The Rocket Equation

What is a Rocket?

- Combustion or Burning: high temperature chemical reaction between a fuel and an oxidant (often oxygen) which produces heat (exothermic) and an oxidised product (gases or smoke)
- Rocket: any motor which contains its own mass to expel and oxidant
- Works in the vacuum of Space
- Propellant is the Fuel and the Oxidiser which react through combustion

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Newton's Laws of Motion

- 1st Law: an object either remains at rest or continues to move at a constant velocity, unless external forces act on it

- 2nd Law: The sum of the external forces applied on an object is equal to the mass of that object multiplied by its acceleration:

$$F = ma$$

F: Force (N), m: Mass (kg), a: Acceleration (m.s-2)

- 3rd Law: If body A exerts a force on body B, then body B exerts an equal force in magnitude and opposite in direction on body A

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More on the 2nd Law of Newton:

$$F = ma \text{ with } a = \frac{dv}{dt}$$

So,

$$F = \mathrm{m}\frac{dv}{dt} \text{ or } F = \frac{d(mv)}{dt}$$

with: v: Velocity (m/s) t: Time (s)

- mv is called the linear momentum and is usually abbreviated by the letter p.
- Momentum: mass in linear motion or amount of motion of an object. The resistance of an object to a change in its state of motion.
- Force= the change of momentum with time = time derivative of linear momentum

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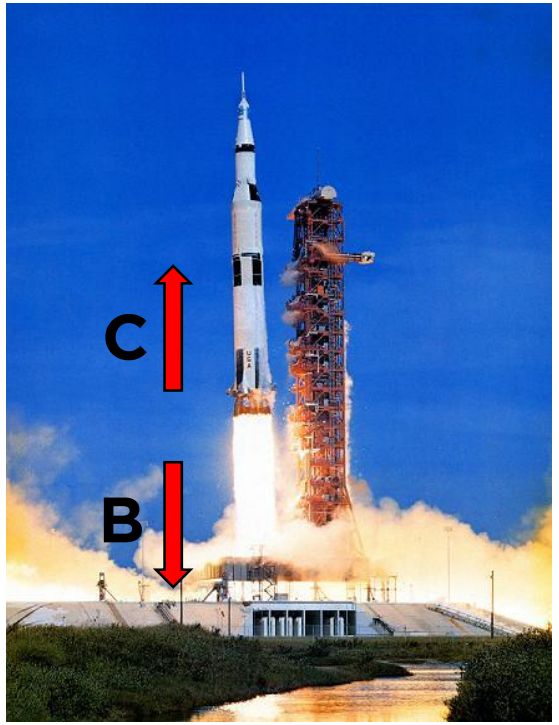
How Do Newton's Laws Apply to Rockets?

- $F = \frac{d(mv)}{dt}$ means that the force exerted on an object depends on how fast the mass and/or velocity of this object is changed.

- 3 Laws of Newton:

- A small amount of mass is thrown out at a high velocity from a body in a certain direction B.
- A force is consequently exerted on that body in the direction that is opposite to B: C.
- The body accelerates in the same direction as that force, C.



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Also named Tsiolkovsky's Equation, it tells us the change of velocity that a rocket can achieve.

Ejected mass with exhaust velocity
V and mass M

$$Change\ in\ Velocity = \Delta V = C.\ln\left(\frac{initial\ mass}{initial\ mass - \Delta m}\right)$$

C is the exhaust velocity of the mass in m/s and Δm is the ejected mass in kg.

The only things affecting the rocket velocity are its exhaust velocity and its ratio of initial mass to final mass, this is why mass is so important in rocket design.

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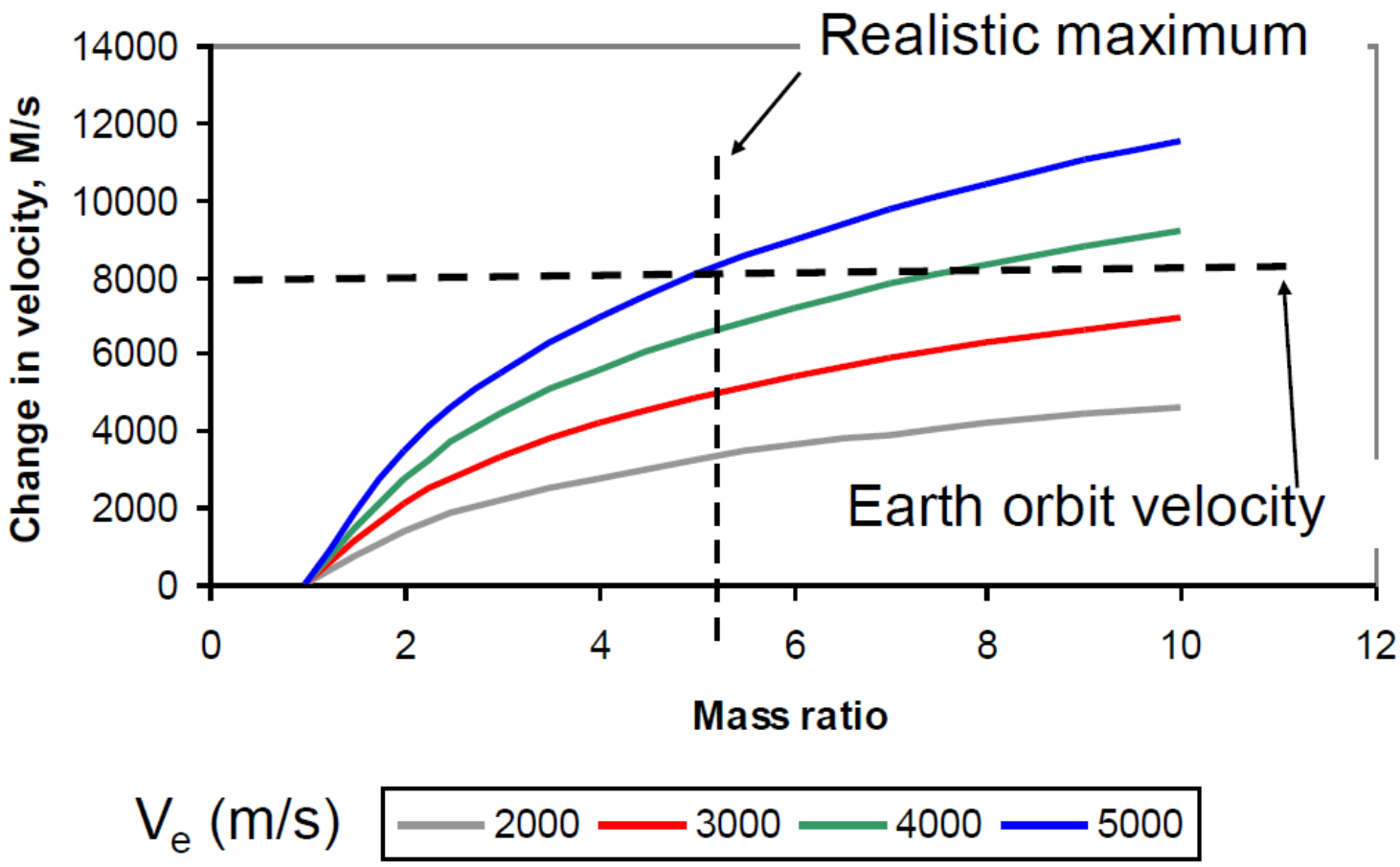

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