National Aeronautics and
Space Administration

NASA Student Launch ARW Rocket Structures

PRESENTED BY NASA Student Launch

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NASA STEM

Hardware: Overview

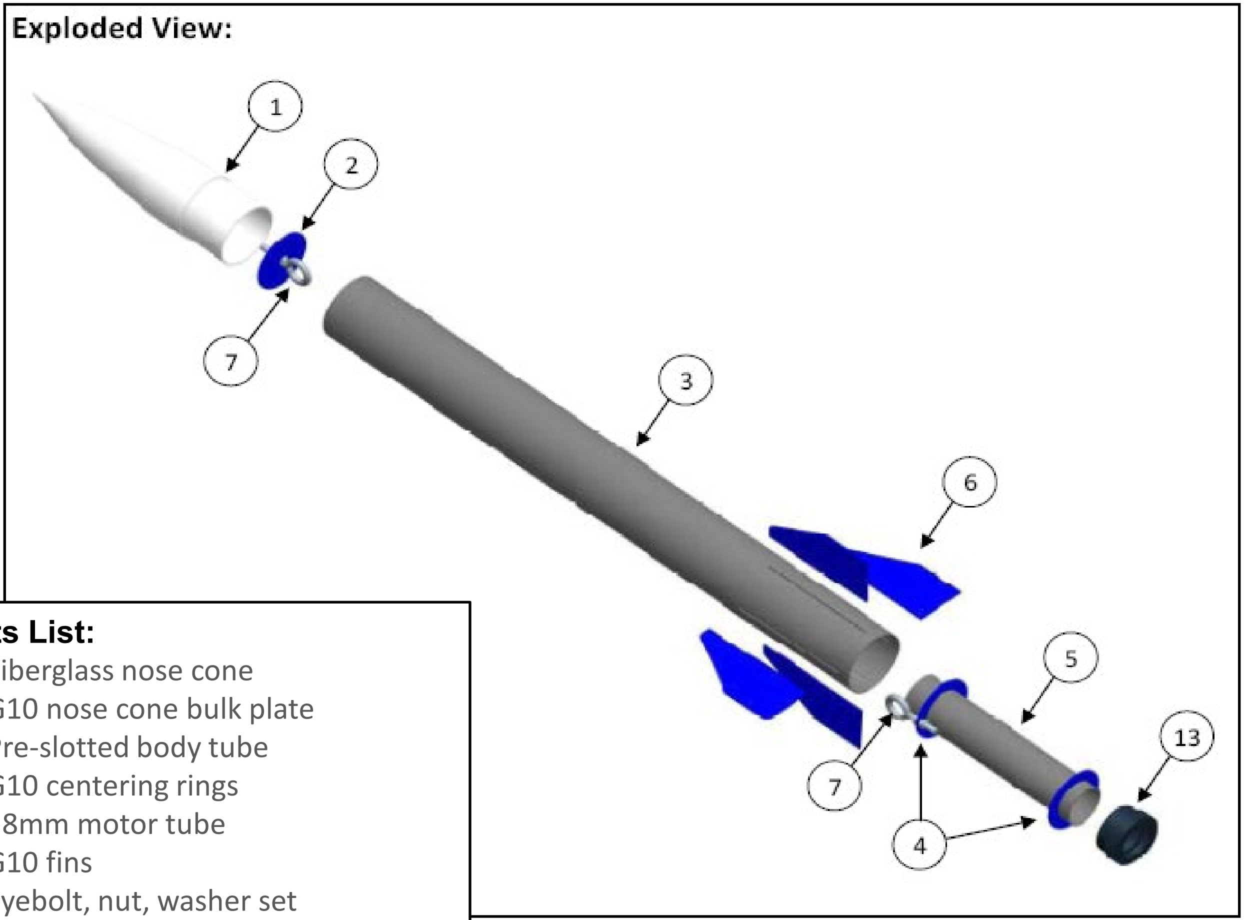
All high-powered rockets have the same basic parts.

From the outside of a rocket, only a few are visible

- Nose cone
- Airframe
- Fins
- Rail Buttons
- Motor Retainer

On the inside of a rocket, there are:

- Couplers
- Motor Tubes
- Centering Rings
- Bulk plates /Bulkhead



Parts List:

1. Fiberglass nose cone
2. G10 nose cone bulk plate
3. Pre-slotted body tube
4. G10 centering rings
5. 38mm motor tube
6. G10 fins
7. Eyebolt, nut, washer set
13. Aero Pack 38mm Motor Retainer

Hardware: Subassemblies

Subassemblies:

A subassembly is an assembled unit designed to be incorporated with other units into a finished product

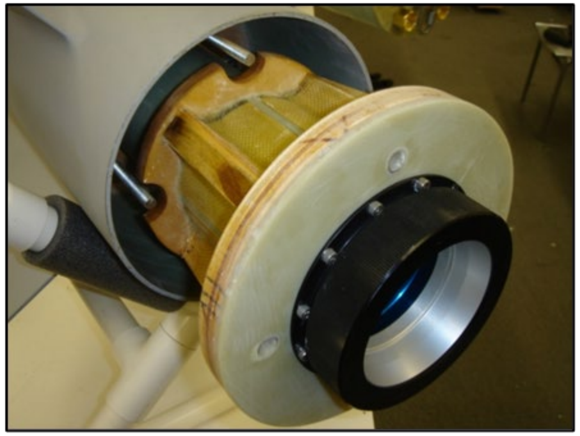
The nose cone can be considered a subassembly

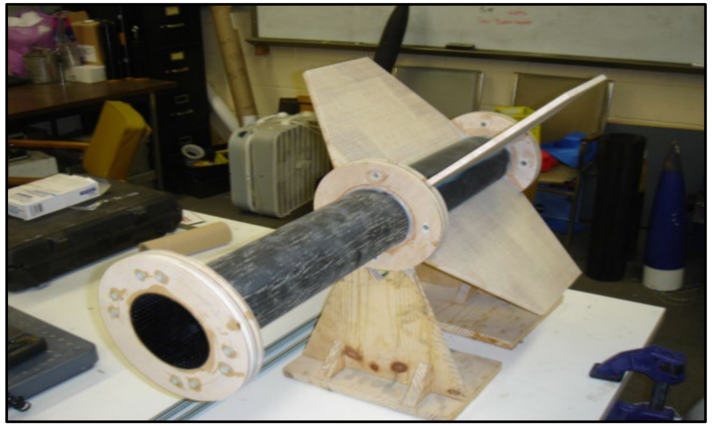
A *booster subassembly*, sometimes called a “*fin can*”, is built from:

- A section of airframe
- a motor tube
- centering rings
- bulk plates
- fins
- motor retainers
- couplers

The nose cone subassembly has a removable plate on the bottom for access to the interior volume where a payload can be carried.

The motor tube subassembly is removable so the builder can inspect the fin tangs and centering rings between flights.





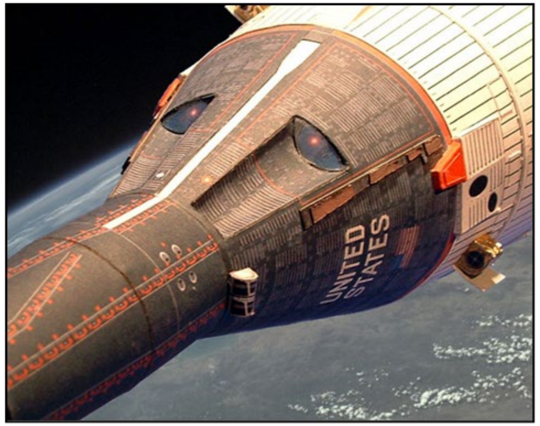
The fin can subassembly is ready for installation into a custom-made carbon fiber airframe.

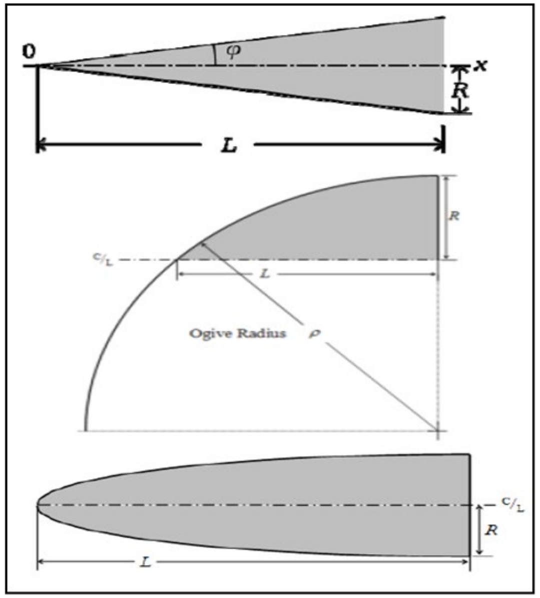
Hardware: Nose Cones

Nose Cones:
Forward most section of a rocket, missile, or aircraft
Can be the payload or used to shield payload until deployment
Shape chosen for minimum aerodynamic resistance (drag)

Typical HPR nose cone shapes:
Conical, Ogive, Elliptical

Typical HPR nose cone materials:
- Composite: made of two different materials with different properties. The new material has better performance characteristics than the original materials on their own.
- Fiberglass –glass and plastic. Strong and affordable
- Carbon fiber – polymer resin and tiny carbon fibers. Very lightweight and strong
- Urethane plastic – not brittle, has greater elasticity and strength that regular plastic.



Hardware: Airframe

Airframe:

Generally smooth thin-walled cylinders with an aspect ratio (length : diameter) of roughly 10:1 to 20:1

Encompass the rocket's propulsion system, recovery system, electronics, and payload

Nose cone fitted to the forward end

A set of fins are mounted towards the aft end.

For *Minimum Diameter* rockets, the airframe also serves as the motor tube

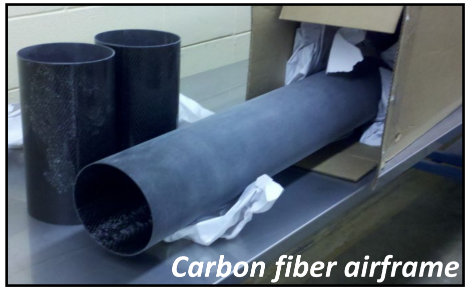
Typical HPR airframe materials:

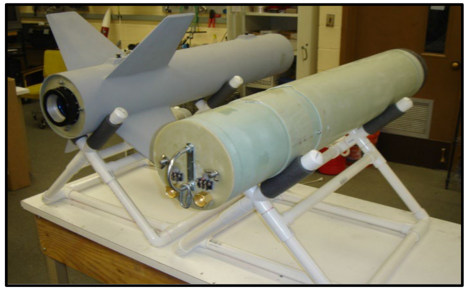
Fiberglass

Carbon fiber

Phenolic – resin impregnated, spiral wrapped, heat cured tube; stronger than cardboard, helps to strengthen with fiberglass or carbon fiber.

Blue tube –"shatterproof" alternative to phenolic that has been used for military operations in tank ordinance





High powered rocket airframes are typically made of non-metallic, high strength to weight ratio composite materials like carbon fiber, fiberglass, phenolic and blue tube. (NAR rules) Paper and cardboard will not handle the loads of high-powered rocket motors unless they are sufficiently reinforced with composite materials.

Hardware: Airframes

Airframes:

Generally, fin slots in airframes come one of two ways:

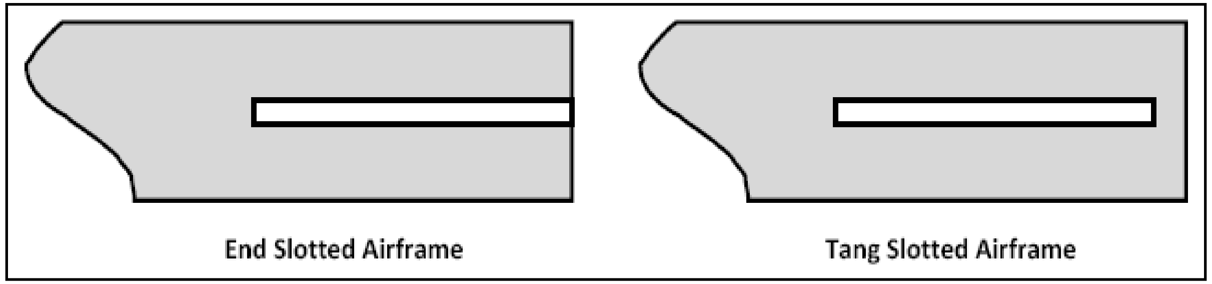
End slotted airframes:

- the fin slot is cut all the way to the end and the airframe can be slipped over a fin can subsystem.

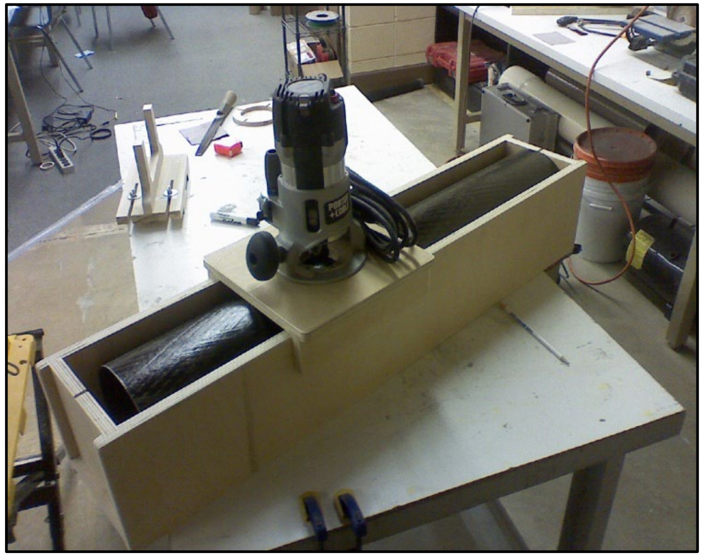
Tang slotted airframes:

- The fin slot is stopped before the end of the airframe
- The fins must be epoxied on after the motor tube subassembly is installed.

The rocket you can build from the workshop is tang slotted.



A jig is any device used to maintain, mechanically, the correct position relationship between a piece of work and the tool.



Hardware: Couplers

Couplers:

Joins multiple segments of airframe

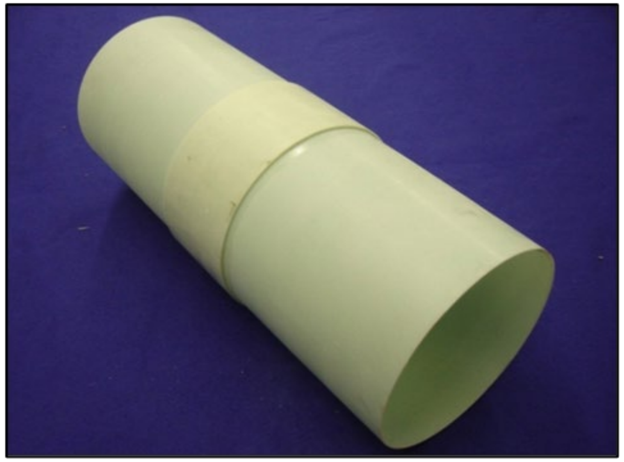
Its *Outer Diameter (OD)* is equal to the *Inner Diameter (ID)* of the airframe it connects

makes a good place to store electronics (avionics bay)

Typical HPR coupler materials:

- Fiberglass
- Carbon fiber
- Phenolic
- Blue tube

*Note: when joining airframes with a coupler, the coupler should extend at least one airframe diameter into each joined segment. So, if you were to join two 6-inch diameter airframes, you would need a coupler at least 12 inches long.



The *avionics bay* in the photo is built from a 12-inch-long coupler with a 4-inch *collar or switch band* in the center. The collar allows direct access to the switches that power on the altimeters. This coupler joins two airframe segments that contain the recovery system by clicking into place with quick connect snap buttons.

Hardware: Motor Tubes

Motor Tubes:

Any tube inside of a rocket that is intended to fit a rocket motor

Diameters are typically called out in millimeters and refer to the maximum diameter motor it is design to hold

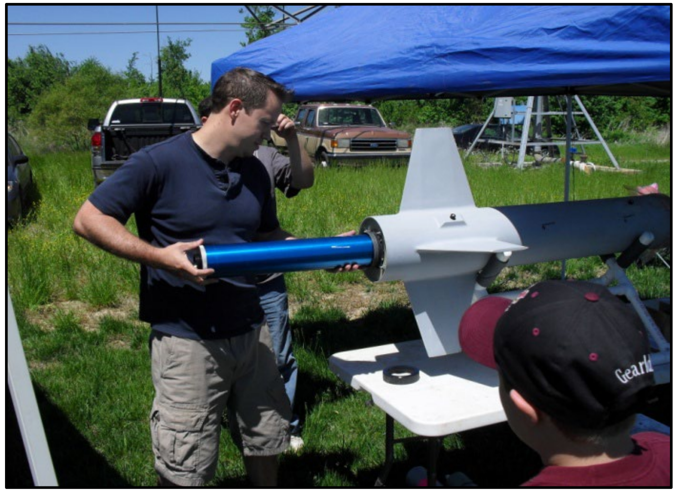
- 38mm
- 54mm
- 75mm
- 98mm

Larger HPR motor tubes may only encompass half of the tube because a full-length motor tube can be heavy

Typical HPR motor tube materials:

- Fiberglass
- Carbon fiber
- Phenolic
- Blue tube


38mm Motor Tube Subassembly before installation



Hardware: Motor Retainers

Motor Retainers:

Any device that positively retains the rocket motor case inside of the rocket prohibiting it from falling out during flight

There are many commercial motor retainers available for every size motor

It is also very common for rocket builders to fashion their own motor retainer

In this workshop, you will be provided an Aero Pack 38mm motor retainer. The Aero Pack motor retainer base epoxies to the bottom end of a motor tube. The threaded cap screws on to the base after the motor has been installed into the motor tube.

Hardware: Centering Rings, Bulk Plates and Bulkheads

Centering Rings:

Are used to concentrically align small tubes, like motor tubes, inside of an airframe

and take many shapes depending on the number of inside tubes that are to be aligned

Bulk Plates / Bulkheads:

Circular disks that fit inside of tubes to separate volumes

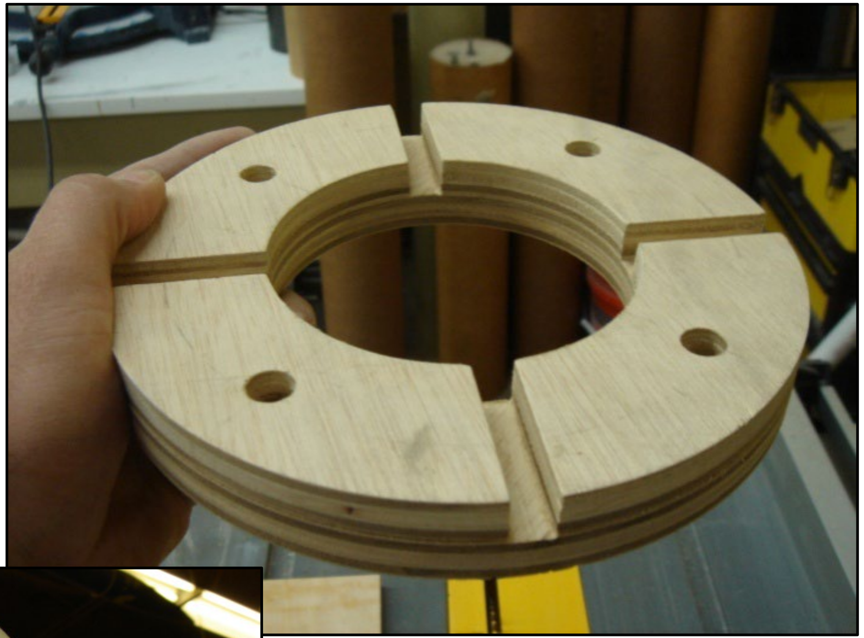
serve as the mounting structure for other components

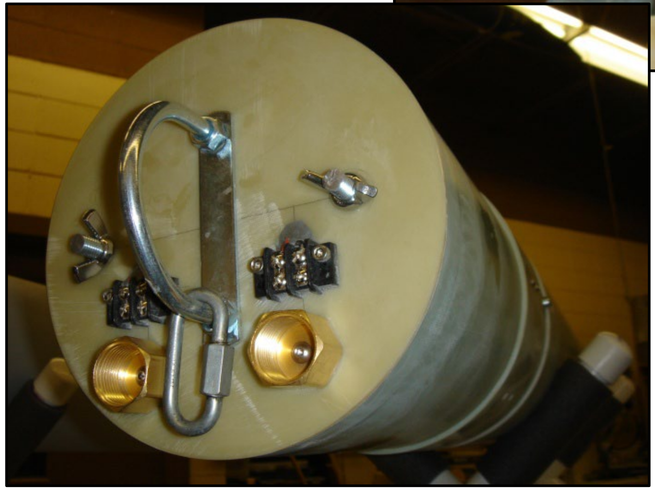
Typical HPR CR & BP materials:

Birch Plywood

Fiberglass

Carbon Fiber





Hardware: Fins

Fins:

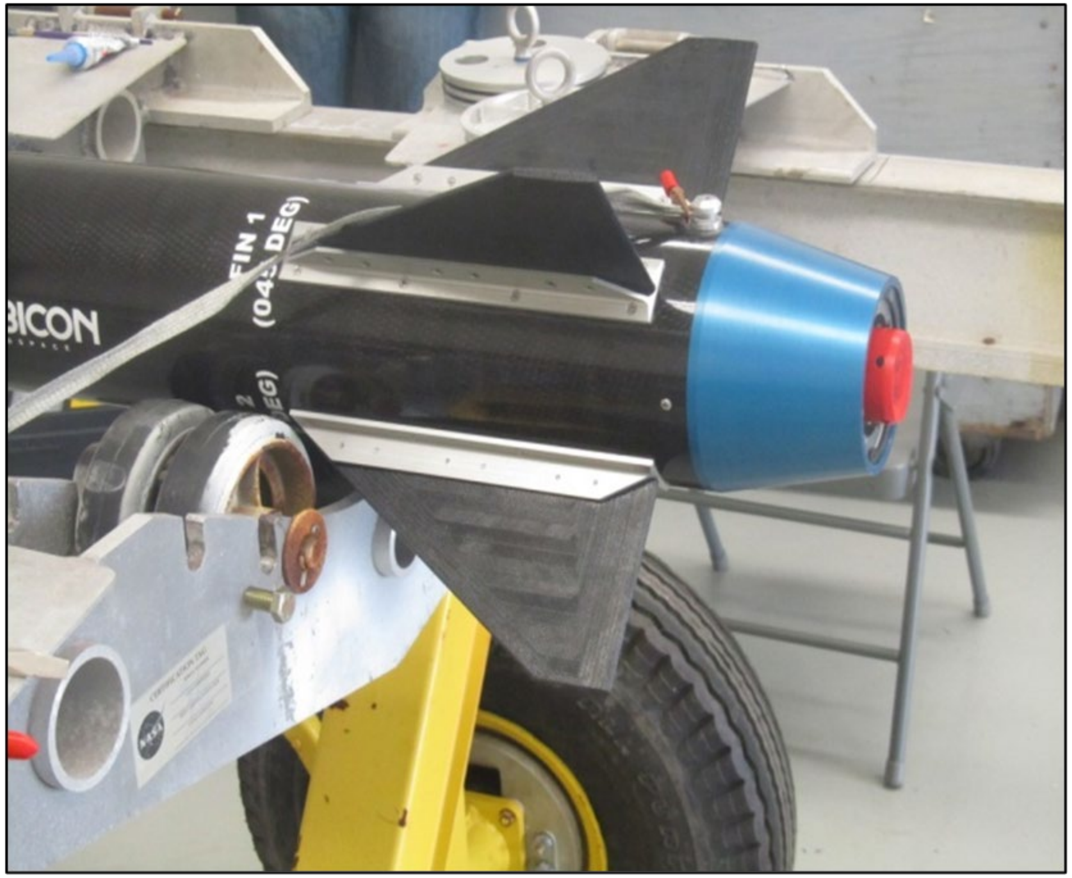
Most rocket fins are designed with:

- low aspect ratios (AR < 4)
- taper ratio between 0.2 and 0.4 ideal for minimum induced drag (δ)

Typical fins Materials:

- G10 fiberglass
- Carbon fiber
- Plastics
- Plywood

More complex fins are composites of two or more of these materials



Hardware: Fins

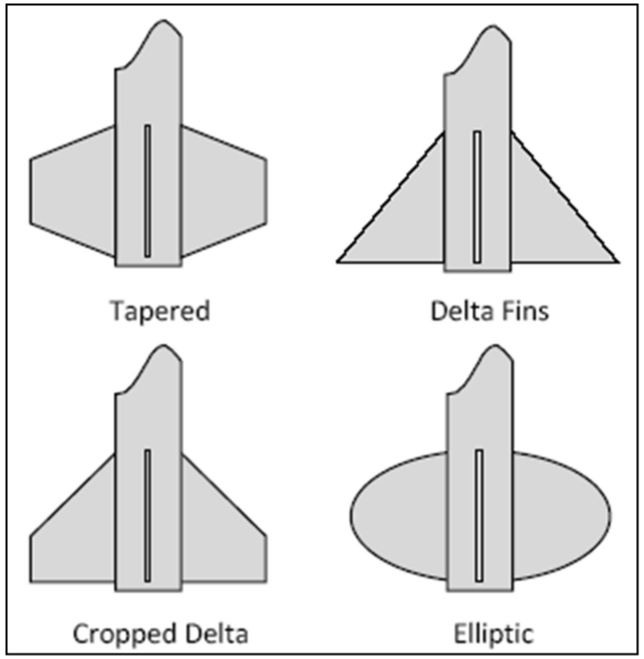
Fins:

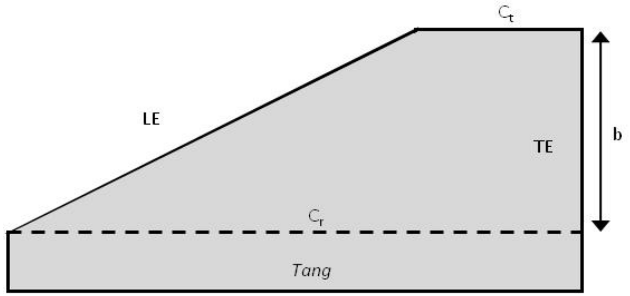
Flat fixed stabilizing structures extending from the body of a rocket that give stability in flight

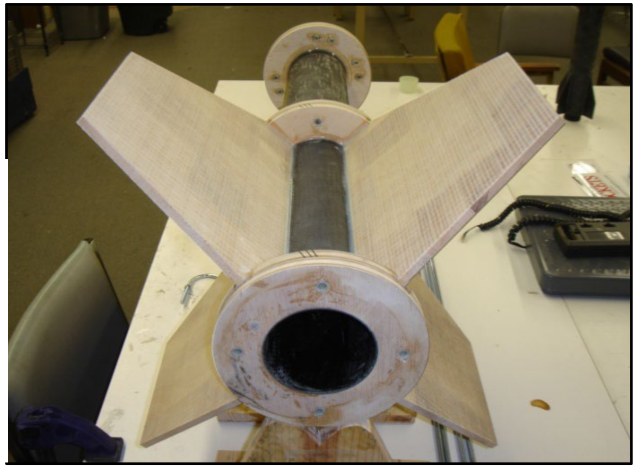
There are four common fin shapes:

Each fin has several features used to characterize its design & performance:

- Tip chord (c_t)
- Root chord (c_r)
- Span (b)
- Leading Edge (LE)
- Trailing Edge (TE)
- Aspect ratio (AR)







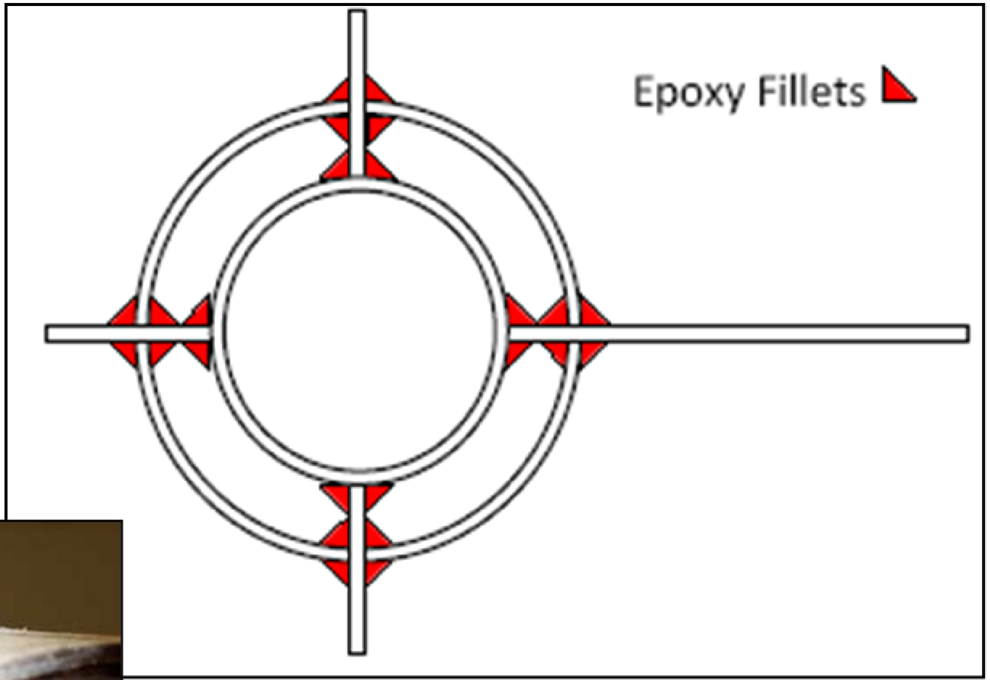
Construction Technique: Fins

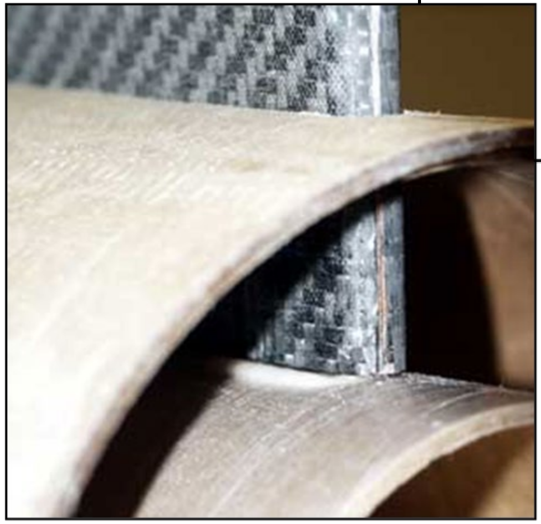
Through-The-Wall (TTW):

Widely used fin mounting technique

The fin tang passes through a slot in the airframe and epoxies flush against the motor tube

Epoxy fillets are applied on every side of each joint.





Construction Technique: Epoxy

Epoxy:

Epoxies are two-part adhesive systems – 1) resin and 2) curing agent

Chemically react to cure/harden and adhere materials together

Mixing epoxy can prove to be messy

Time critical task that require some technique and planning to maximize use

Hardware: Rail Buttons

Rail Buttons:

Most HPRs use rails / not rods

Require rail buttons

Usually, hard smooth plastics

Slides freely inside channel of extruded aluminum

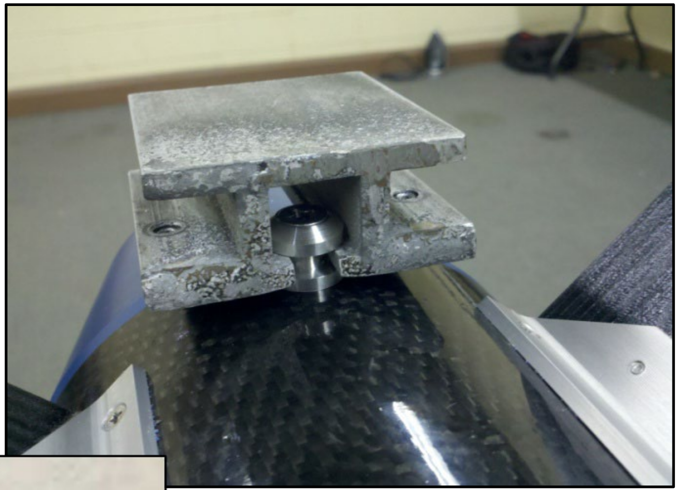
Constrains the rocket's movement until sufficient velocity is achieved that the fins become effective for flight stability

Two rail buttons are required, and one is typically located:

- Near the bottom of the booster or center of pressure
- Near the center of gravity

Should be rigidly mounted to the rocket

- Large washer and nut inside airframe near a CR.



Construction Technique: Rail Buttons

Rail Button Jig:

Simple tool to accurately and quickly repeat rail button alignment

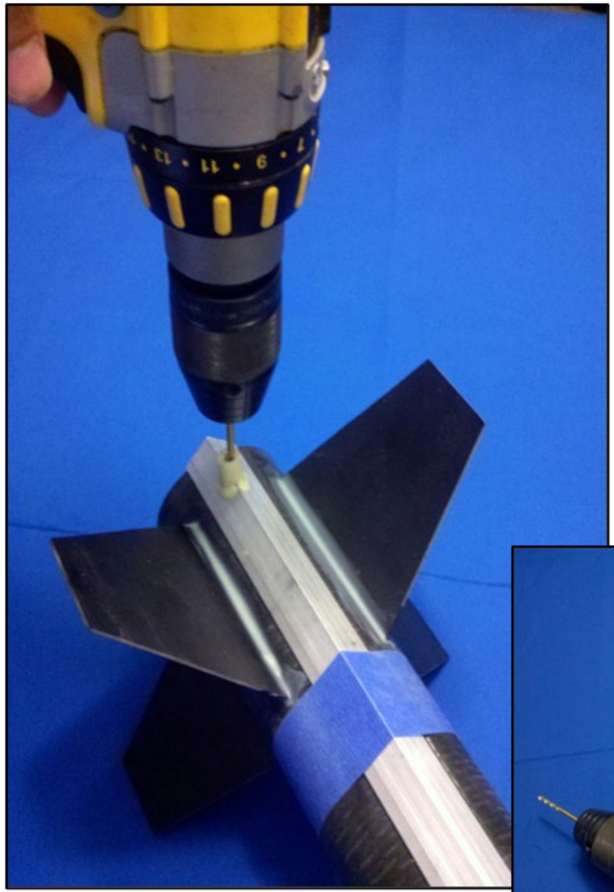
Made from a length of angled aluminum with drill bit alignment guides

The angled aluminum will align itself when laid flush on the airframe

Tape the jig in place with some masking tape

Drill the forward and aft rail button screw holes with the desired size drill bit

Small rail buttons usually use a #8 size machine screw



Structural Testing

Development Testing:

Developmental tests are conducted during the design phase of the project

Generally, only a representative test of a component of a subsystem

Verify that the hardware will perform as required

Develop a manufacturing method conceived of in the early design process before committing resources to the development of the flight hardware

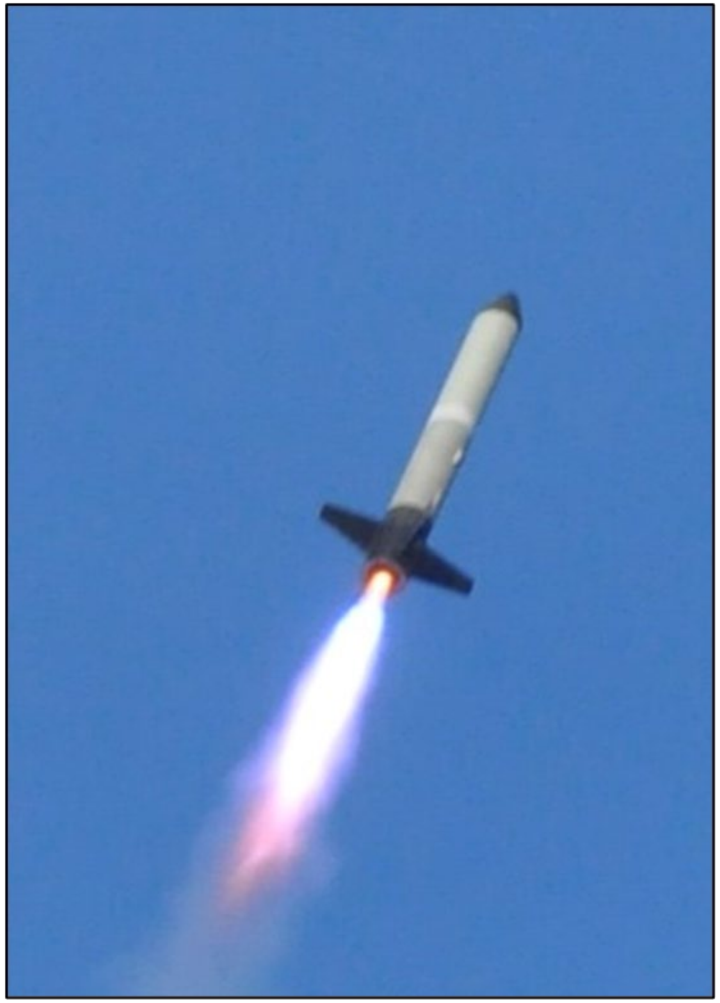
Qualification Testing:

Qualification test are conducted at the end of the design process

These tests are generally flight components or entire systems

Once Qualification Tests are completed, the components or systems can be classified as approved for flight

Forces on a Rocket



In flight, a rocket is subjected to four forces:

- *Weight* - always directed towards the center of the earth and acts through the center of gravity
- *Thrust* – Opposes *Weight* depends on the mass flow rate through the engine and the velocity and pressure at the exit of the nozzle
- *Lift* - act through the center of pressure
- *Drag* –depends on the shape, size, and velocity of the rocket and on properties of the atmosphere

Summation of these forces, accounting for the direction, results in a net external force on the rocket

The resulting motion of the rocket is described by Newton's laws of motion

- Newton's 1st Law: Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.
- Newton's 2nd Law: The relationship between an object's mass m, its acceleration a, and the applied force F is F = ma.
- Newton's 3rd Law: For every action there is an equal and opposite reaction.

Questions?

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