Rocketry Basics

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What’s the goal?

- Understand rocketry terminology
- Have fun with a hands-on project
- Fly your first high power rocket with the team
- Get your L1

L1?

Permission from the National Association of Rocketry (or Tripoli) to use motors above a certain size at sanctioned launches.

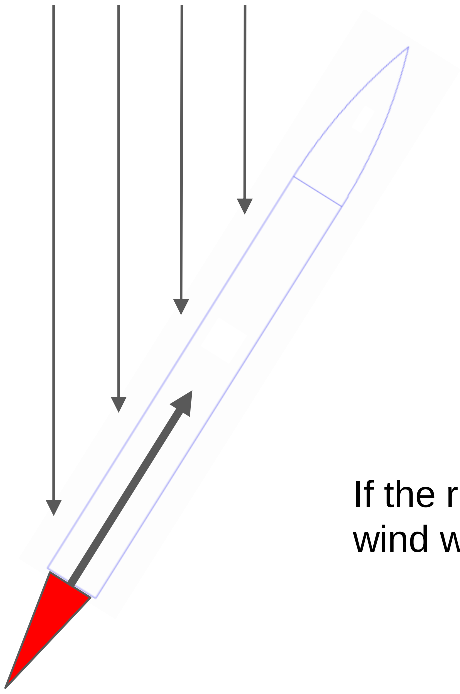
Requirements:

- Be familiar with your own rocket and how it works (we’ll teach you)
- Safe flight
    - Sucessful launch
    - Doesn’t break
    - Stability
    - Recovery
- Motor
    - H or I impulse
    - T/W > 5, ideally

Stability

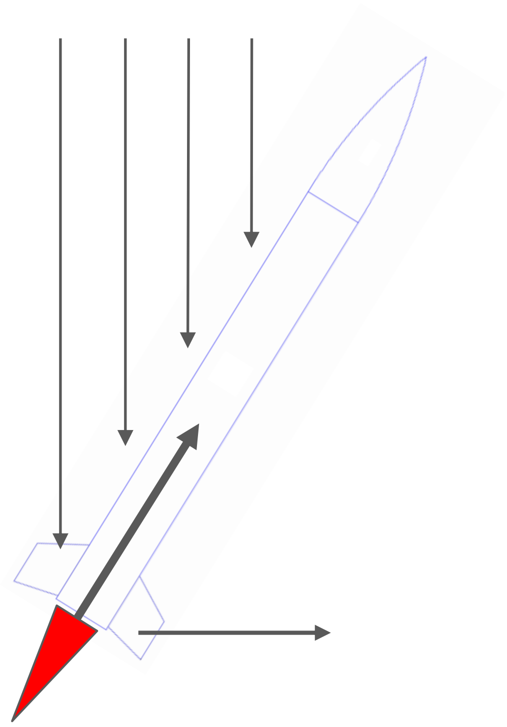
In an ideal world, the rocket just goes up

Stability



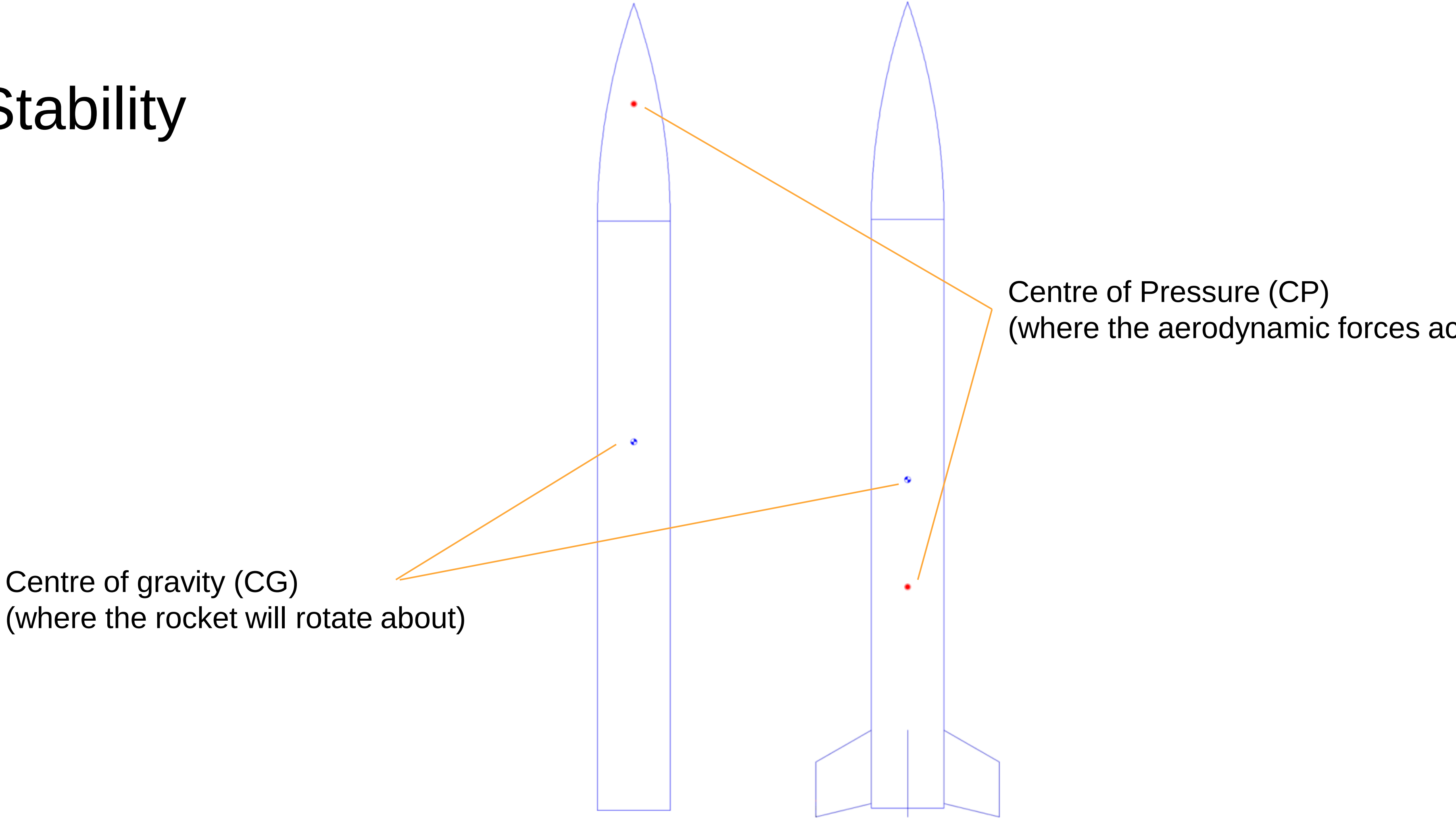
If the rocket starts to tip, notice how the wind will make it tilt even more

Stability



But if you add fins, the rocket will return to a stable direction **passively**!
No active controls needed :D

Stability


Centre of Pressure (CP)
(where the aerodynamic forces ac
Centre of gravity (CG)
(where the rocket will rotate about)

Is my rocket stable?

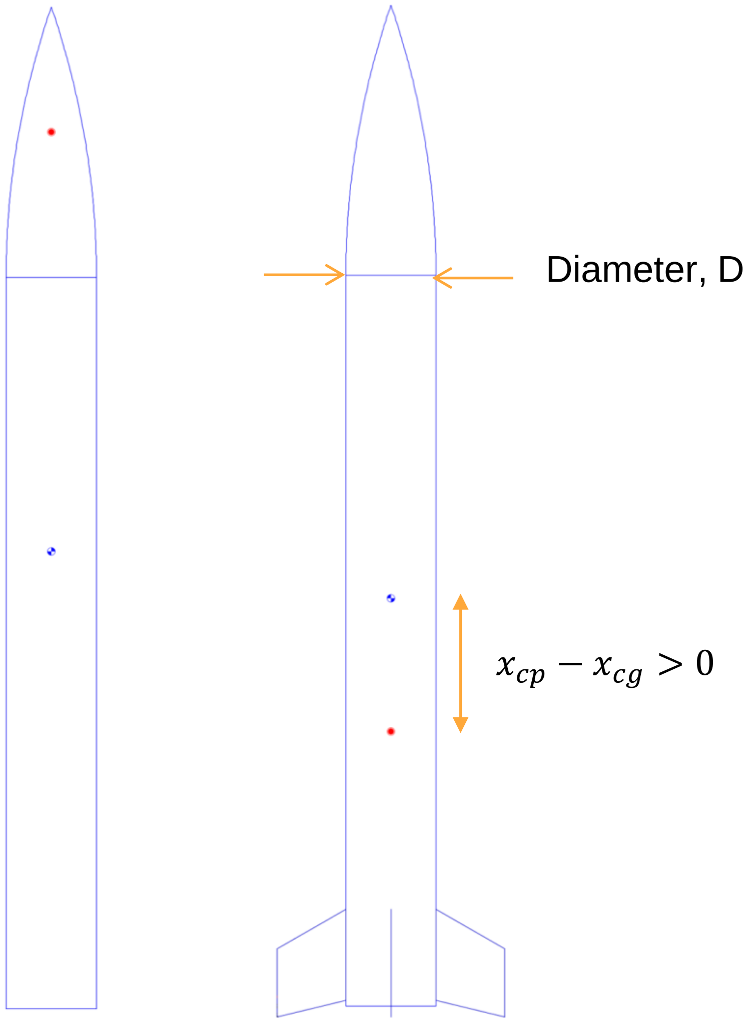
Proper method is to determine aero forces accurately and assess stability (like we study in mechanics of flight)

Hobby method is to measure STATIC MARGIN:

Static margin = $K = \frac{x_{cp} - x_{cg}}{D}$

K < 0: Definitely unstable
K > 1.5: Probably stable
K > 2: Safely stable

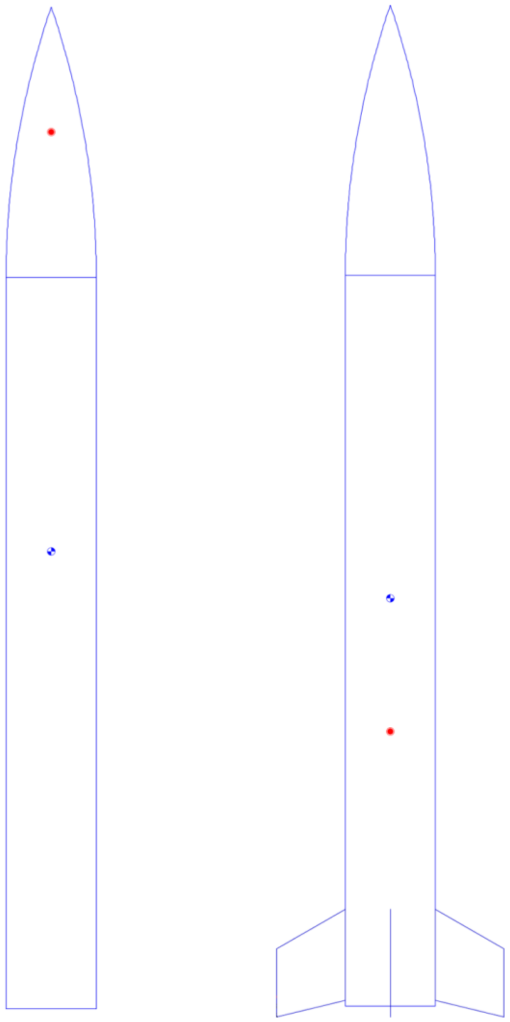
Use as a guide
If there is confusion, use D at base of nose cone.



To increase Stability:

Adding mass forward, pushes the CG forwards
 (but also reduces altitude)

Adding fins increases aerodynamic forces at the back of rocket, pulling the CP backwards
 (but also increases drag and may be harder to handle)



So how to calculate CP and CG?

- **Proper method**: CFD at a range of (small) angle of attacks
- **Approximate Analytic method**: Barrowman method (developed by Barrowman in 1967: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20010047838.pdf)
- **Simple method**: Use OpenRocket - implements a modified Barrowman method (http://openrocket.info)

- More on this later

- Garbage in, Garbage out: ensure you are being reasonable in your inputs, and the outputs will probably be reasonable – use your engineering judgement to ensure this happens.

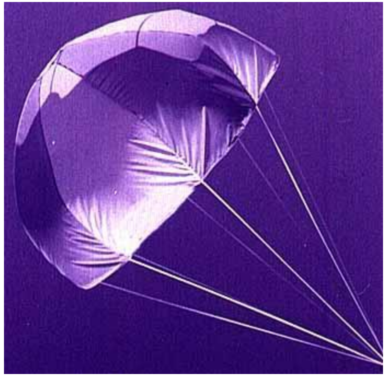
L1 Requirements: Motor

Must use an H or I motor (160 - 640 Ns)

Motor class specifies the total impulse of a rocket

Thrust ring

L1 Requirements: Recovery

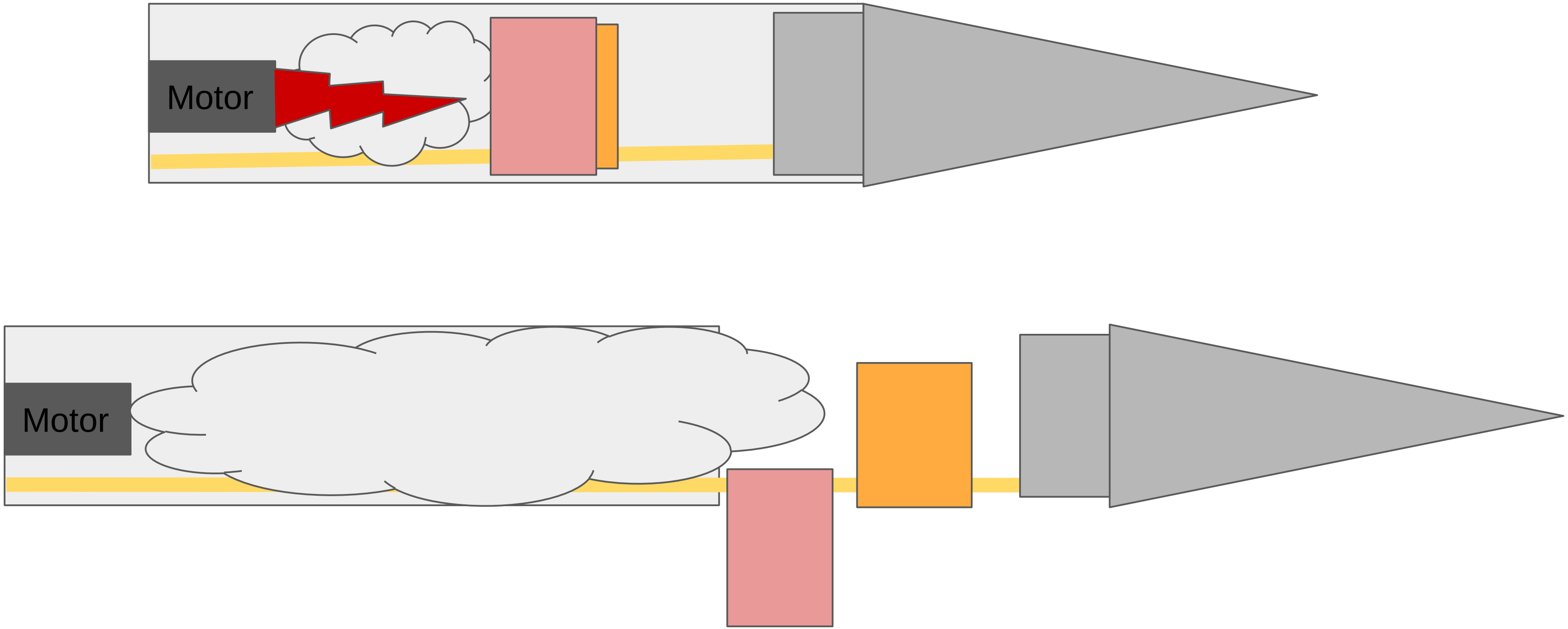


Parachute

Parachute protector

Shock cord

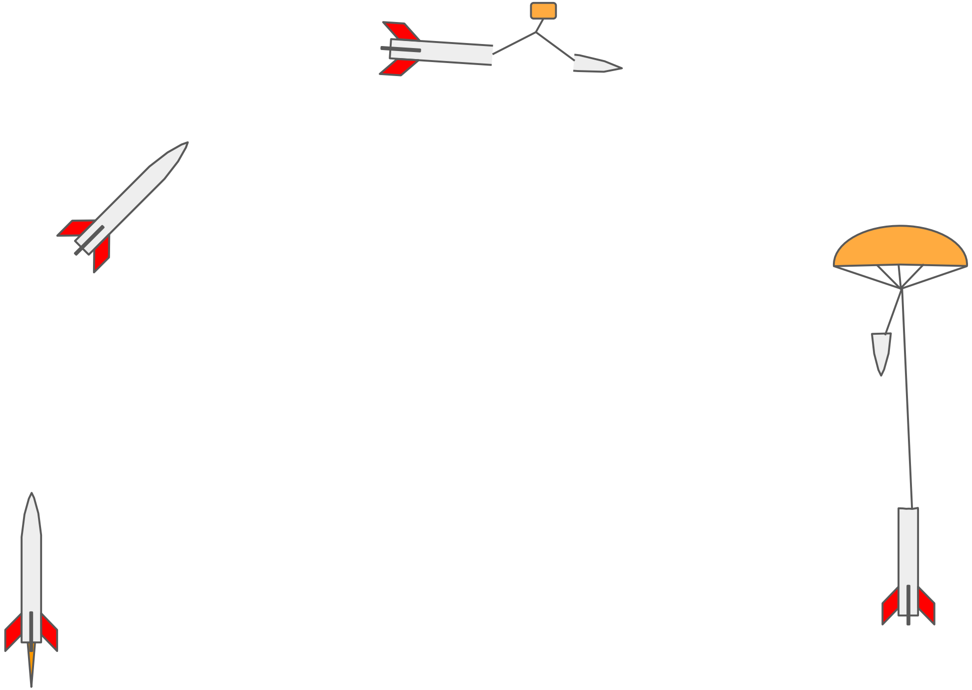
L1 Requirements: Deployment



Summary of requirements

Note:
- No altitude req
- No payload req
- No avionics req

Design Principle:
- Make L1 as simple, cheap as possible
- Make more interesting rockets once you have the L1

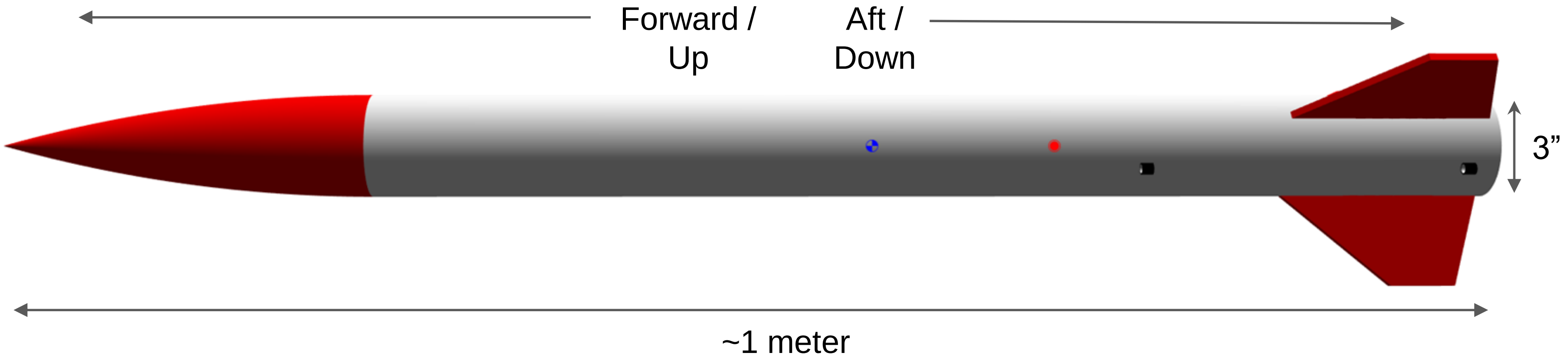


Stable boost on H/I motor

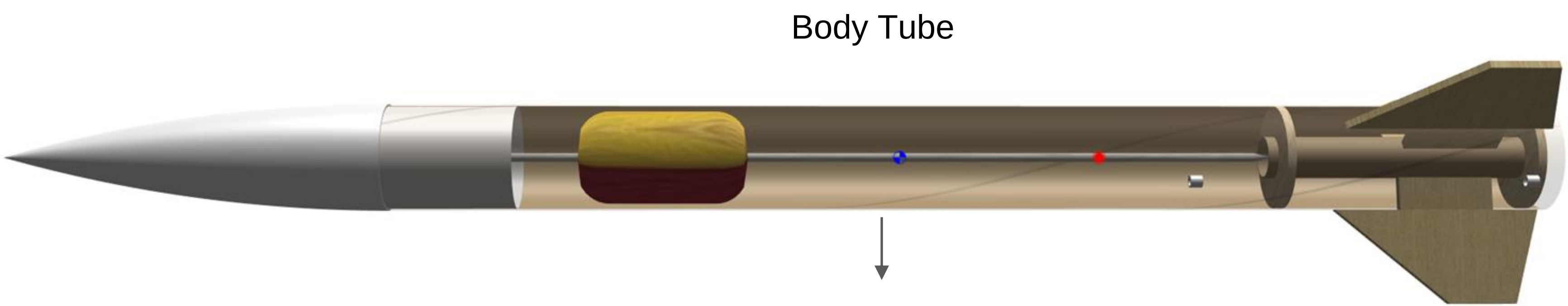
Safe recovery

A basic rocket

A basic rocket



A basic rocket



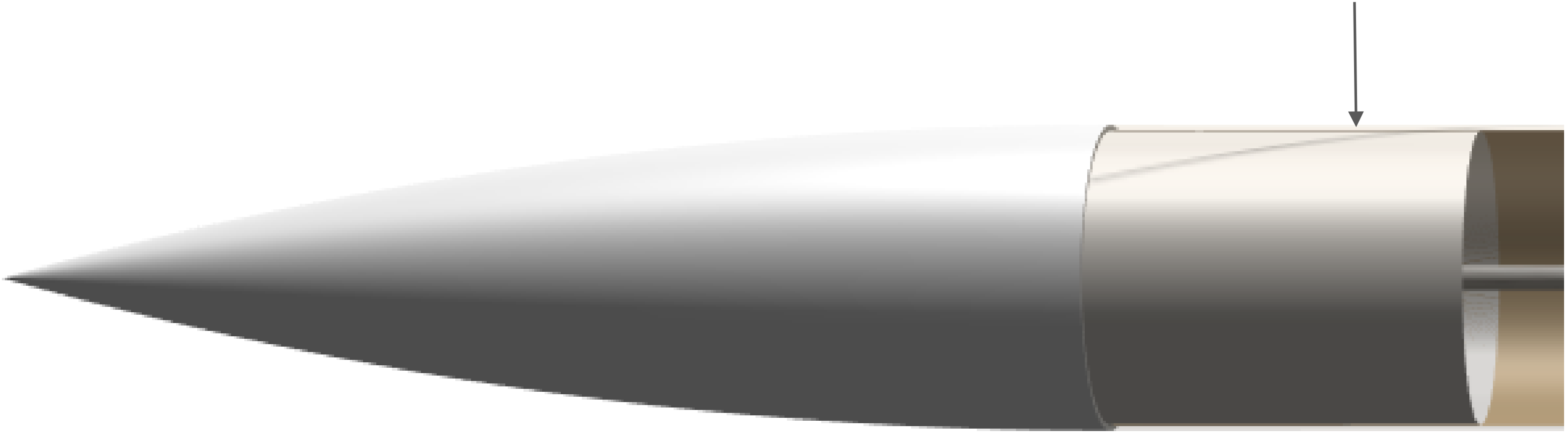
We will buy this tube: LOC precision 2.56 in x 34 in (http://www.rocketsandthings.com/view/product/318/)

OpenRocket Preset: LOC BT-2.56

Inner Dia: 3 in, Outer dia: 3.1 in,

£9.25

Nosecone



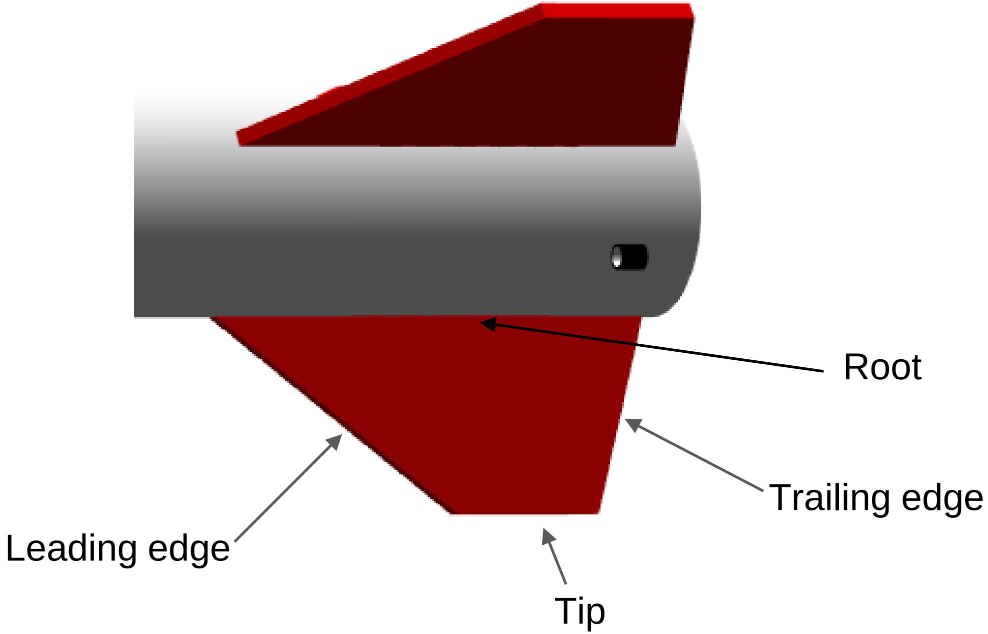
Two Options:

1) http://www.rocketsandthings.com/view/product/1119/: £14.50
   2.56 in Ogive section
2) 3D print your own at Hackspace (and pay them for material)

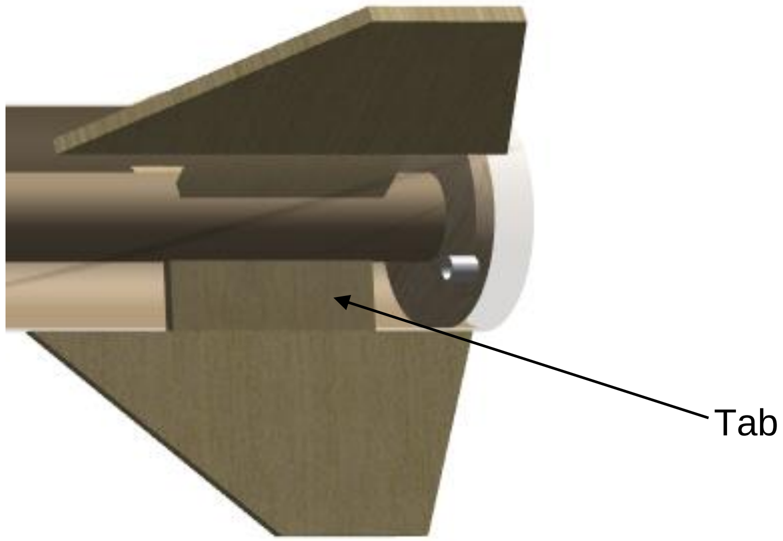
Fins

Few design constraints – be creative!
Ensure stability of rocket

Lasercut from 3mm plywood @ ICRS
(by Dev – submit dxf files to him)



Fins

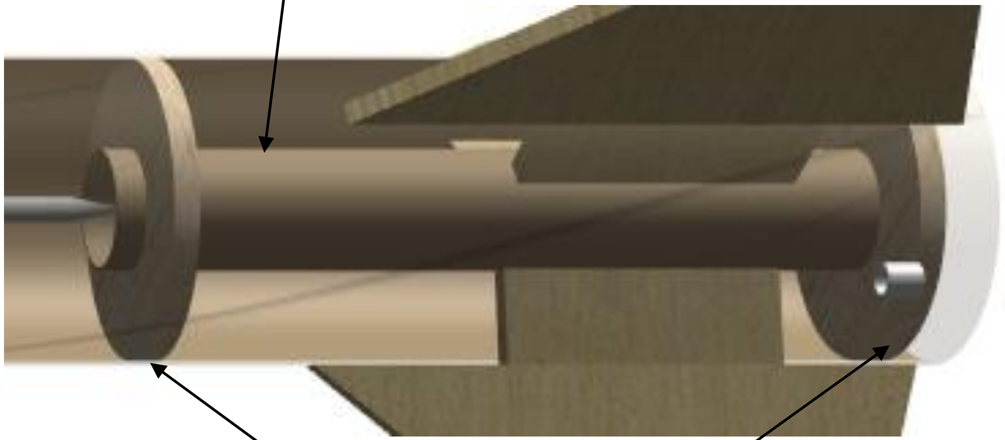


We will epoxy inside of the fin tabs and the outside too

Motor mount

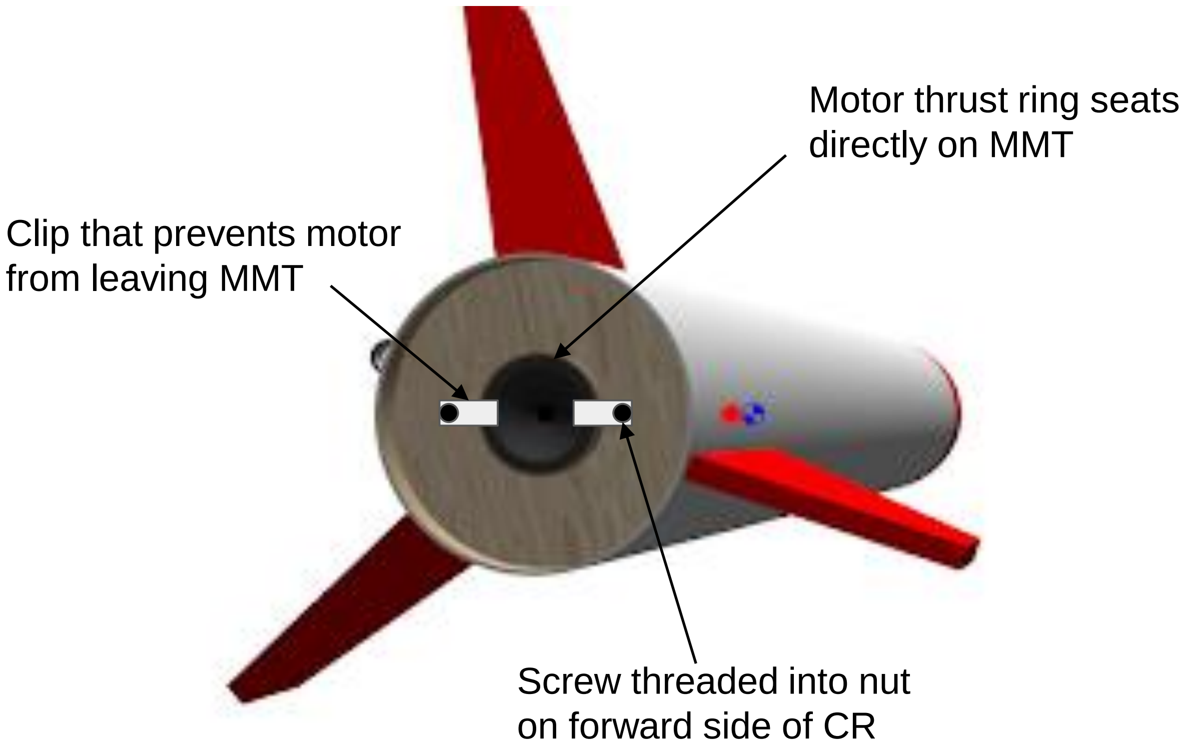
Motor case slides into motor mount tube, allowing motor case to be reused amongst members
We will use CESARONI 29MM 3-GRAIN CASE
And so the motor mount tube will be
http://www.rocketsandthings.com/view/product/1565/
Balsa Machining 1.14 in tube

Motor mount tube



Centering rings
Laser cut!

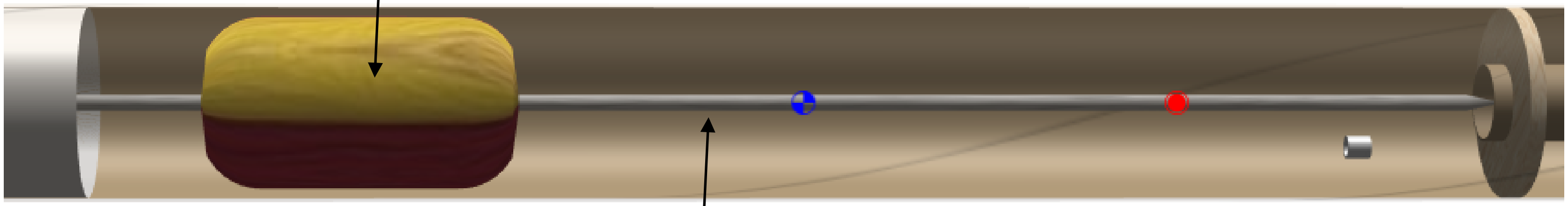
Motor retention



Rail buttons/Tubes

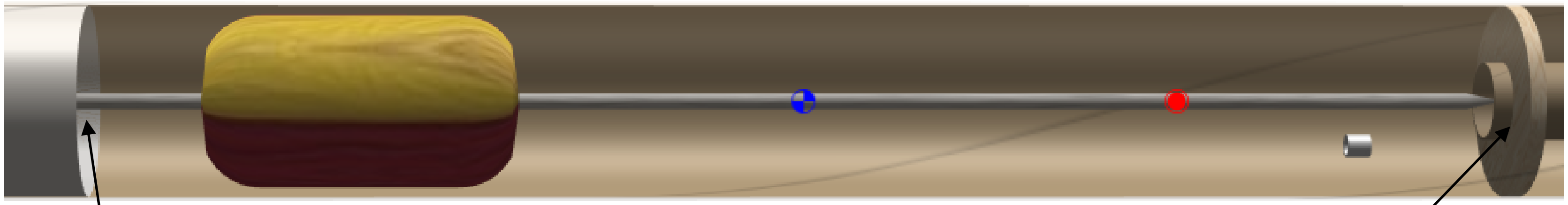
Recovery system

Parachute: 24 in Nylon from Estes



Shock cord – Kevlar rope,
approximate 12 ft of ¼'' kevlar

Recovery system



Threaded through holes in nose cone shoulder. Don’t use the built-in attachment point!

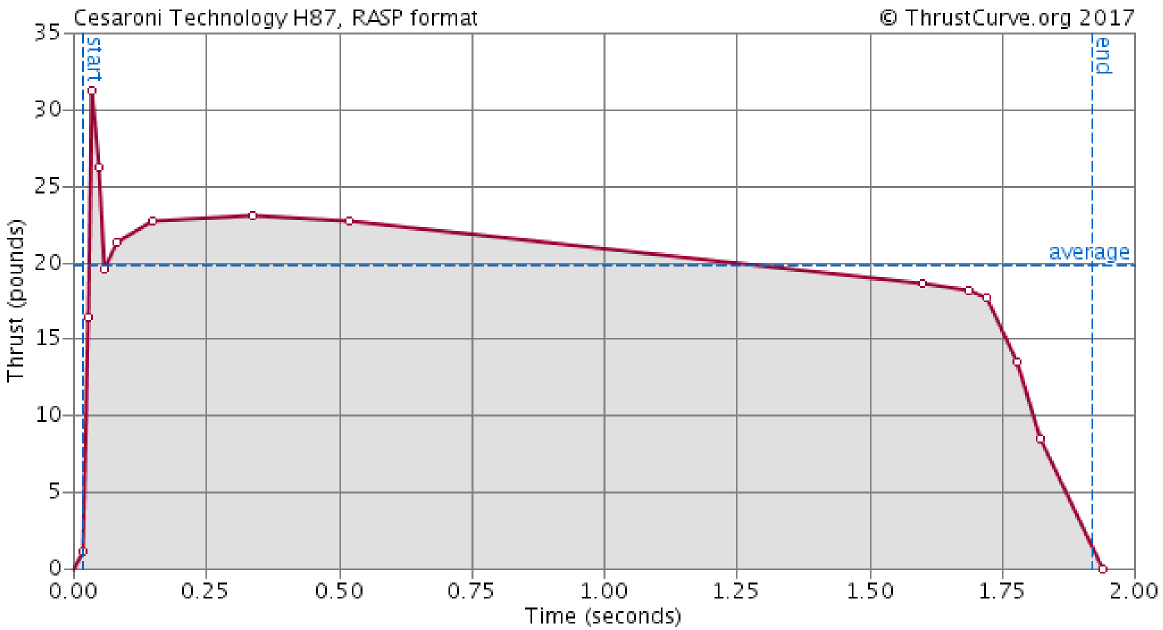
Passed through notch in CR, glued to MMT

An H or I motor?

Impulse classes

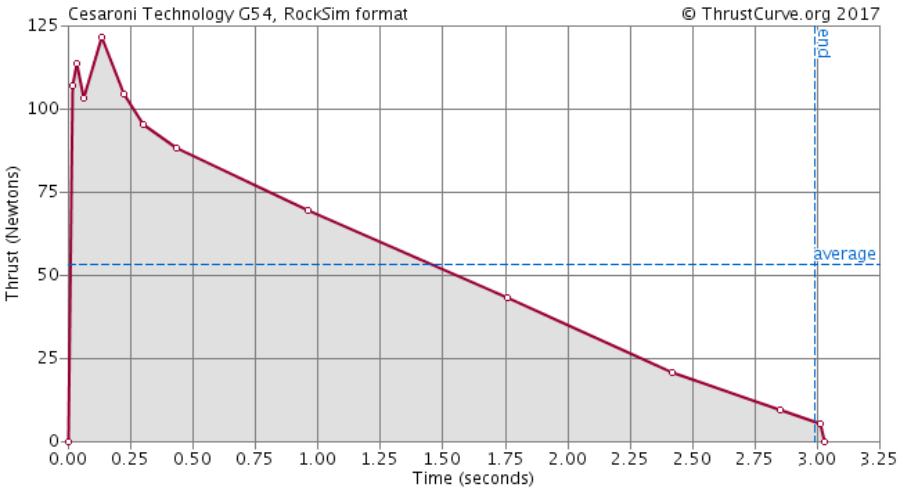
Class	Impulse range	Certification required
G	80 - 160 Ns	None!
H	160 - 320 Ns	L1
I	320 - 640 Ns	L1
J	640 - 1280 Ns	L2
...		
P	40960 - 81920 Ns	L3

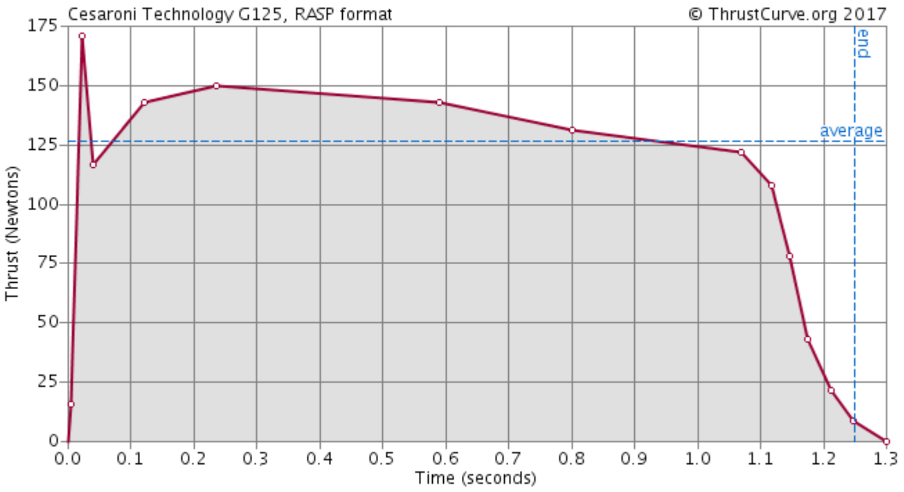
Thrust curves



Useful website: Thrustcurve.org

Thrust curves





G54

159.1 Ns

G125

159.6 Ns

Motors

- Only look at 3 grain or 4 grain, but ensure motor mount is suitably long.

- Pro29-**4G**
- Means 4 grain

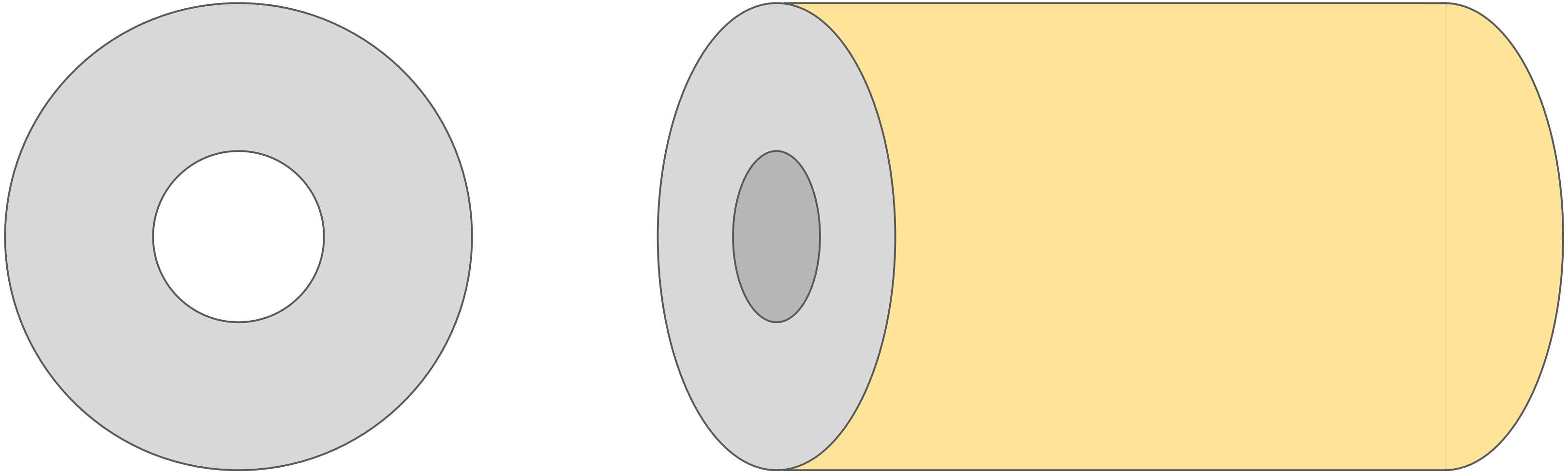
- H133 means H class motor with 133 N of average thrust

Motor	Type	Diam	Impulse	Avg Thr	Burn	Propellant	Hardware	Files
Cesaroni H133	reload	29	163.3Ns	133.1N	1.2s	Blue Streak	Pro29-3G	2
Cesaroni H90	reload	29	164.2Ns	90.3N	1.8s	Classic	Pro29-3G	2
Cesaroni H175	reload	29	166.0Ns	175.1N	1.0s	Smoky Sam	Pro29-4G	2
Cesaroni H163	reload	29	166.3Ns	162.7N	1.0s	White Thunder	Pro29-3G	2
Cesaroni H410	reload	29	167.7Ns	409.0N	0.4s	Vmax	Pro29-3G	2
Cesaroni H54	reload	29	167.7Ns	53.8N	3.1s	White	Pro29-3G	2
Cesaroni H87	reload	29	167.9Ns	86.7N	1.9s	Imax	Pro29-3G	2
Cesaroni H123	reload	29	176.5Ns	123.0N	1.4s	Skidmark	Pro29-4G	2
Cesaroni H42	reload	29	186.0Ns	42.2N	4.4s	Mellow	Pro29-4G	1
Cesaroni H237	reload	29	206.2Ns	237.2N	0.9s	Smoky Sam	Pro29-5G	2
Cesaroni H151	reload	29	207.2Ns	150.8N	1.4s	Red Lightning	Pro29-4G	2
Cesaroni H118	reload	29	216.2Ns	118.4N	1.8s	Classic	Pro29-4G	2
Cesaroni H135	reload	29	216.7Ns	135.1N	1.6s	White	Pro29-4G	2
Cesaroni H170	reload	29	217.1Ns	171.3N	1.3s	Blue Streak	Pro29-4G	2
Cesaroni H160	reload	29	220.5Ns	159.0N	1.4s	Skidmark	Pro29-5G	1
Cesaroni H255	reload	29	229.3Ns	254.3N	0.9s	White Thunder	Pro29-4G	2
Cesaroni H53	reload	29	234.2Ns	52.7N	4.4s	Mellow	Pro29-5G	1
Cesaroni H295	reload	29	252.7Ns	296.0N	0.9s	Smoky Sam	Pro29-6G	2
Cesaroni H180	reload	29	258.0Ns	179.6N	1.4s	Skidmark	Pro29-6G	2
Cesaroni H194	reload	29	260.3Ns	194.3N	1.3s	Red Lightning	Pro29-5G	2
Cesaroni H200	reload	29	260.8Ns	201.7N	1.3s	Blue Streak	Pro29-5G	2
Cesaroni H140	reload	29	268.0Ns	141.8N	1.9s	Classic	Pro29-5G	2
Cesaroni H399	reload	29	282.2Ns	399.3N	0.7s	White Thunder	Pro29-6G	2
Cesaroni H340	reload	29	287.3Ns	340.6N	0.8s	Smoky Sam	Pro29-6GXL	2
Cesaroni H159	reload	29	298.2Ns	158.9N	1.9s	Green3	Pro29-6G	2
Cesaroni H226	reload	29	305.0Ns	225.6N	1.4s	Skidmark	Pro29-6GXL	2
Cesaroni H233	reload	29	311.5Ns	233.5N	1.3s	Red Lightning	Pro29-6G	2
Cesaroni H160	reload	29	311.7Ns	161.5N	1.9s	Classic	Pro29-6G	2
Cesaroni H255	reload	29	315.4Ns	254.2N	1.2s	Blue Streak	Pro29-6G	2

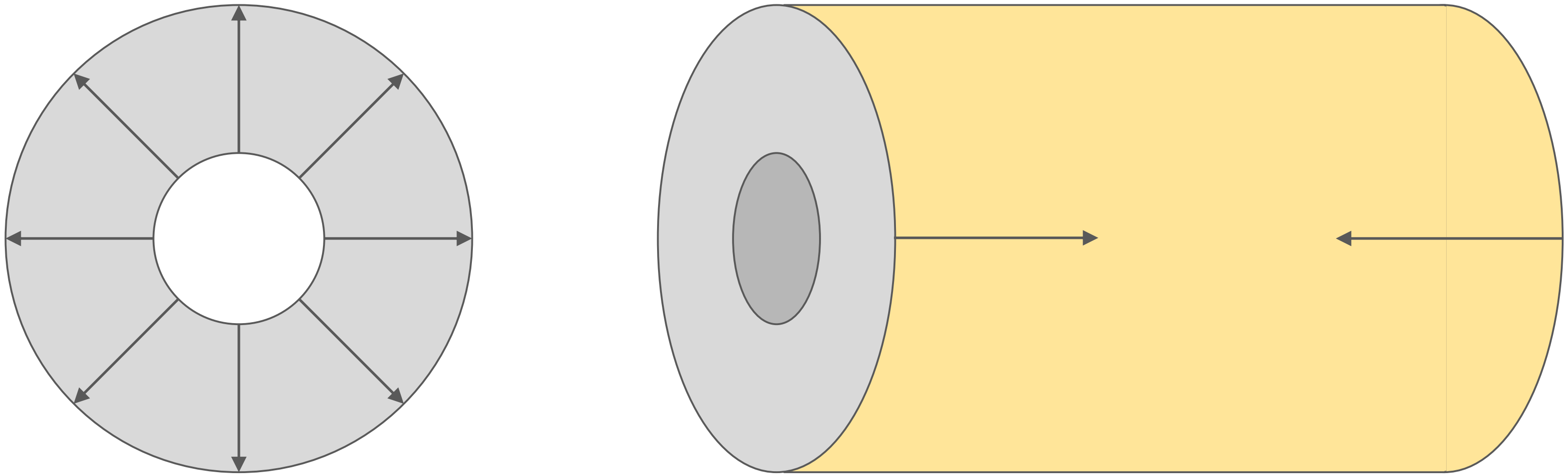
Some look cooler


AEROTECH
RMS™ 54/1706
RMS™ Reloadable Motor System™
CAUTION

Motor geometry



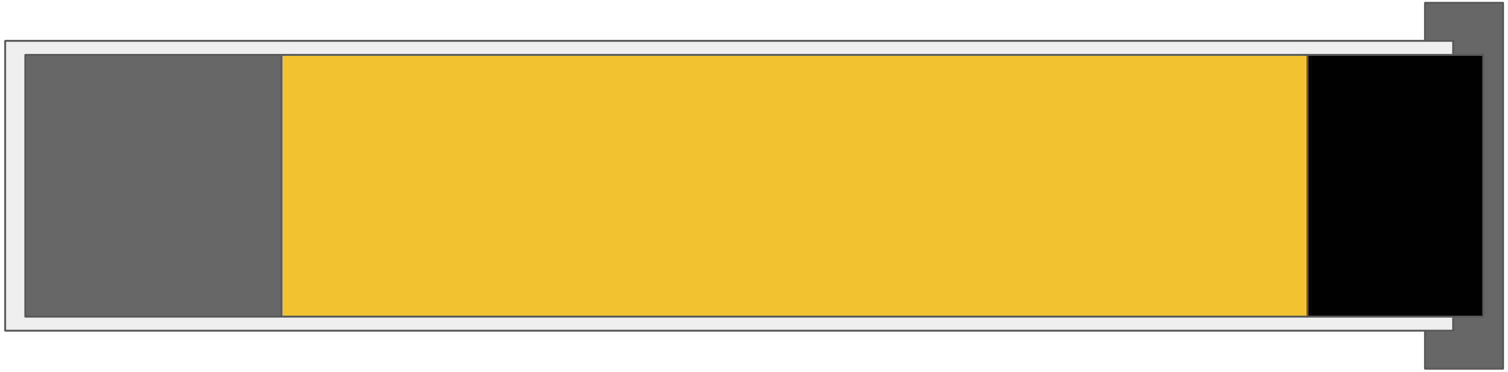
Motor geometry



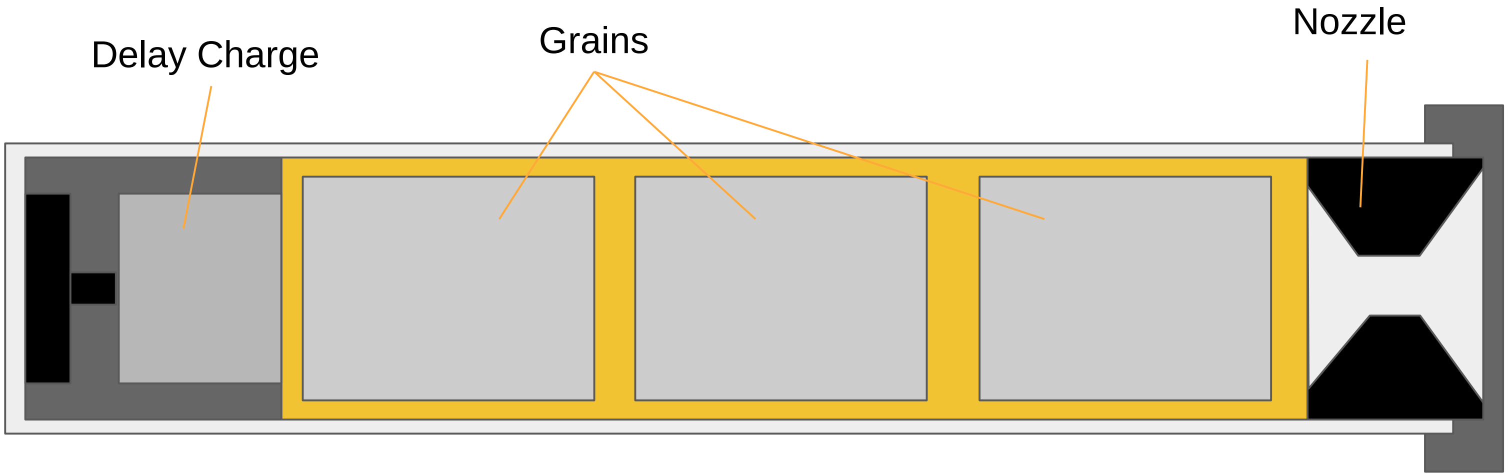
Motors burn outwards

Motor hardware features

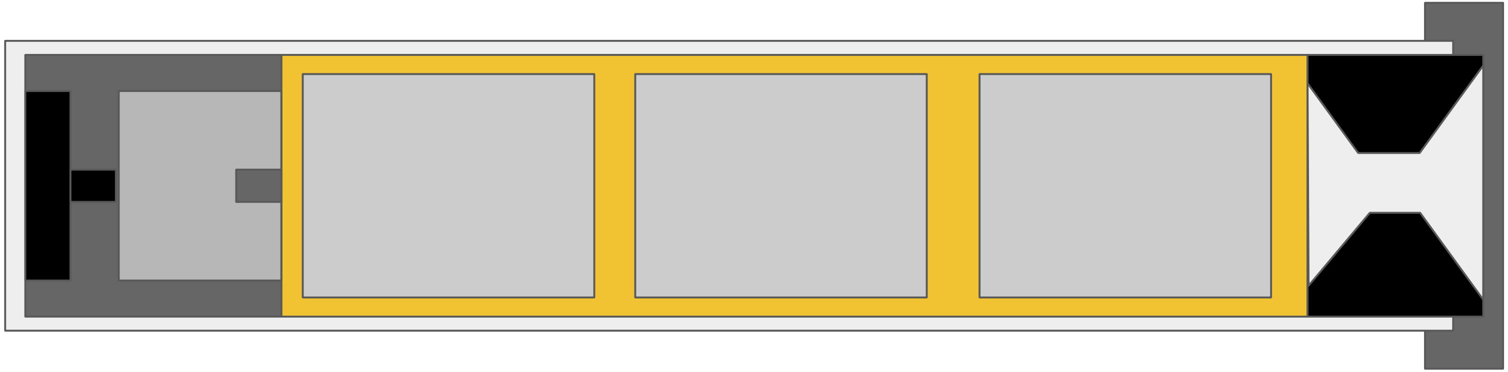
Motor hardware features



Motor hardware features

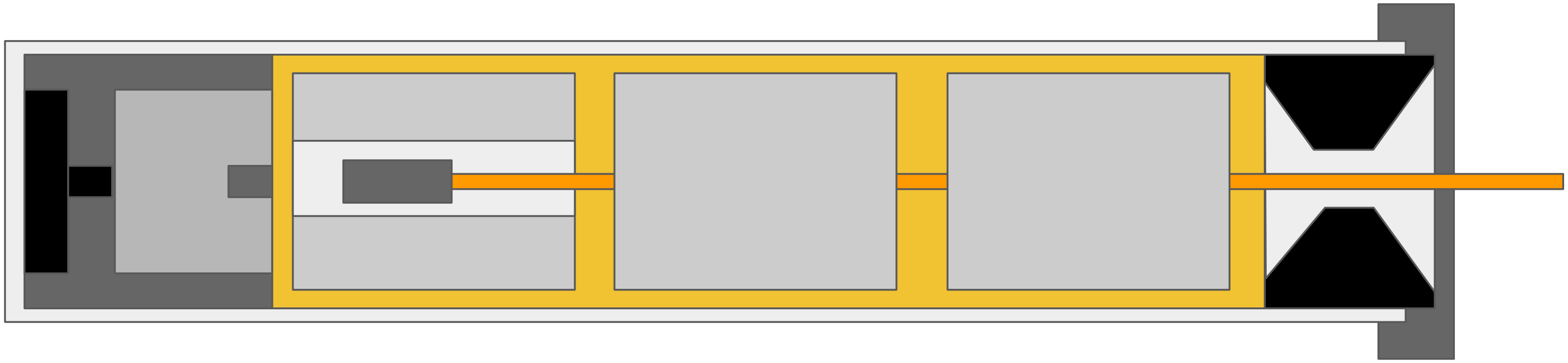


Motor operation



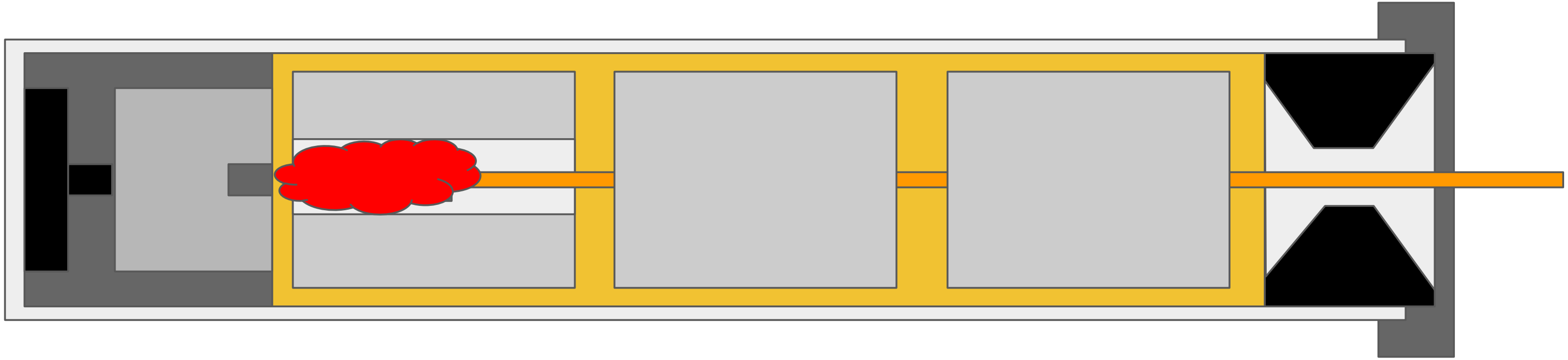
Drill the correct delay charge in

Motor operation



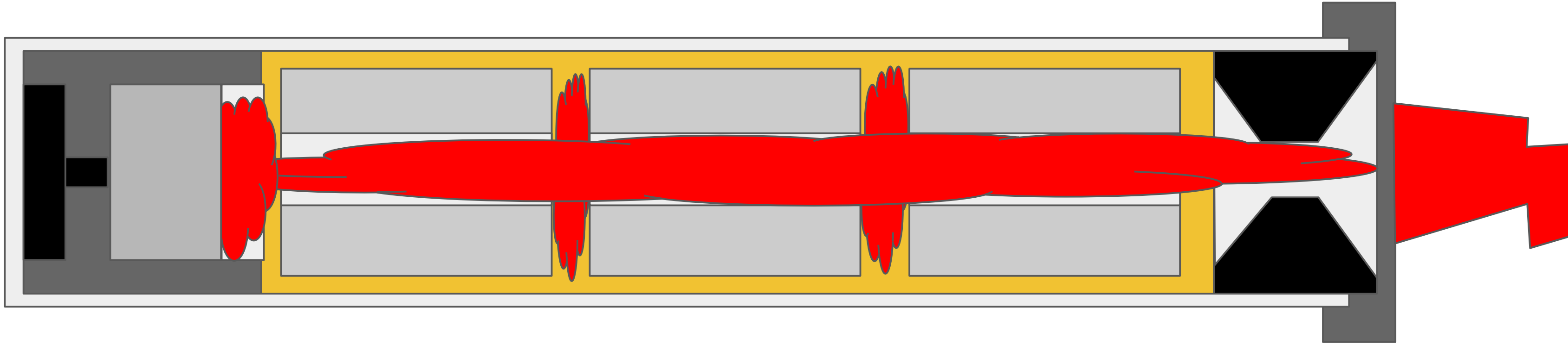
Insert E match

Motor operation



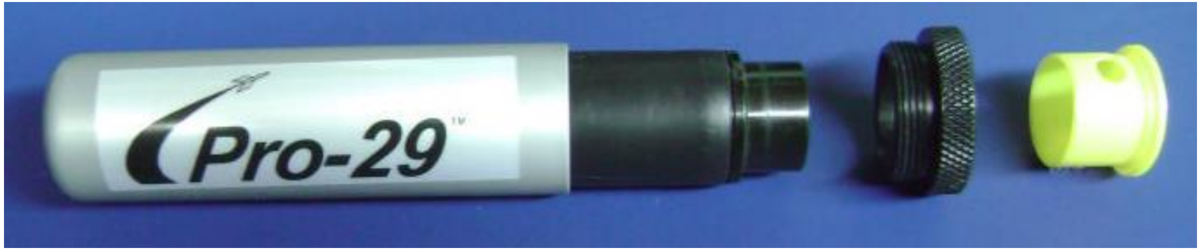
kaba

Motor operation



kababoom

What will your motor look like?



Design Guide (entirely in OpenRocket)

1. Make the nose cone + body tube
2. Make motor mount tube, 2 bulkheads
3. Add your motor
4. Make fins, add fin tabs
5. Add in recovery system
6. Iterate lengths, fins, motors until rocket is stable and to your liking.

7. Add a payload?

Assembly Guide

1. Sand fins to be rounded (and optionally tapered at trailing edge)
2. Epoxy shock cord and fore-centering ring to motor mount tube
3. Epoxy screw for motor retainer into aft-centering ring
4. Mark fin slots accurately (Having four fins makes this way easier)
5. Cut fin slots
6. Epoxy fore-bulkhead and motor mount tube into body tube
7. Epoxy fins (ensure you apply epoxy to body tube interface AND motor mount interface)
8. Epoxy aft-centering ring to body tube and motor mount tube
9. Check friction fit of nose cone
10. Paint rocket
11. Assemble with parachute
12. Ensure/fix stability