 HPR Certification Procedures - NPR
- Contains links to written exam study guide and test parameters

A Level 2 Certification flight is, in essence, an L1 certification flight with a higher class motor and a written examination component. The overall build process should be exactly the same accounting for additional stresses on the rocket due to the more powerful motor.

Aiming for Level Three

NAR's How to Build Your Level 3 Certification Rocket
Level 3 Certification - NAR
- Contains links to certification requirements, package requirements, and applications

Level 3 Certification Procedure - Tripoli
- Contains links to all necessary TAP (Technical Advisory Panel) forms and required pre-flight documentation

Level 3 requires the successful launch and recovery of an L2 rocket with an electronic deployment. If you are attempting an L3 flight, you should be proficient in the design and construction of a rocket airframe from your L1 and L2 certifications; therefore, I'm focusing on the new components introduced when working with these extremely powerful motors.
Intro to Dual Deployment in Rocketry
Dual-Event Recovery Information
Electronic Parachute Deployment for High Power Rockets - Simple motor delay replacement
Dual Deployment for High Power Model Rockets (old, but the basic principles should be the same):
- Part 1
- Part 2
- Part 3

Best of luck as you start and/or continue your high power rocketry journey!
~ EJ Denker, Former HPR Co-Director, BSAAE Class of 2025

Appendices

Appendix A: Pre-Launch Checklist

Tripoli Checks:

- ☐ Launch waivers/paperwork is ready to go
- ☐ CP and CG appropriately far away from each other
- ☐ CP and CG marked
- ☐ Igniter not yet in motor

Basic Fastening:

- ☐ Rail buttons securely installed
- ☐ Fins are securely attached
- ☐ Parachute cord securely attached to vehicle
- ☐ Nose cone fits with appropriate snugness

Electronics (if applicable):

- ☐ Electronics are alive
- ☐ Battery has sufficient charge to withstand a launch delay
- ☐ System is giving good telemetry

Motor install:

- ☐ Motor retainer is securely fastened against the lip of the motor
- ☐ Cellulose insulation (dog barf) in vehicle
- ☐ Approval from PSP and IRI authorities to begin igniter install given
- ☐ Igniter wires are not interfering with each other
- ☐ Igniter is pushed as far into the motor as it will go
- ☐ Igniter is taped to the end of the motor