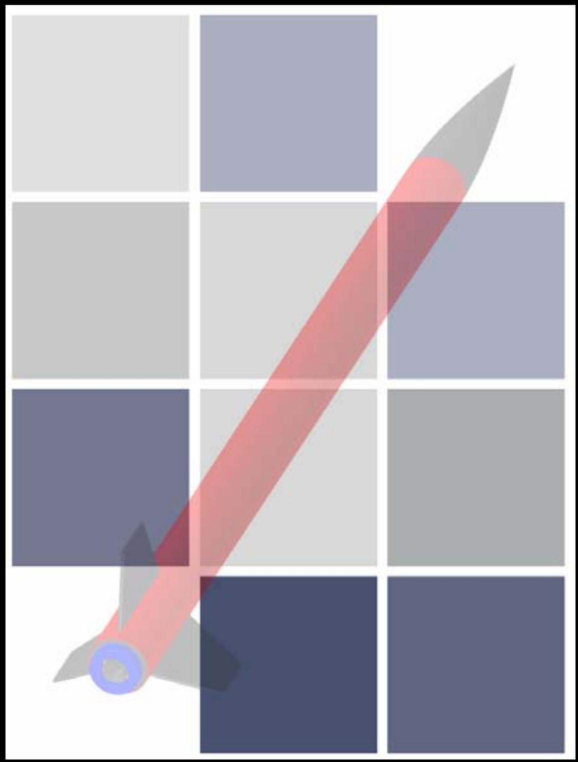
Lockheed Venture Crew 90



Rocketry Program Overview

South Jersey Area Rocketry Society (SoJARS)

January 11, 2009

Overview

1. Flight Profile
2. Air Drag
2. Rocket Propulsion
3. Rocket Stability

Brief History of Rocketry

- Chinese invent gunpowder around 3 BCE using saltpeter, sulphur, and charcoal.
- Gunpowder = 75% Potassium Nitrate, 10% Sulphur, and 10% Carbon
- Gunpowder filled bamboo for religious ceremonies
- 13th Century Chinese used rockets as offensive weapons

Brief History of Rocketry (cont)

- British used rockets during battles in 17^{th} Century
- Robert Goddard = Grand Dad of Rocketry
- 1958 – NASA established
- July 20, 1969 – "The Eagle has Landed"

Flight Profile

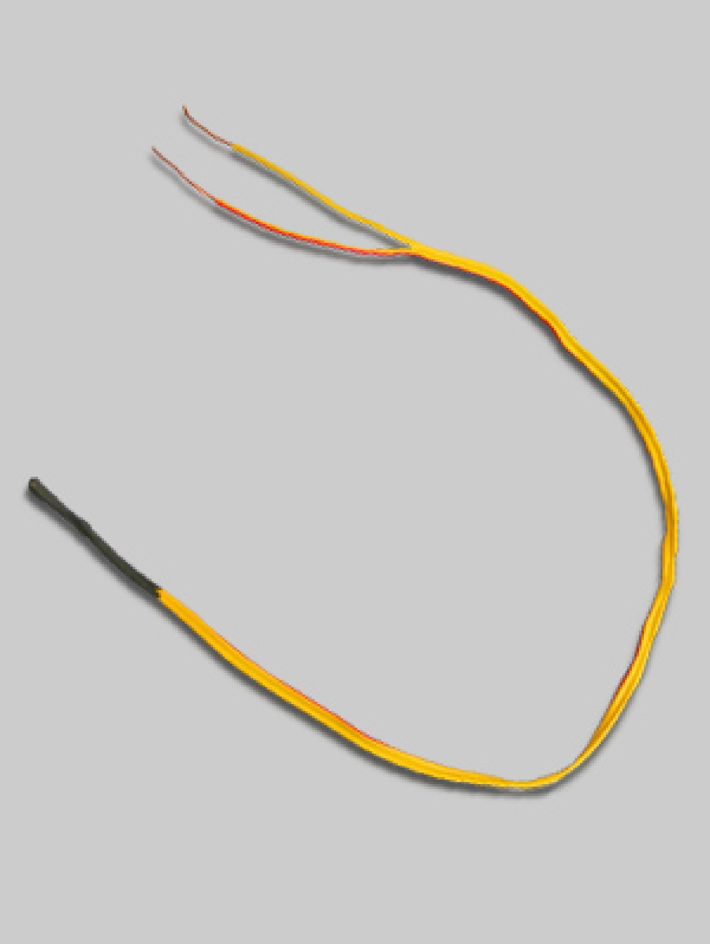
Phases of Flight

- Ignition
- Thrust (Boost Phase)
- Coast
- Apogee
- Recovery

Ignition

- Ignition of propellant by electrical means
- Electrical Igniters

Electrical Igniters



Aerotech First Fire Igniter

Thrust Phase (Boost)

- From ignition to motor burn-out
- Upward thrust provided by motor
- Types of Motors
  - Different motors determine flight characteristics
  - High-avg impulse – short burns – high speeds
  - Low-avg impulse – long burns – slower speeds

Coast Phase

- From motor burn-out to apogee
- No more thrust provided by motor
- Tracking smoke and delay element burn
- *What forces are being applied to the rocket?*
- Those forces slow the rocket to Vy = 0.

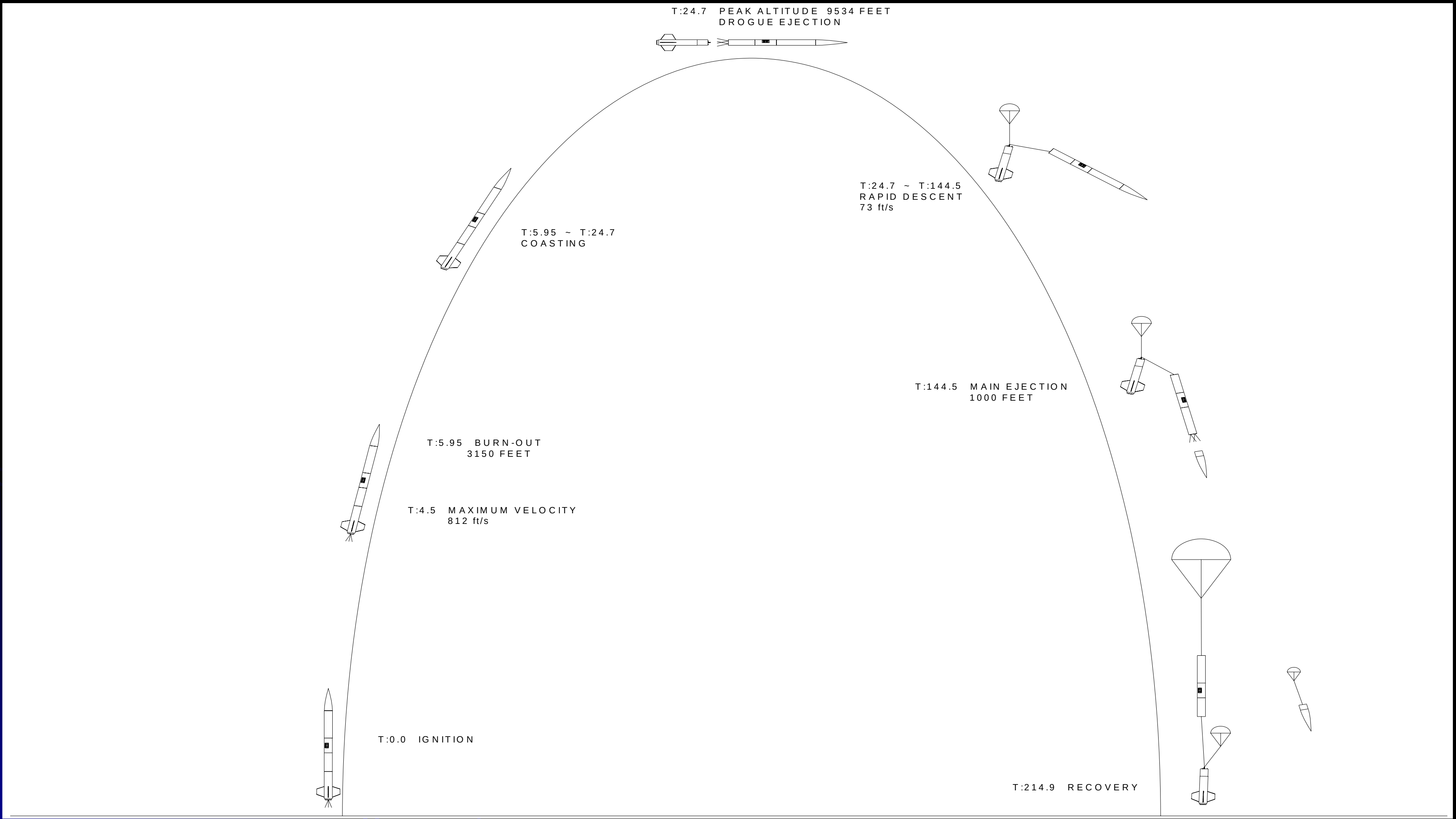
Apogee

- Drag inducing device deployed to slow rocket to a soft recovery to prevent damage upon landing
  - Parachute – high drag, slow descent, more prone to drifting
  - Streamer – lower drag, faster more direct descent
  - Helicopter – blades deploy and rotate airframe
  - Glider – separate winged section detaches and glides to the ground – booster uses streamer

After Flight

- Check for broken parts
- Reset recovery device
- Install new motor and igniter
- Fly it again (and again and again!)

Flight Profile



Rocket Propulsion

Terms

- Motor / Engine – The motive force making a rocket go.
- Propellant – Chemical reactants in the motor
- Types of Motors
  - Solid Propellant (Blackpowder and Composite)
  - Liquid Propellant
  - Hybrid

What is Boost Phase?

Boost Phase

- Time from launch to motor burn-out
- Part of flight where rocket is under power by motor

What is Burn-Out?

Burn-Out

- Point where all propellant is burnt up within motor
- Also the point of highest velocity

What is Coast Phase?

Coast Phase

- Part of flight from motor burn-out to apogee
- Rocket is no longer under power.
- Rocket continues upward until is decelerates to zero vertical velocity

What forces are acting on the rocket during this phase to "slow" the rocket down?

What is Apogee?

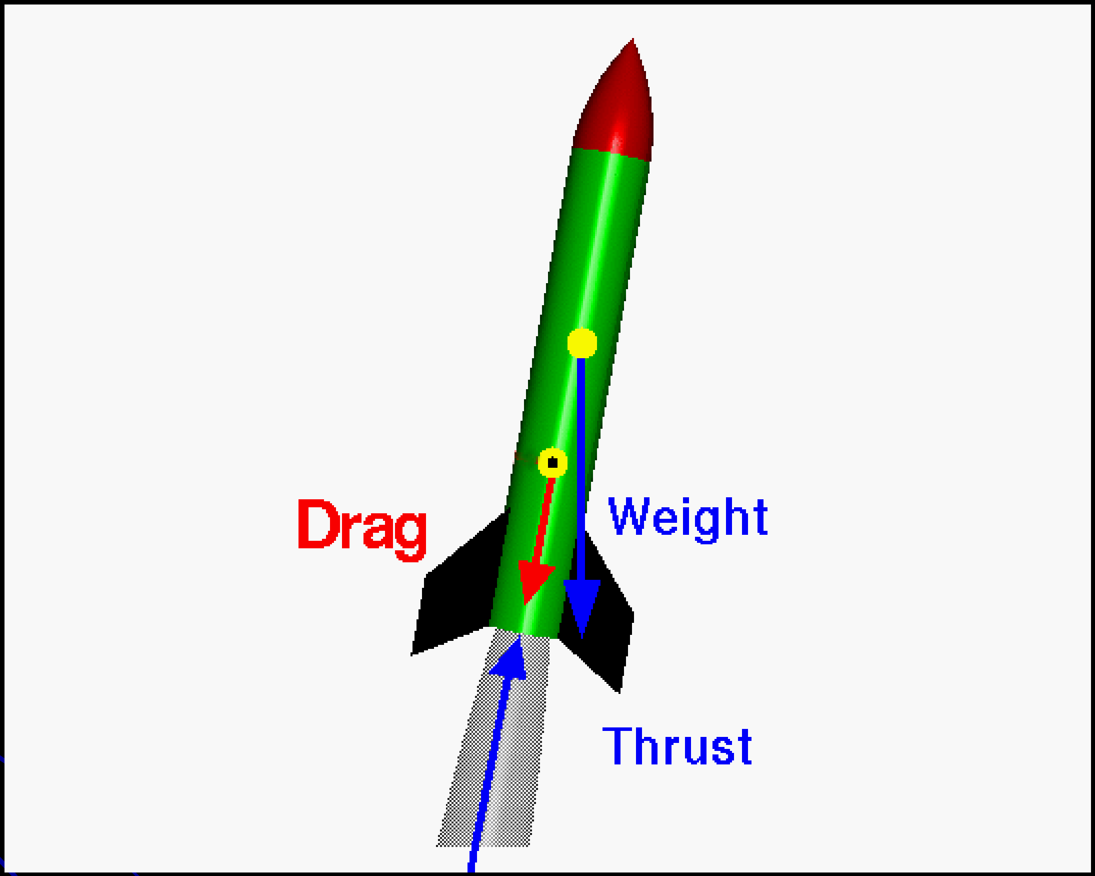
Apogee

- Highest altitude of rocket flight
- Also the point where vertical velocity = zero

Why is this a good time to eject a parachute?

Forces Acting on a Rocket

Forces on a Rocket



Thrust, weight, and drag are the three primary forces acting on a rocket during flight.

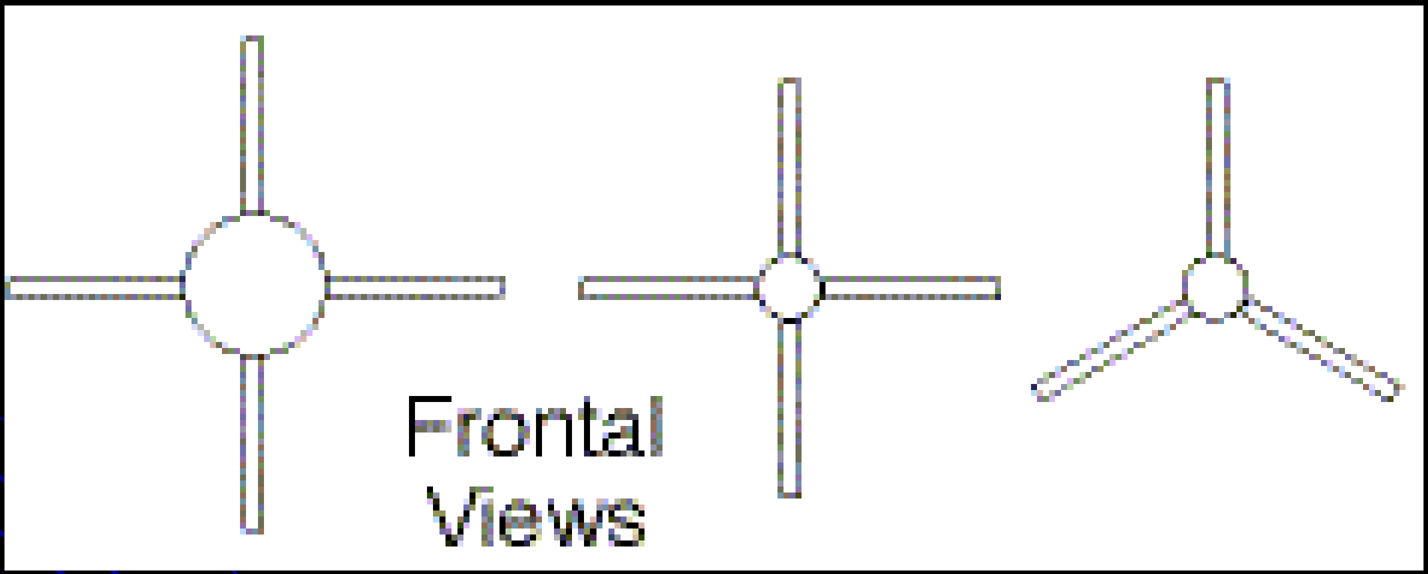
We know what gravity is . . .
so what is Air Drag?

Air Drag

- Friction (interaction) between air molecules and rocket
- Designated by greek letter rho - ρ
- Air density is approximately 1.22 kg/m^3 at sea level
- Influenced by three (3) major parameters
  - Form Drag – due to shape of rocket
  - Skin Friction Drag – Air molecules being slowed down by surface imperfections in the rocket
  - Induced Drag – Caused by fins which are used for stability

Form Drag

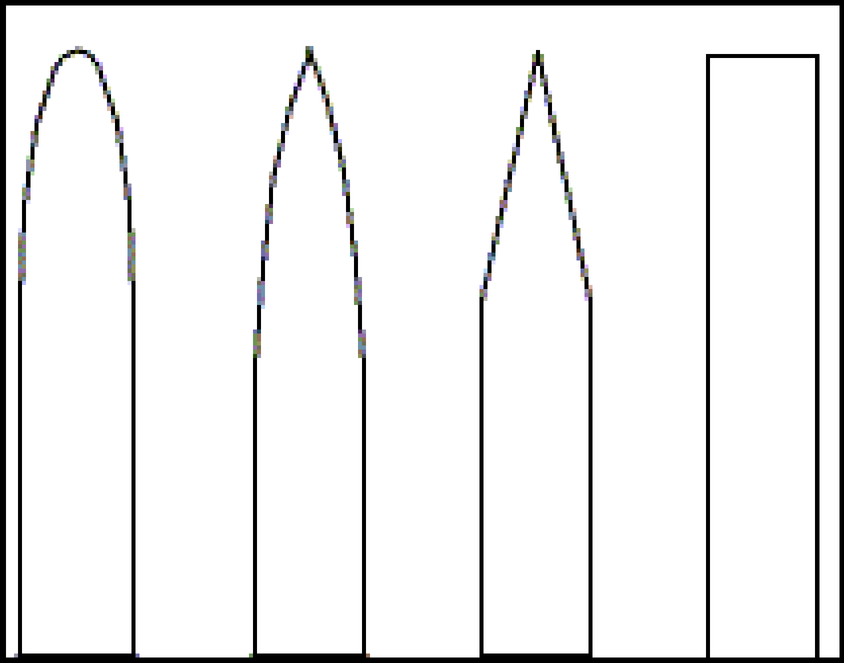
- Area you see looking straight down rocket from top



Which profile has the least amount of form drag?

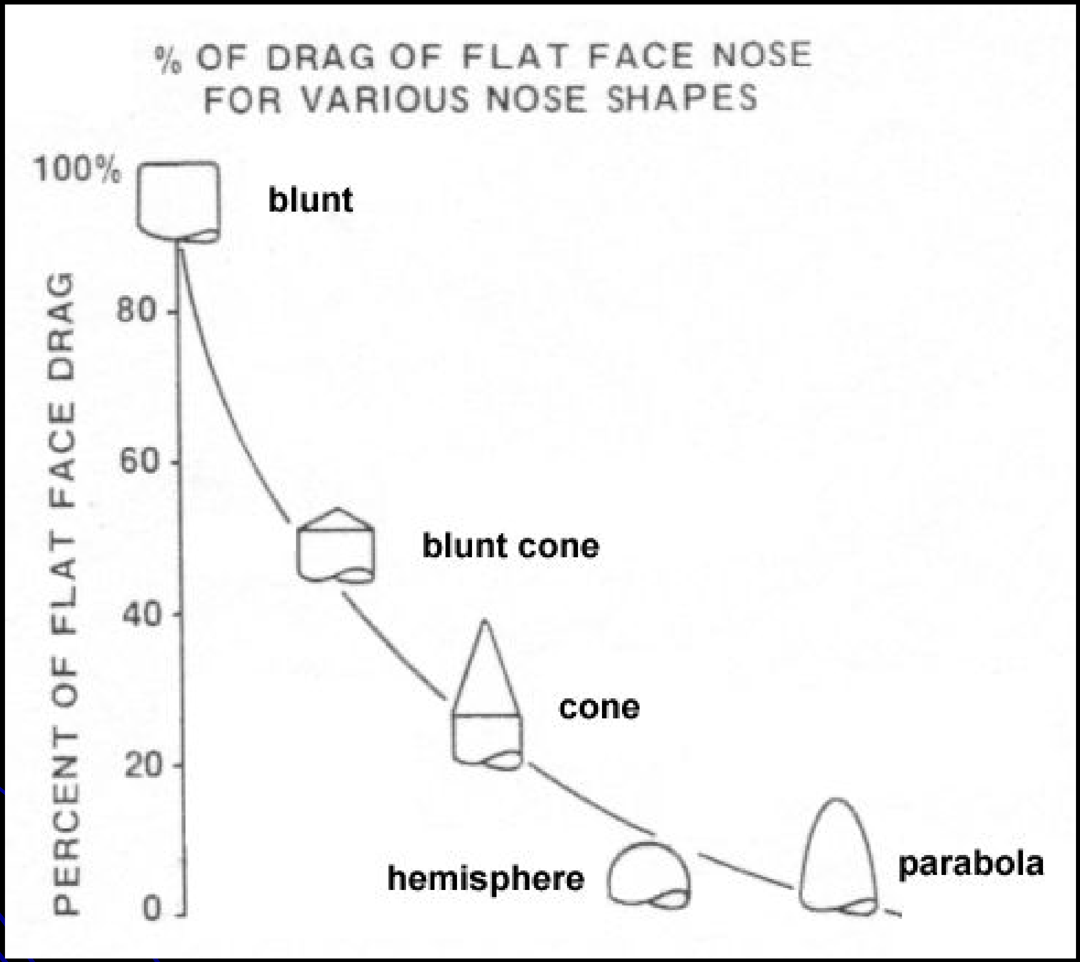
Form Drag (Nose)

- Nosecone also has major impact on drag of rocket



Which nosecone profile has the least amount of form drag?

Form Drag (Nose)



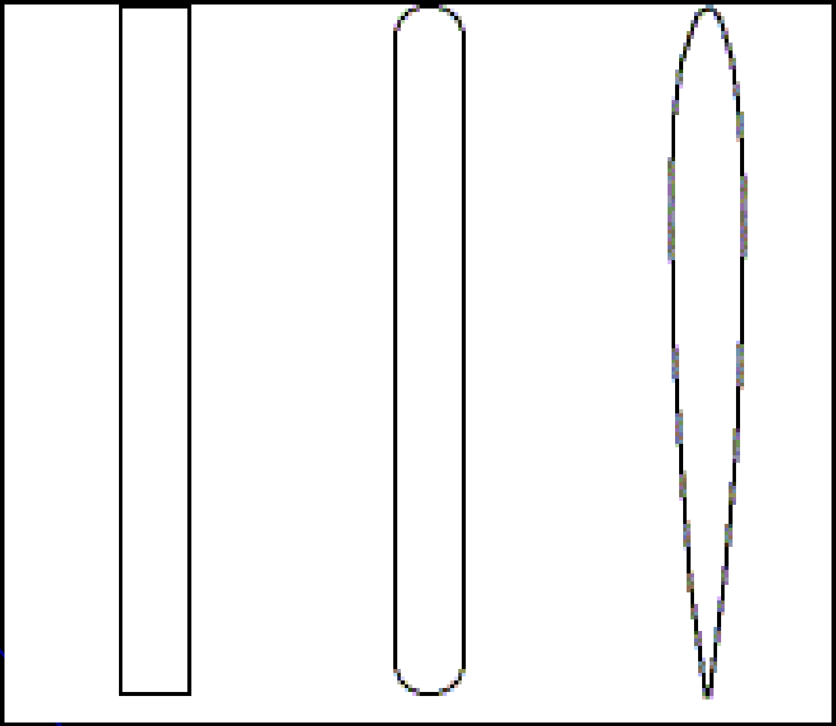
Parabolic nosecones have least amount of drag.

Form Drag (Nose)

AIM-54 Pheonix missile has parabolic nosecone

Induced Drag (Fin Shape)

- Fin cross-section (airfoil) is also a major player in amount of drag seen by the rocket.



Which fin airfoil has the least amount of induced drag?

Why is Drag a problem?

Air Drag (cont)

Why is Drag a problem?

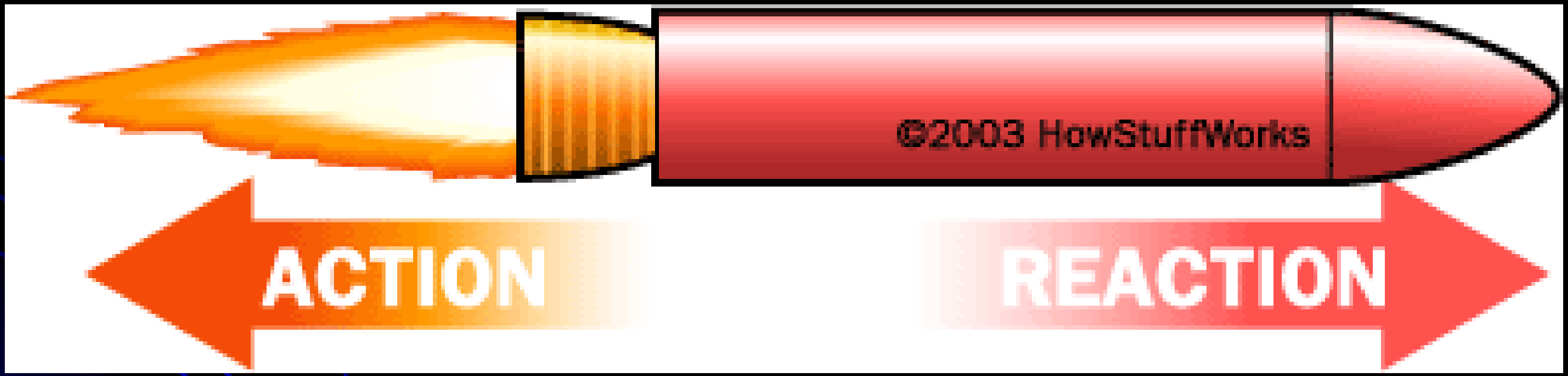
- Limits performance of a rocket
- Reduces max. achievable velocity of a rocket
- Limits the altitude a rocket can reach
- Thermal damage can occur during MACH flights

And finally while we're on the subject of forces . . .

What is Newton's Third Law?

Newton's Third Law

- "For every action, there is an equal and opposite reaction"
- Rockets "throw" a lot of mass in one direction, and thus move in the opposite direction.

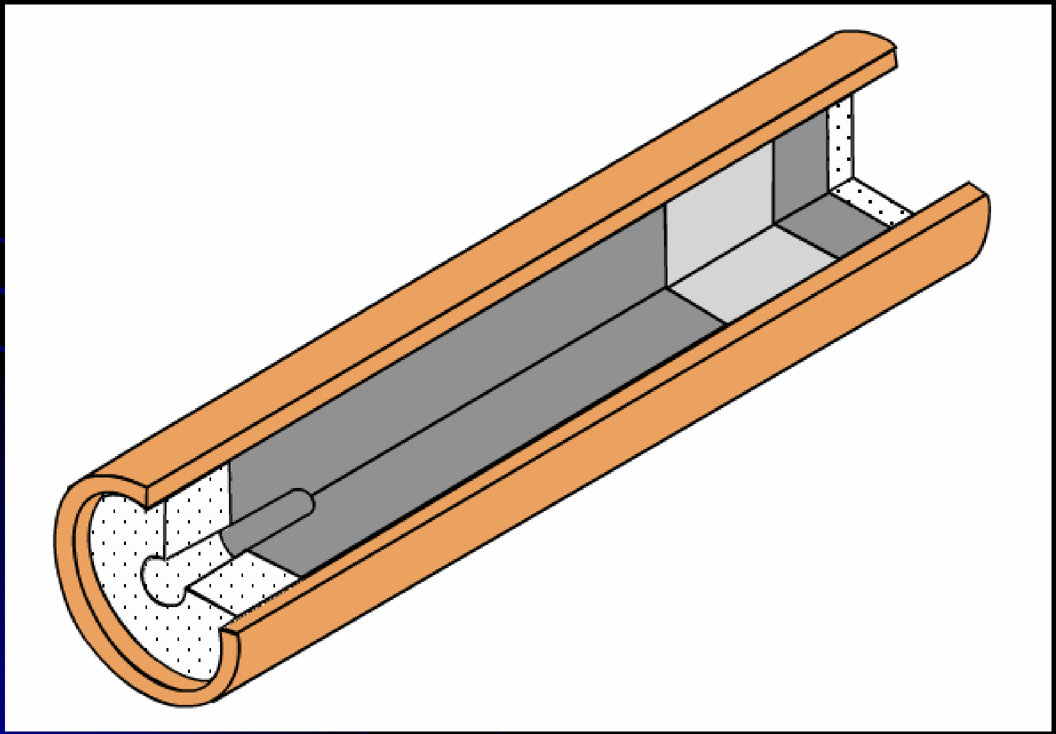


It is thee Law that defines how rockets "work."

Rocket Motors

Black Powder Rocket Motors

- Propellant is made up of blackpowder
- Estes Rocket Motors – End burners
- Low thrust-to-weight compared to composite motors



Composite Rocket Motors

- Propellant is made up of two primary components
- Fuel – When fuel burns, it creates heat and hot gases which exit the rocket provide the thrust to propel the rocket
- Oxidizer – Provides the oxygen necessary for the fuel to “burn.”
- Commonly known as APCP motors (Ammonium Perchlorate Composite Motors)

Fuel

- Typically Aluminum (extremely fine powder)
- Mixtures of Aluminum and Magnesium are also commonly used

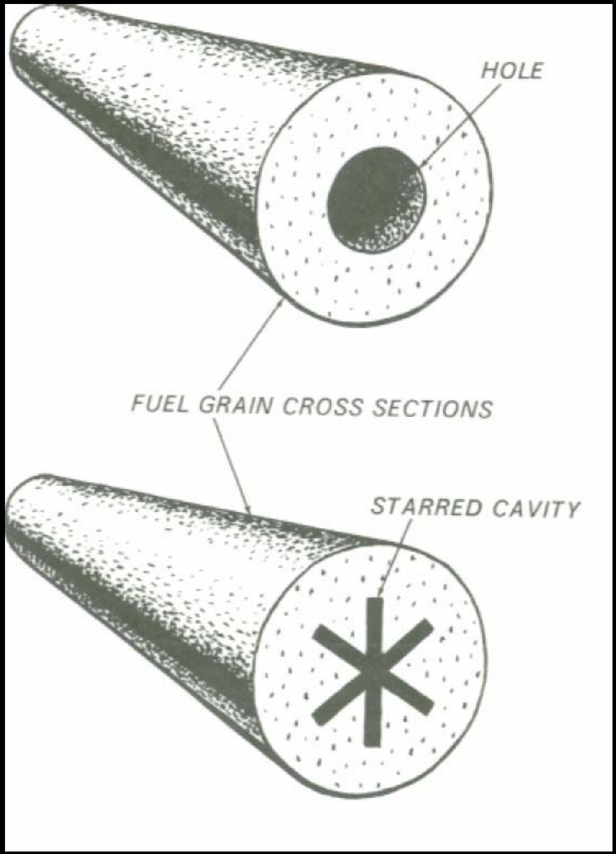
Oxidizer

- Typically Ammonium Perchlorate (NH4ClO4)
- Commonly known as AP

Solid Fuel Motor

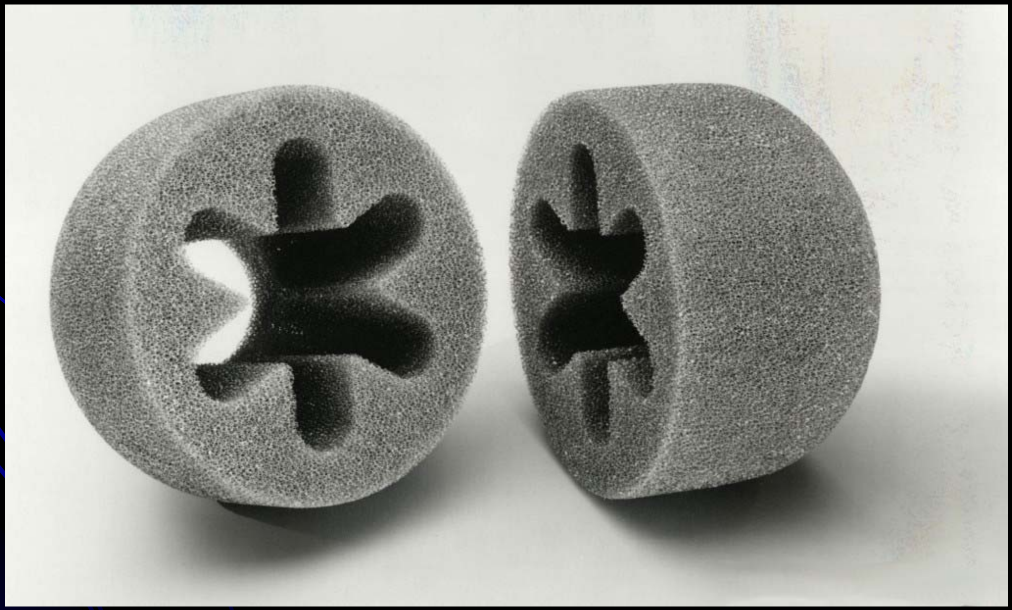
- Oxidizer and Fuel are mixed together with a binder (glue) and poured or packed into a cylindrical form to create a propellant grain

Why do some grains have star shape cavities and others have circular cavities?



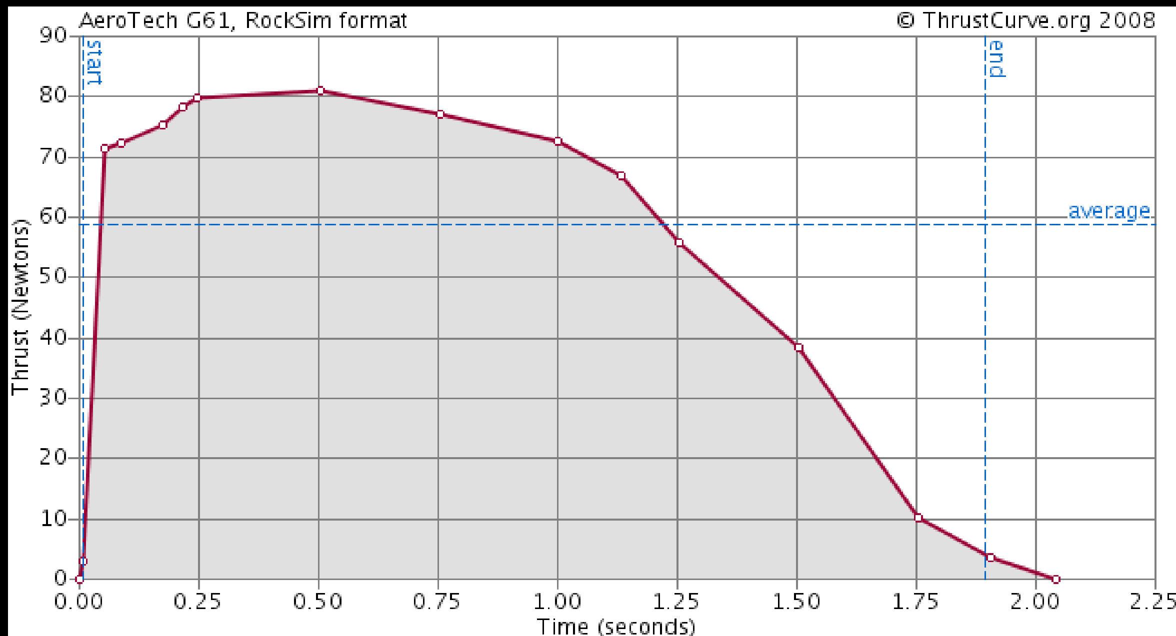
Propellant Grain Cross-Section

- Cross-section of grain affects the rate at which the propellant burns
- By using different shapes, one can control precisely how the motor burns through its entire duration of operation



Thrust Curve of Motor

Thrust (Newtons)



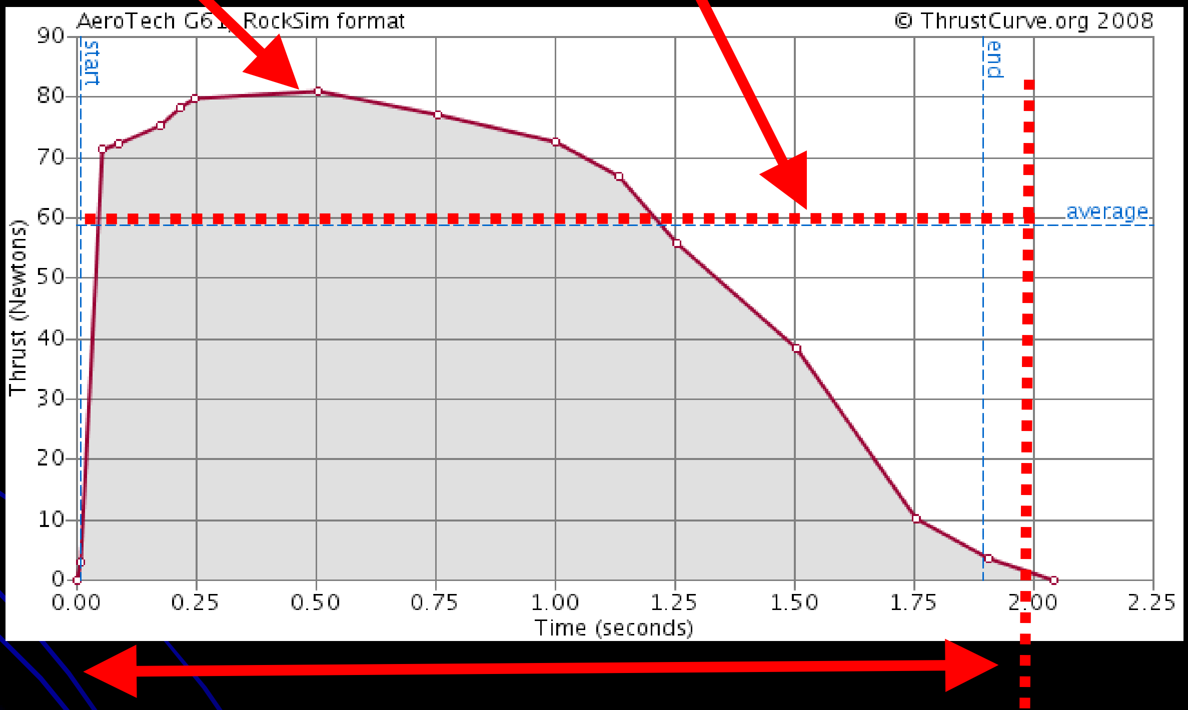
Time (seconds)

- Provided by manufacturer based on test data

Thrust Curve of Motor

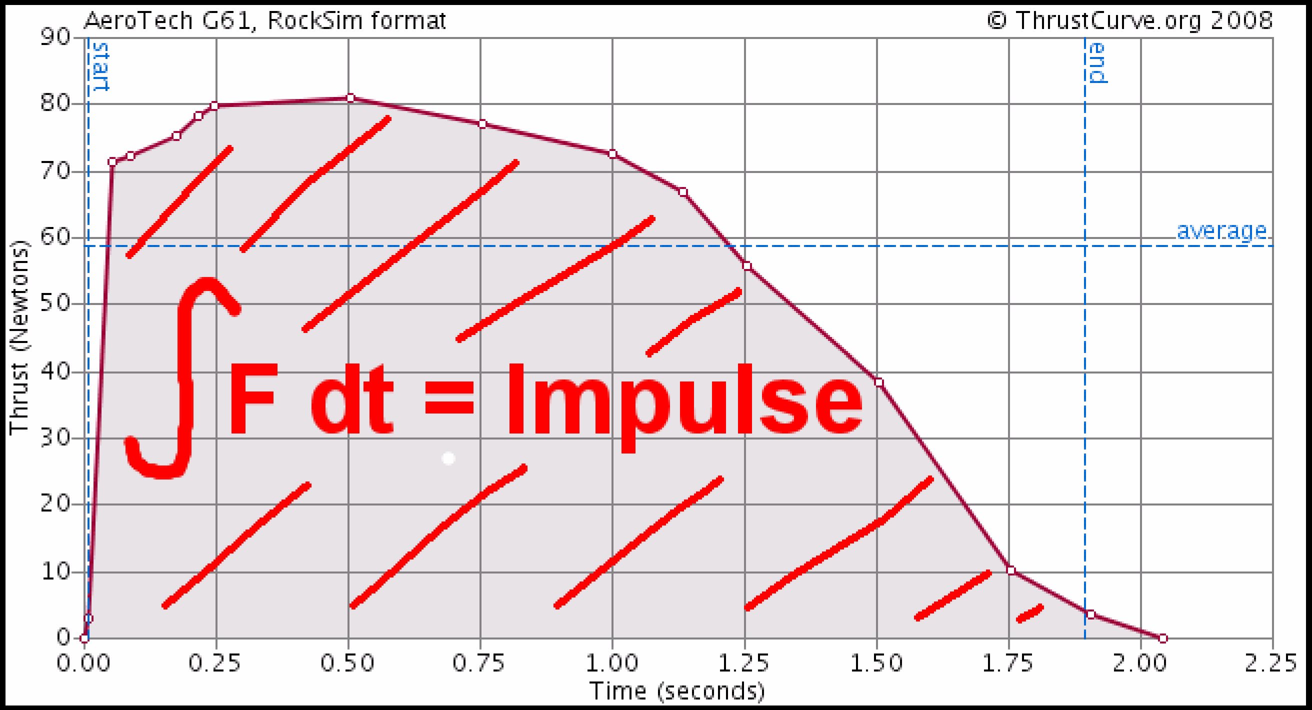
Peak Thrust

Avg. Thrust (61 N)



Burn Duration

Thrust Curve of Motor



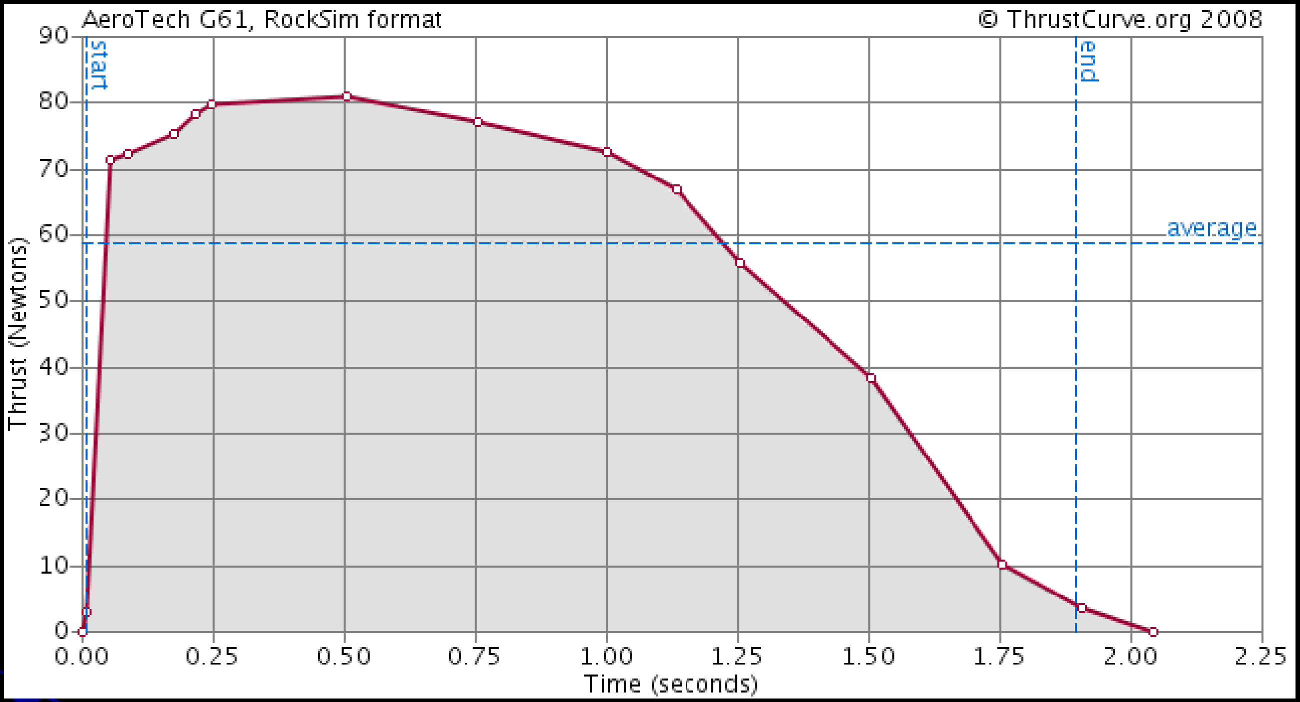
Impulse is measure of total power of motor

Impulse = Avg. Thrust * Burntime

= Integral of Force with respect to time

= Area under the thrust cove

Thrust Curve of Motor

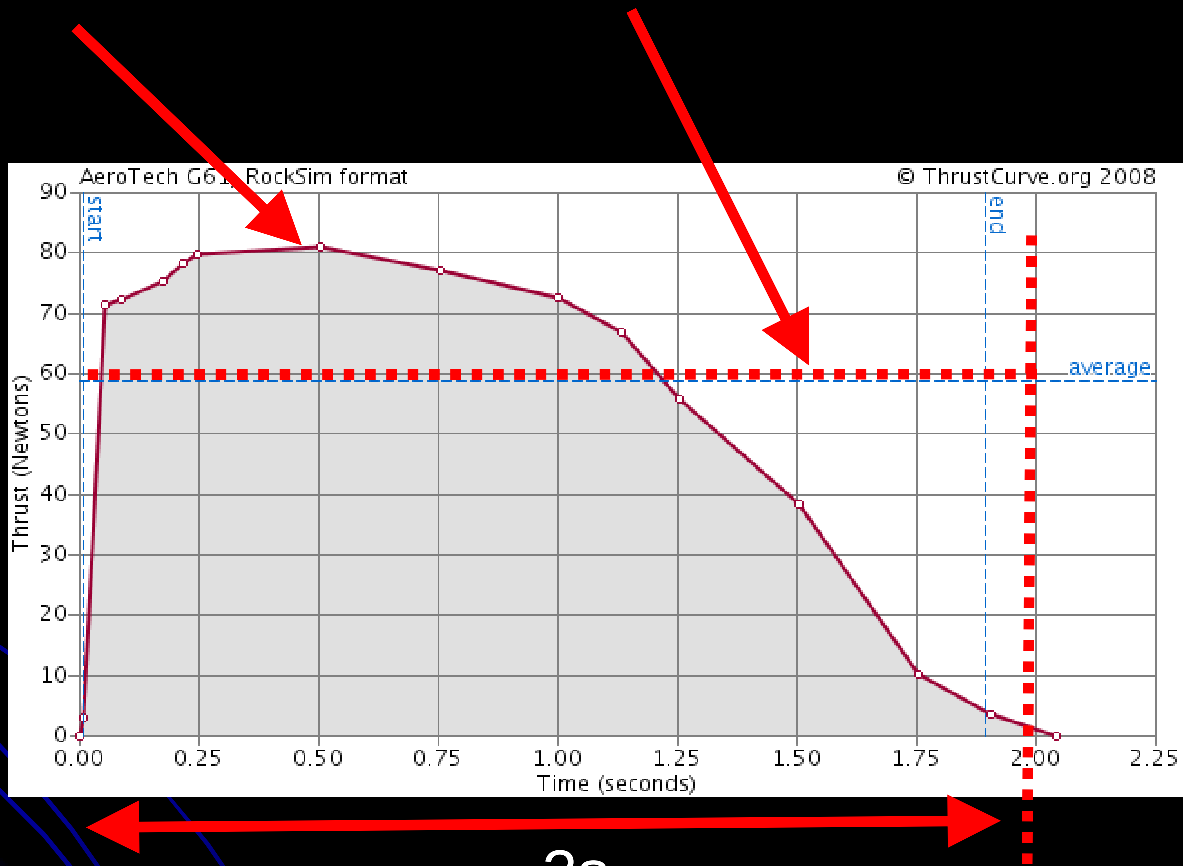


- What is peak thrust of motor in newtons?
- What is peak thrust of motor in lbs?
- What is burn-time of motor?
- What is average thrust of the motor?

Thrust Curve of Motor

Peak Thrust

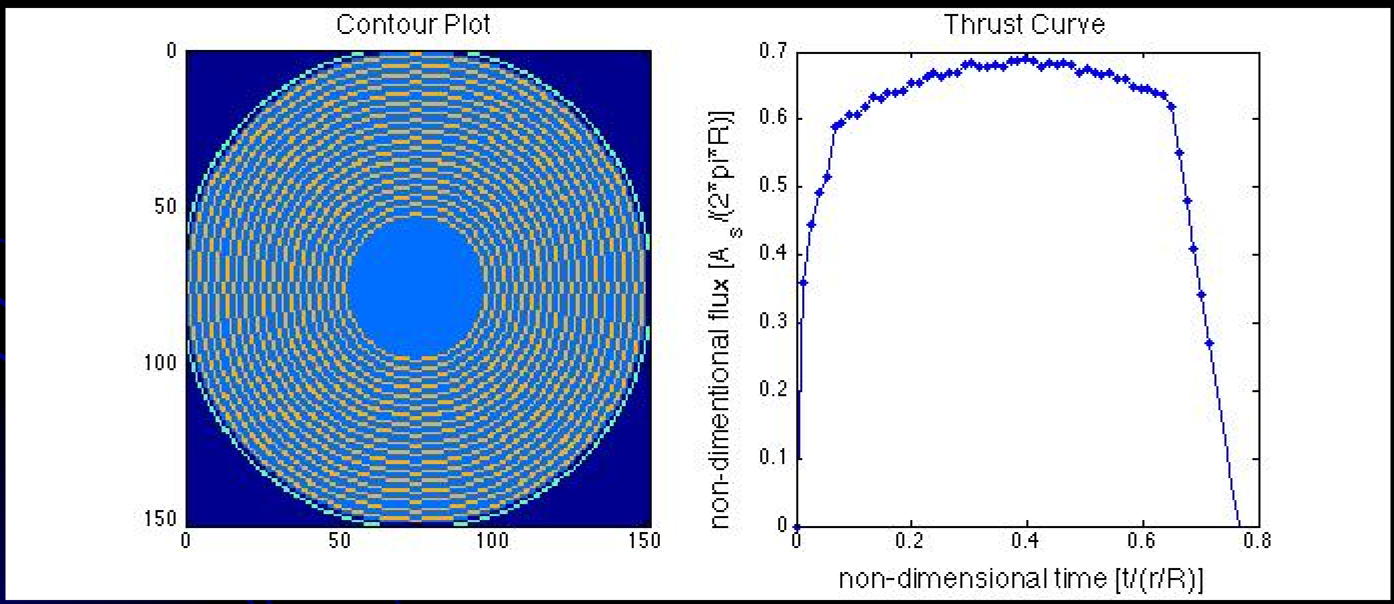
Avg. Thrust (61 N)



- What is the total impulse of this motor?

Circular Cross-Section

- Progressive to Regressive Thrust Curve
- Fairly flat thrust curve
- Most commonly used in amateur rocketry

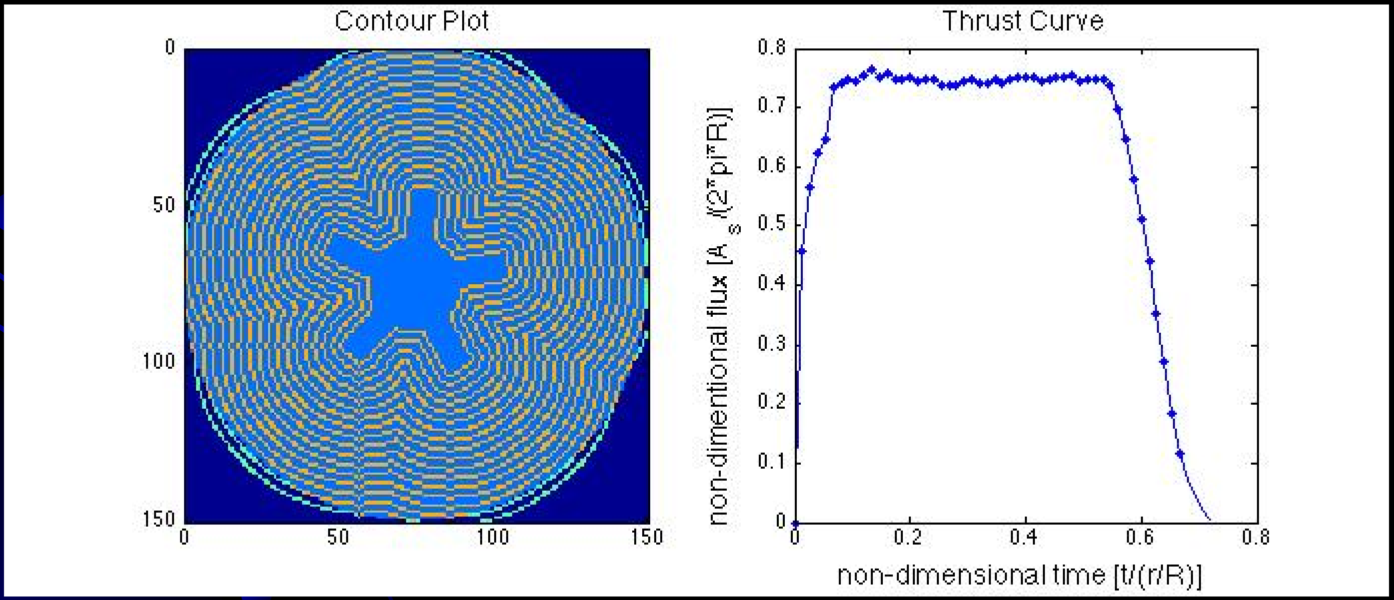


Circular Cross-Section (cont)

- Space shuttle solid rocket boosters use a Circular cross-section

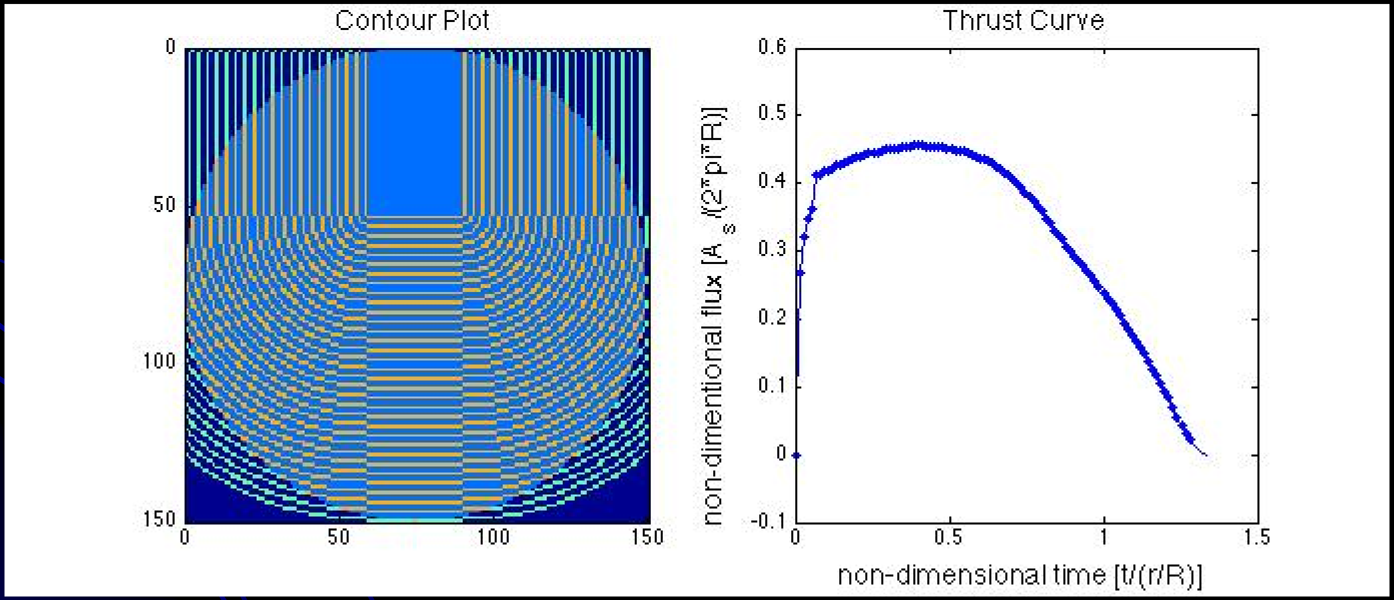
Star-Shaped Cross-Section

- Produces very level (constant) thrust
- Also produces higher peak thrust due to increased surface area

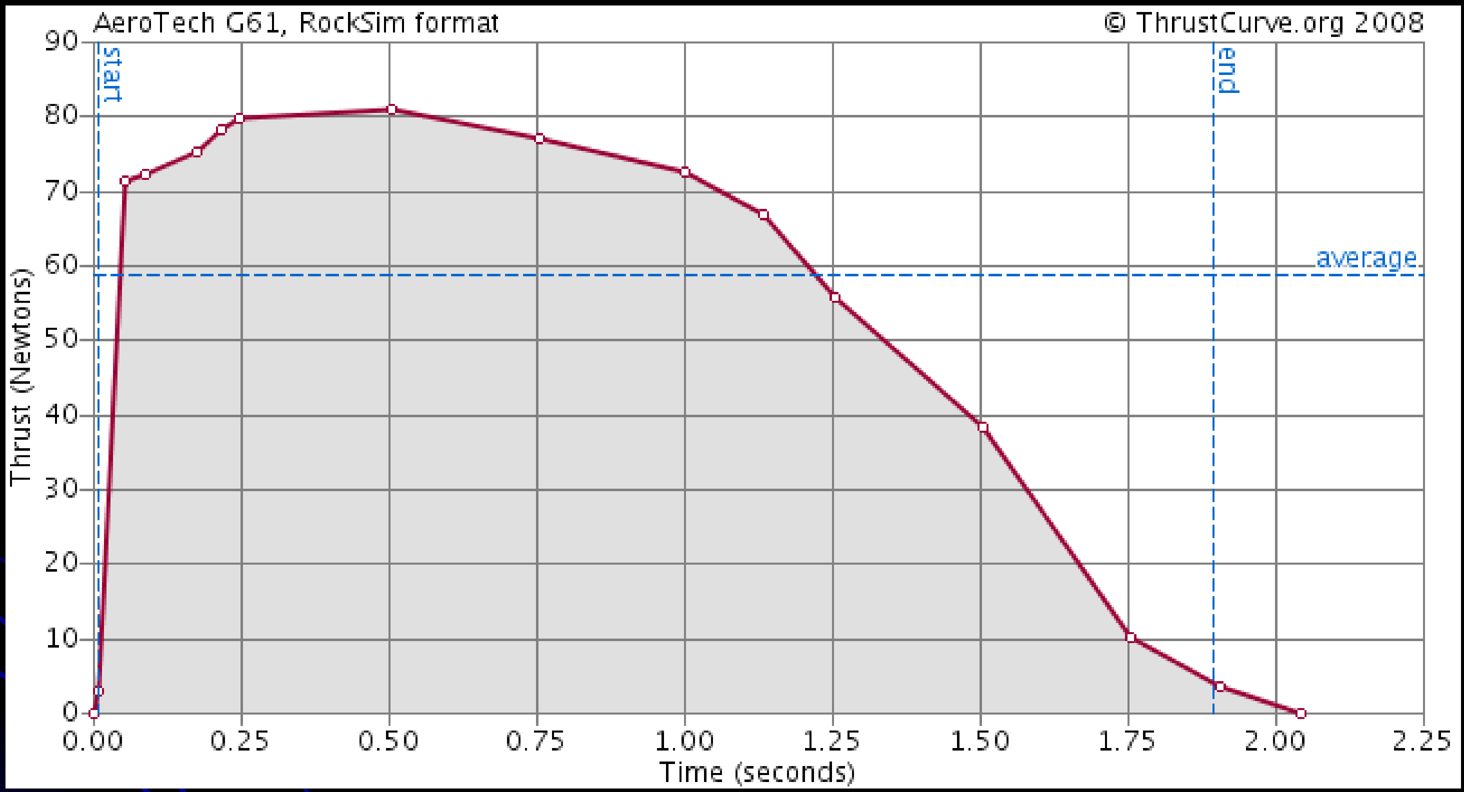


C-Slot Cross-Section

- Fairly long regressive thrust
- Easy to manufacturer and to create long burning motors as well



Aerotech G61 Thrust Curve



What kind of grain cross-section does this have?

Rocket Motor Classification

- Rocket motors classified according to their total impulse rating
- Thrust – Instantaneous Power of Motor
- Impulse – Total Power Output of Motor

  = Thrust x Duration (measured in N*s)

- 4.45 Newtons = 1 Lb Thrust

Rocket Motor Classification (cont)

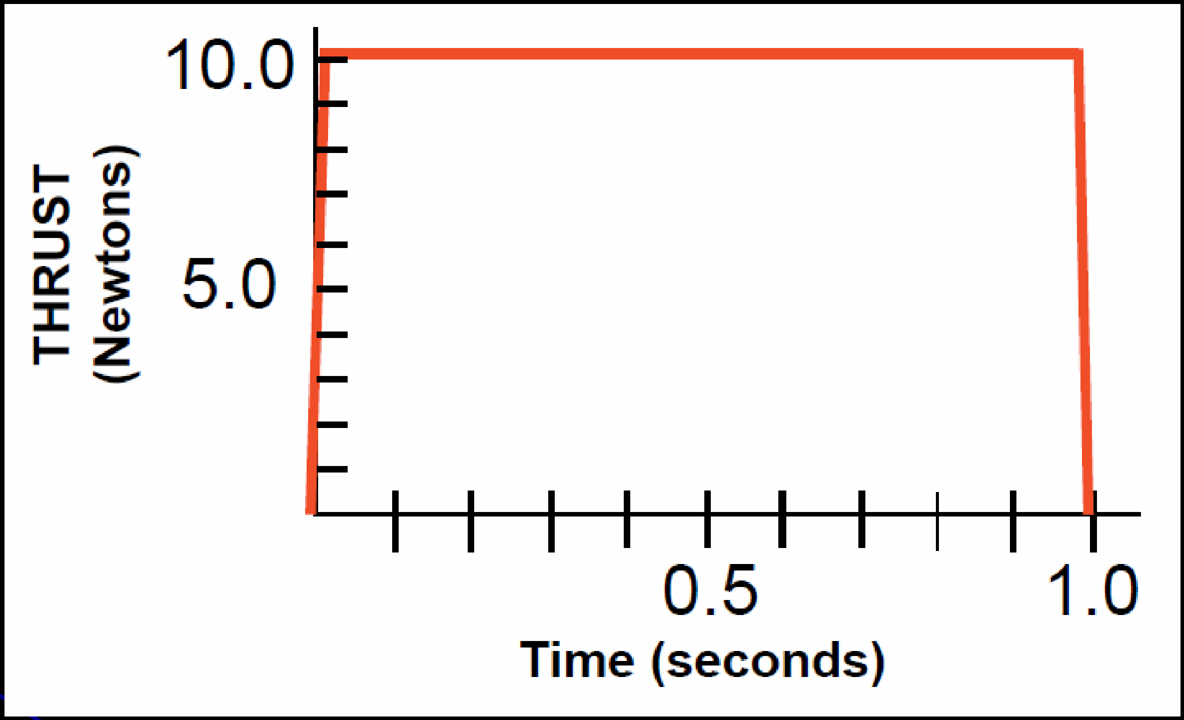
Aerotech G61W-7

- “G” specifies the total impulse of the motor
- “61” designates the average thrust of the motor (N)
- “W” designates the type of propellant (White Lightning)
- “7” designates the amount of ejection delay

Rocket Motor Classification (cont)

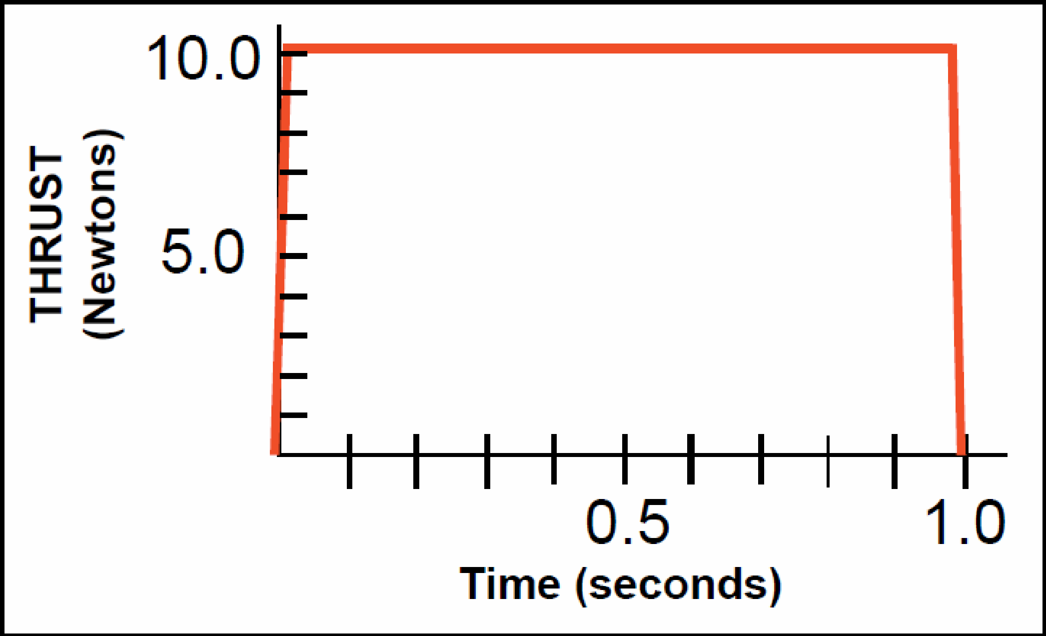
=	Low Limit (NtSec)	High Limit (NtSec)	Low Limit (lbsSec)	High Limit (lbsSec)	200 ISP Propellant Weight (grams)	(lbs)
A	1.26	2.5	0.28	0.56	1.3	0.0028
B	2.51	5.0	0.56	1.12	2.5	0.0056
C	5.01	10.0	1.13	2.25	5	0.0112
D	10.01	20.0	2.25	4.5	10	0.02
E	20.01	40.0	4.5	9	20	0.04
F	40.01	80.0	9	18	41	0.09
G	80.01	160.0	18	36	82	0.18
H	160.01	320.0	36	72	163	0.36
I	320.01	640.0	72	144	326	0.72
J	640.01	1,280.0	144	288	652	1.44
K	1280.01	2,560.0	288	575	1,305	2.88
L	2560.01	5,120.0	575	1,151	2,609	5.75
M	5120.01	10,240.0	1,151	2,301	5,219	11.5
N	10240.01	20,480.0	2,301	4,602	10,438	23.0
O	20480.01	40,960.0	4,602	9,204	20,875	46.0
P	40960.01	81,920.0	9,204	18,409	41,751	92.0

Example Thrust Curve



- What is average thrust of the motor?
- What is the total impulse of the motor?
- What would the letter designation of this motor?

Example Thrust Curve (cont)



- Average Thrust = 10 N
- Total Impulse = Avg Thrust * Burntime = 10N*1s = 10Ns
- Motor Letter Designation = C or D

Propellant Types

Propellant Types (cont)

- High thrust-to-weight
- Lots of white smoke
- Large orange flame
- Most common

Aerotech White Lightning

Propellant Types (cont)

- High peak thrust
- Less smoke
- Bright red flame
- very loud

Aerotech Redline

Propellant Types (cont)

- High thrust-to-weight
- Minimal smoke
- Bright green flame
- Less common

Aerotech Mohave Green

Propellant Types (cont)

- “Sparky” Motor
- A Crowd Favorite
- Low peak thrust
- Very loud

Animal Motor Works Skidmark

Propellant Types (cont)

Animal Motor Works Skidmark

Propellant Types (cont)

- Thick black smoke
- Very low thrust

Aerotech Blackjack

Three Motor Classes

LPR
MPR
HPR

Low Power Rocketry (LPR)

- A, B, C, D motors
- Typically black powder motors made by ESTES
- Model Rocketry
- Available at Hobby Shops, Walmart, Toy Stores, etc...
- Cost - $2.00 - $5.00 per motor

Mid Power Rocketry (MPR)

- E, F, G motors
- Typically composite motors including reloadable
- Estes makes E blackpowder motors
- Available at some Hobby Shops, or rocketry dealers
- Non-Regulated – Anyone can purchase
- Cost - $5.00 - $15.00 per motor

High Power Rocketry (HPR)

- H, I, J, K, L, M, N, O, P, and Q motors
- Composite motors
- Requires High Power Certification to purchase and fly
- Also requires Federal BATFE Explosives Permit
- Cost – H motors start around $20.00 each
- Cost – M motors around $300.00 - $500.00
- Cost – Commercial P and Q motors can cost well over $20,000 each

High Power Rocketry (HPR)

Explosives Magazine (Storage Container) and Motors

High Power Certification

- High Power Motors (HPR) = Total impulse of H and up
- Both National Association of Rocketry (NAR) and Tripoli Rocketry Association (TRA) certify motors and issue certification to users
- Level 1 – Can purchase and fly H, G, I motors
- Level 2 – Can purchase and fly J, K, L motors
- Level 3 – Can purchase and fly M, N, O, P, Q + motors

Motors for this Project (MPR)

- Motors for this event will be limited to G total impulse
- Motors will be single-use motors (not reloadable)
- Motors will be selected according to the following:
  - Maximum altitude of rocket (2000 feet)
  - Maximum weight of loaded rocket (3.3 lbs)
  - Thrust-to-Weight Ratio: Must be greater than 5:1
  - Probably in E, F, and G range

Rocket Stability

Rocket Stability

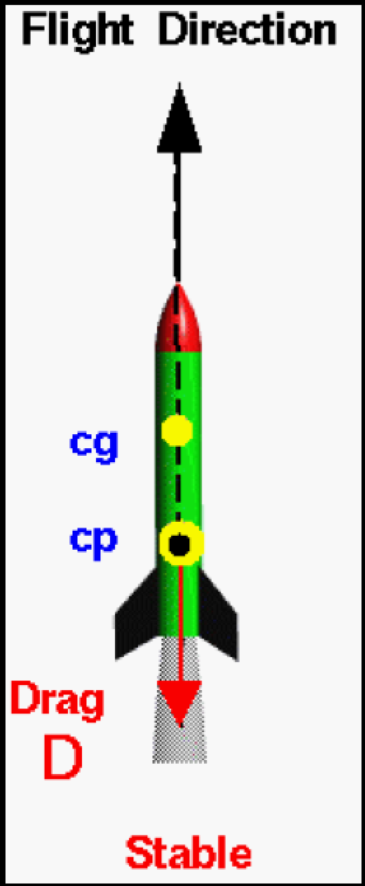
- A rocket is considered "stable" if it can maintain straight vertical flight through the air during its entire flight even in the presence of wind (lateral force)
- If a rocket is unstable, it will likely spin out of control upon launching, especially in the presence of increasing winds

Stability is determined by relationship between Center of Gravity (Cg) and Center of Pressure (Cp)

This is known as "Static Margin"

Static Margin

- A rocket is considered stable if its Center of Gravity is at least one caliber above the Center of Pressure
- What is Center of Gravity (Cg)?
- What is Center of Pressure (Cp)?
- What is a caliber?



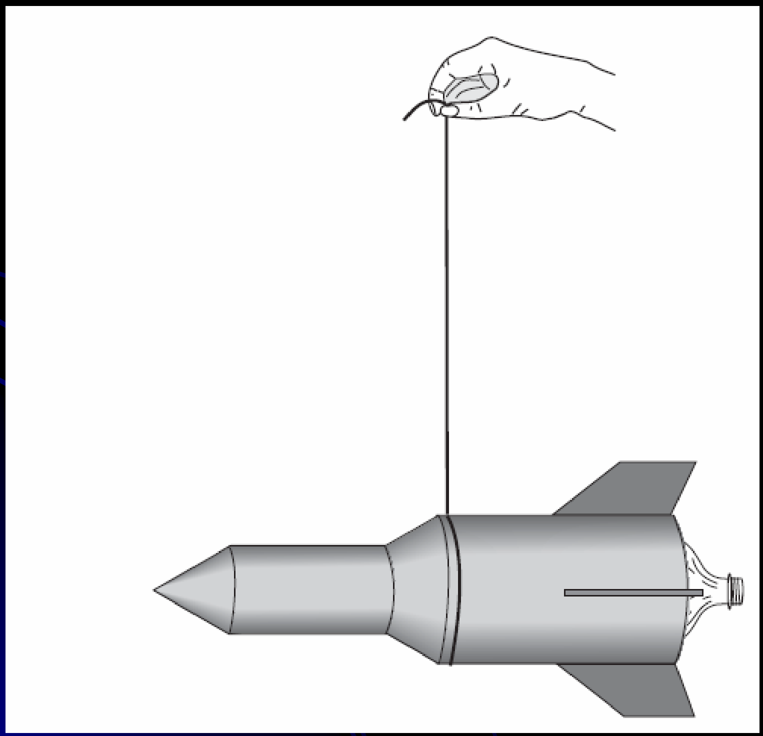
Caliber

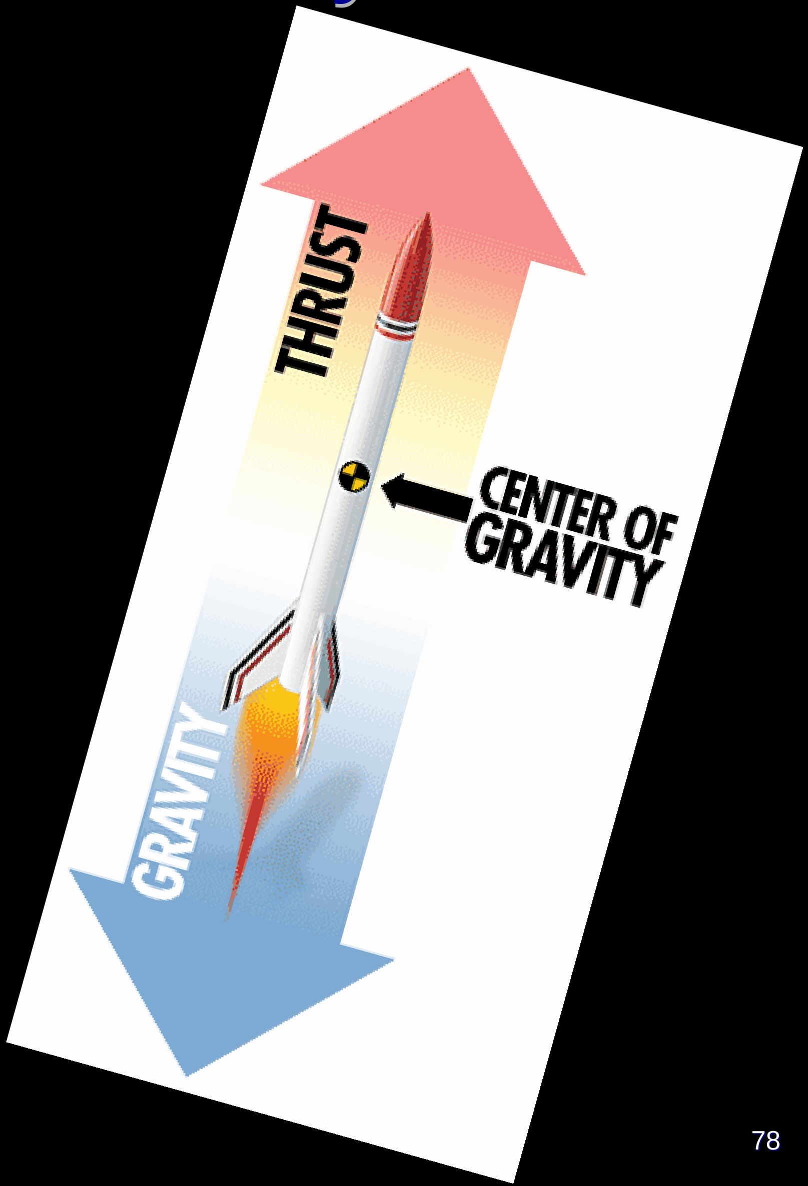
- Caliber simply means “body diameter.”

- If the body diameter of rocket is 3 inches, than you would want the Cg to be above the Cp by at least 3 inches to meet static margin criteria.

Center of Gravity

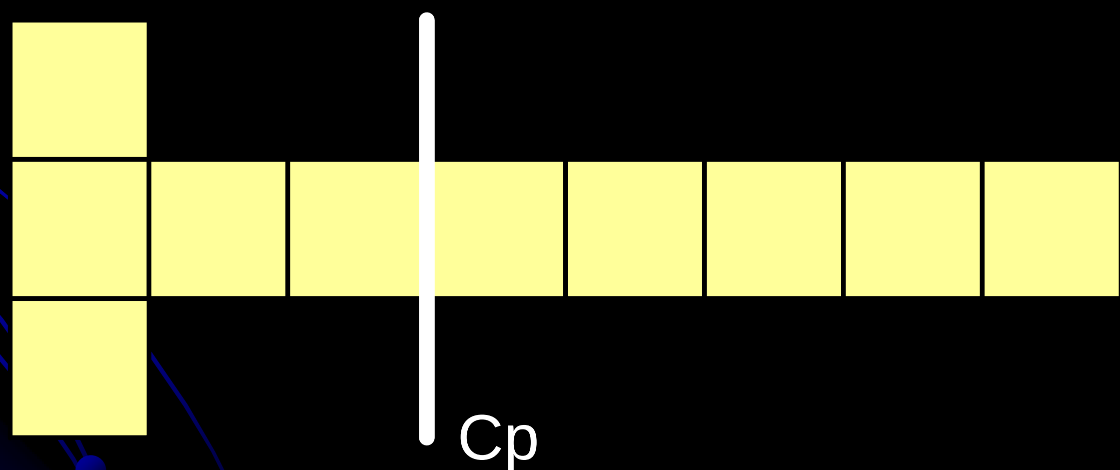
- Center of Gravity (Mass) is the point at which the rocket balances





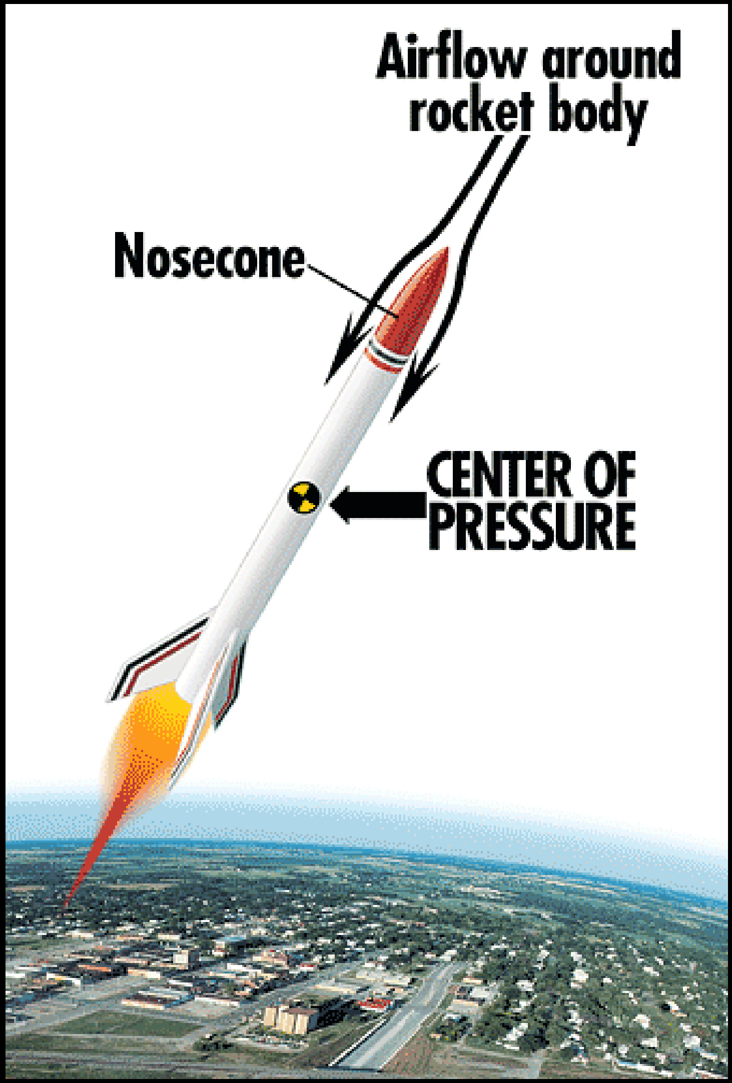
Center of Pressure

- Point where the forces of aerodynamic forces are in balance on the rocket
- Or the point where half the surface area of the rocket is on one side, and the remaining half of the surface area is on the other side

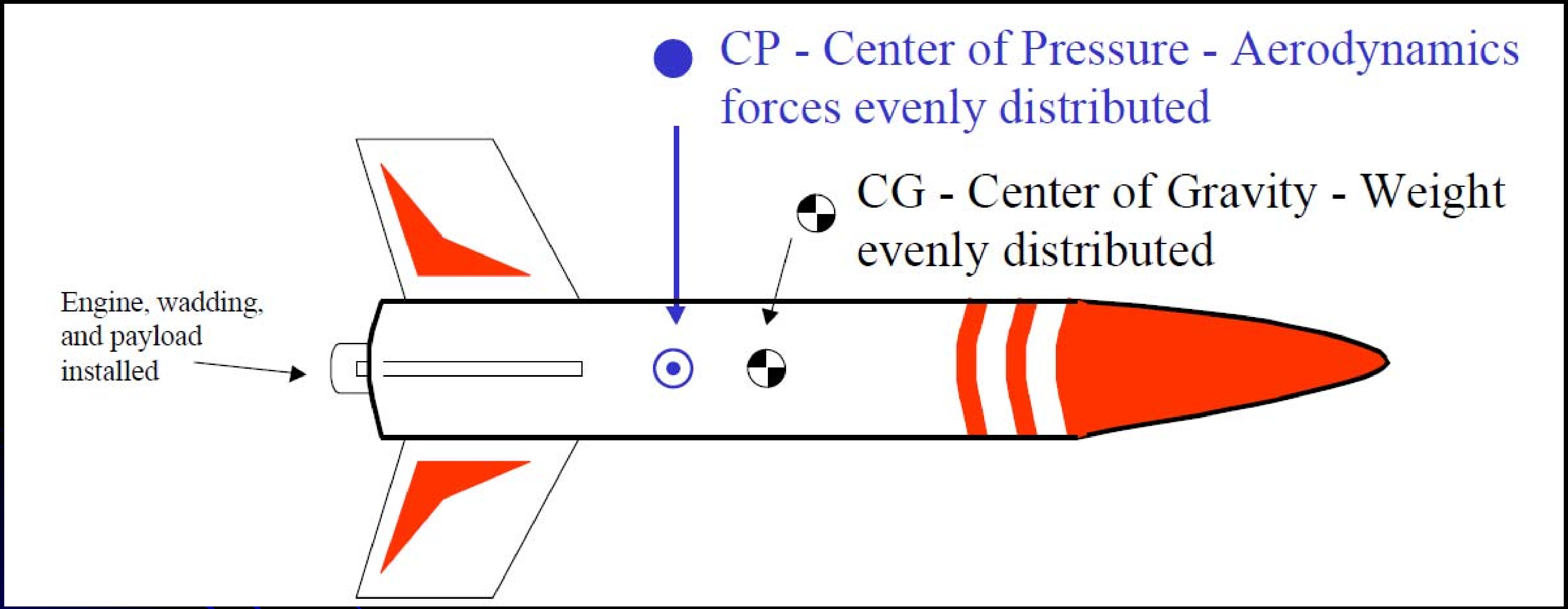


Center of Pressure (cont)

- We will calculate Cp using Barrowman's Equations to determine stability for our rockets.



Static Margin



Cg is at least 1 Caliber in front of Cp = Stable

What purpose do fins have?

Rocket Fins

- For a non-guided rocket, the only purpose fins have is to provide stability for the rocket and to shift the Cp.
- Fins do not cause the rocket to fly straight
- A rocket will fly straight, if stable, without fins
- An example of this is a bottle rocket
- So why is a bottle rocket stable?

How do you make a rocket stable?

Now time for some hands-on exercises!