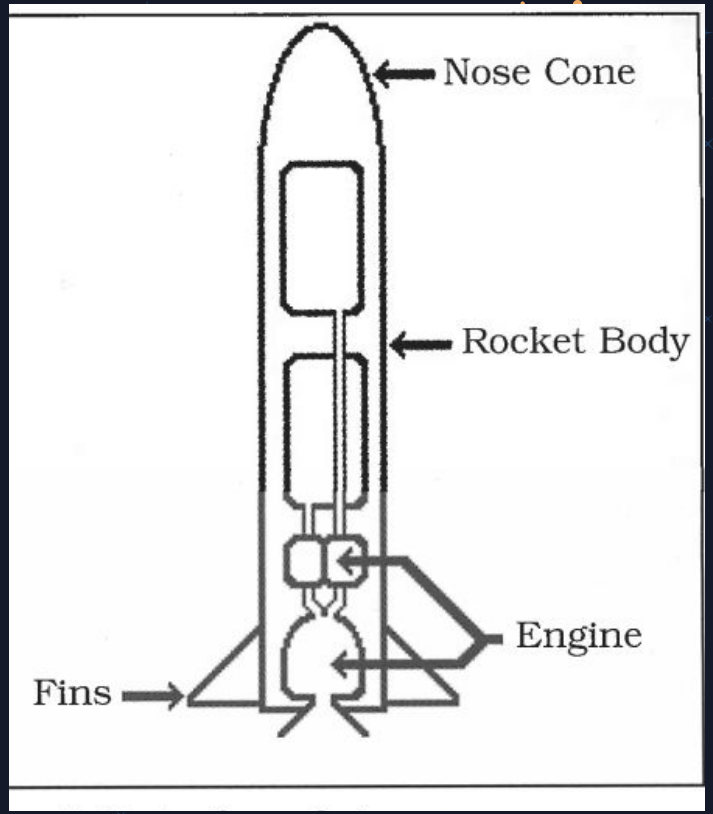
Blast Off!

Lecture 2

Basic anatomy of a rocket

- **Fairing**
  It is the enclosure of the uppermost stage of a rocket and provides protection from heat, atmosphere and biospheric contamination.
- **Fins**
  Fins are usually attached to the bottom of the rocket to add maneuverability and stability in the upper atmosphere.
- **Body**
  This is the main bulk of the rocket mainly made up from rocket engine, fuel tanks (+ propellant and oxidizer) and the external frame of the rocket.
  (Will be covered in detail in a later section.)

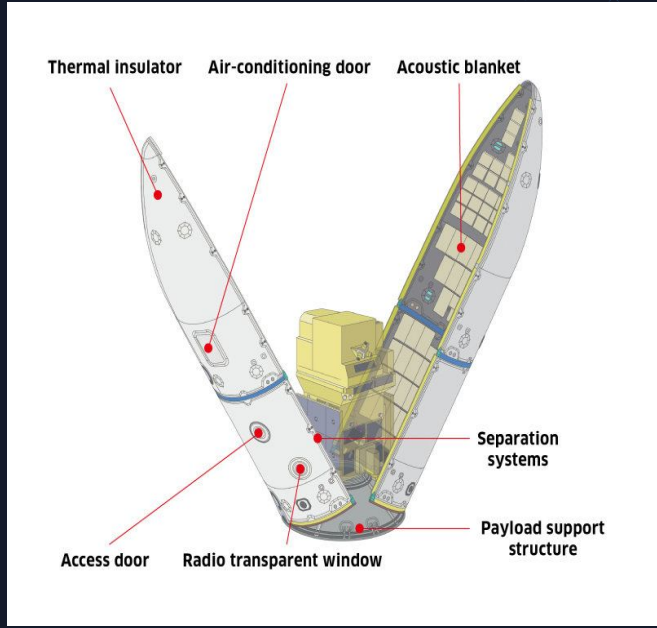


Fairing/Aeroshell

- Why is the fairing used?
- What are the materials used?
- Shape of the Fairing?
- Separation mechanisms?
- Cost to Mission ?
- Reusability?

So why fairings?

- The payload present on the spacecraft is delicate!
- The early stages of the launch
- generally being most intense
- Large aerodynamic forces act on the aircraft
- Also think about the contaminants in the atmosphere



Materials Used

- They are generally made of various composite materials
- For instance the fairing of Falcon 9 is primarily composed of carbon fiber skin overlaid on aluminium honeycomb core
- Ceramic or other materials might be used for the thermal insulation.
- Acoustic panels are present to dampen the large vibrations thus protecting the payload

Shape and Separation Mechanisms

- Apart from protecting the payload fairings also improve the aerodynamics of the launch vehicle by providing a smooth and aerodynamic front cross-section to the launch vehicle.
- Generally the mechanism for separation is to separate the fairing in two halves and jettisoning them.
- These fairings are called as clamshell fairings.
- The bolts interlocking the two halves are generally fired pyrotechnically by mini explosions

Reusability

- Earlier the fairings used to fall down in the ocean or get burnt on the way down
- But the scenario has changed now!
- SpaceX has arrived and changed the scene by recovering the fairings of the Falcon 9
- This has a huge affect on overall launch cost
- But how they are recovered? Let’s see

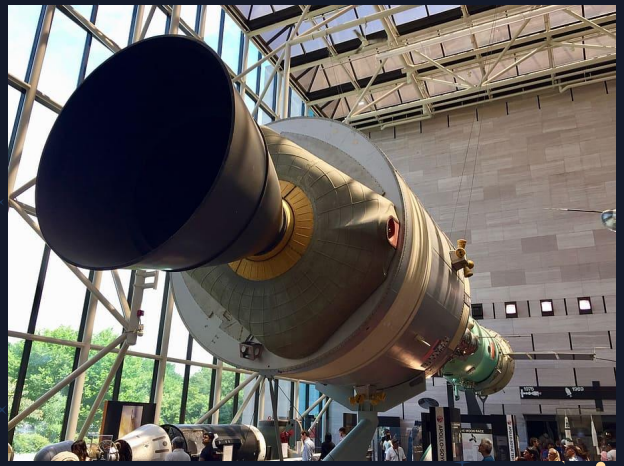
https://youtu.be/oTH3mq7SsK4

Shock Dynamics

Rockets tend to break the sound barrier very fast and often when they haven't even left the lower atmosphere.

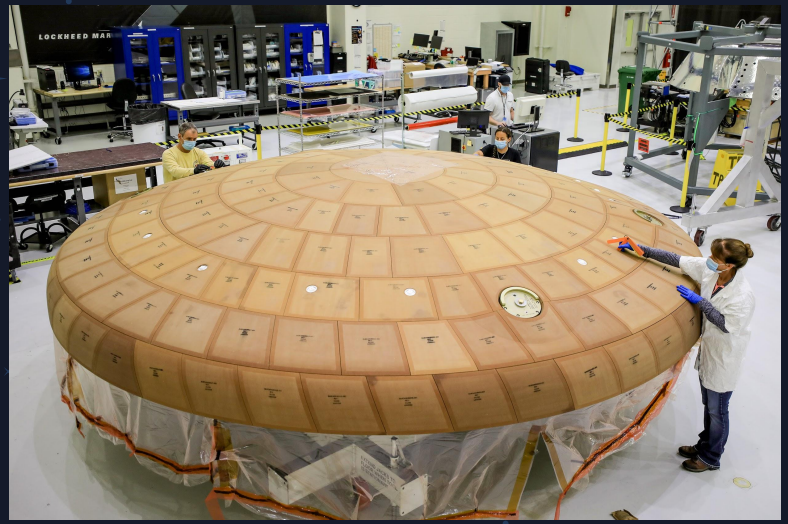
How can this affect the designing of the rocket?

Structural System of Rockets



- The structural system of a rocket includes all of the parts which make up the frame of the rocket; the cylindrical body, the fairings, and any control fins.
- The frame, is made up of strong, but lightweight materials such as aluminum or titanium.
- The performance of the rocket depends directly on the weight of the structure.
- It is coated with a thermal protection system, to keep out heat of air friction during the flight.
- The fins are attached to the bottom for stability during the flight.The materials used in the construction of rocket boosters and space vehicles range from special high-density material for heat absorption to high-strength, lightweight materials to carry flight loads.
- In attempting to reduce weight, vehicle skin thickness must be as low as possible and in some cases the structure can be internally pressurized to keep the walls from buckling.

How are the thin sheets used in the rockets stabilized?



Can you figure out which part of the rocket is shown here?

- New advancements in making the frame of the rocket by using materials such as beryllium and composite materials using high strength filaments.
- The best current high-temperature metals, e. g., nickel and ferrous alloys, may soon be replaced by molybdenum.
- Ceramics such as carbides have very high melting points and show much promise for high-temperature use.

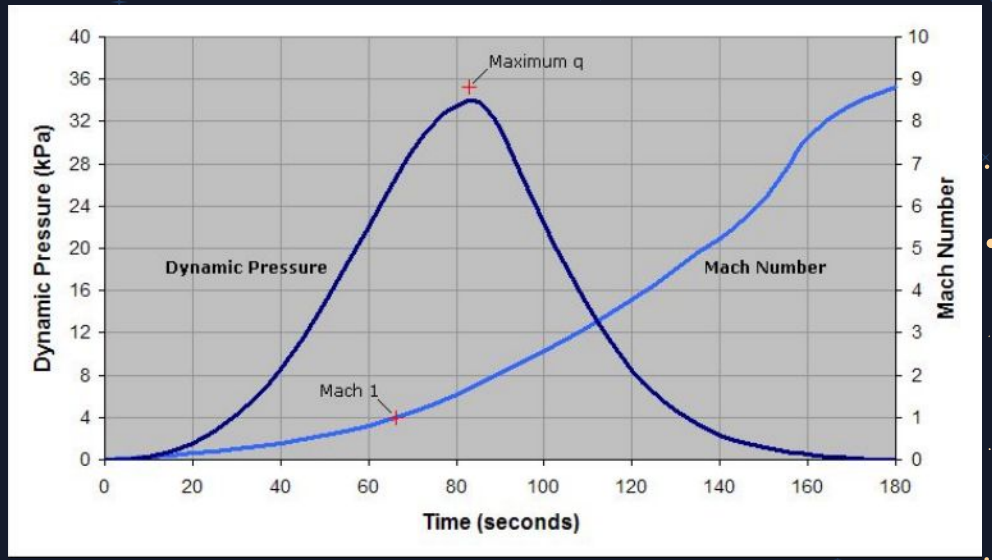
- Relatively brief encounters with a hot environment can be survived by the protection method, as in the insulation of rocket nozzles and reentry nose cones

Dynamic Pressure and MAX Q

- The Dynamic Pressure in a rocket is given by:

$$q = \frac{1}{2}\rho v^2$$

- The Density of Air decreases with altitude
- The velocity of rocket increases with altitude.



What is the physical significance of Max Q?

Aerodynamic Stability of a Rocket

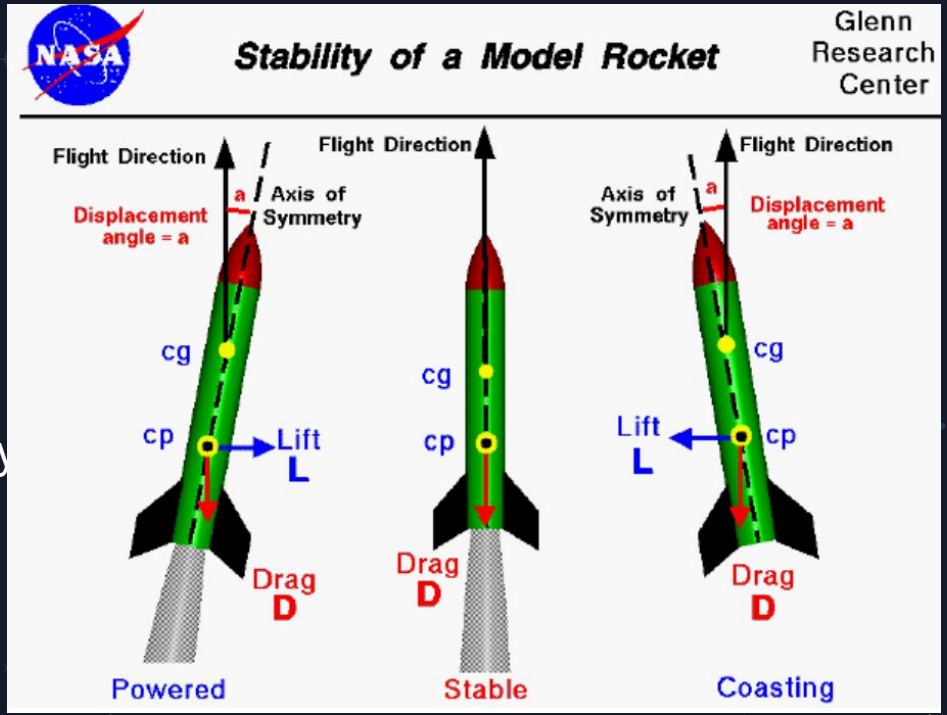
Two major factors of a rocket's stability:

- Location of center of pressure (Cp)
- Location of center of gravity (Cg)

Both follow a certain characteristic nature across the timeline of a rocket.

Location of Cp rises as the ratio of (velocity of rocket/speed of sound) increases while location of Cg FALLS with the burning of propellants.

How do Cp and Cg vary as the rocket breaks the sound barrier?



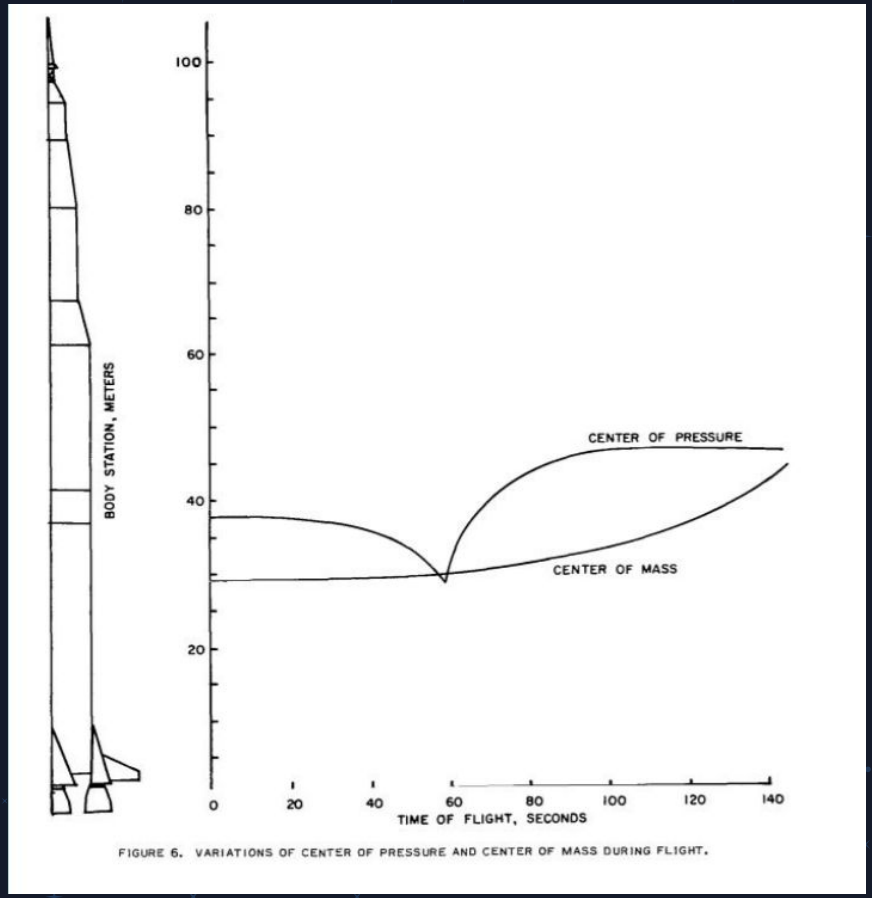
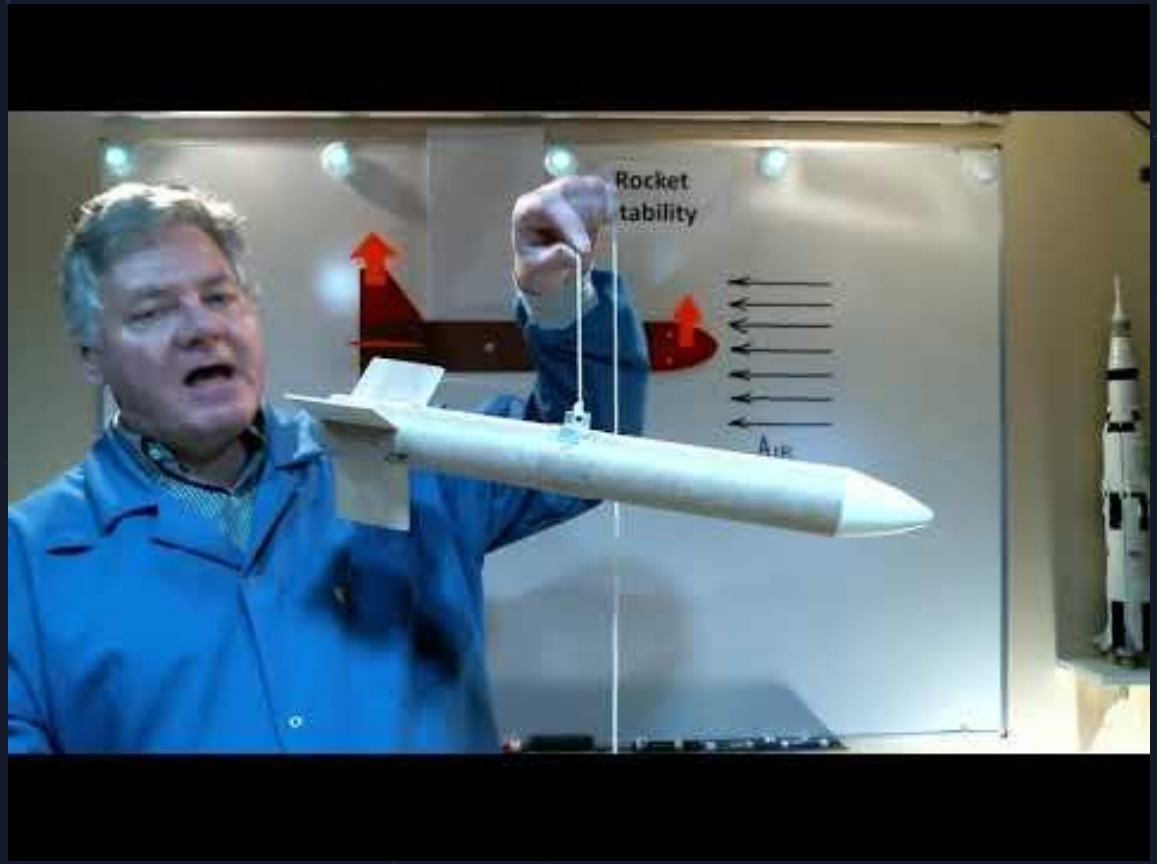


FIGURE 6. VARIATIONS OF CENTER OF PRESSURE AND CENTER OF MASS DURING FLIGHT.

- Center of Pressure and Center of gravity changes drastically when breaking the sound barrier.
- CoP and CoG must be engineered perfectly for each and every stage separately

Why is there sudden dip in the center of pressure?



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