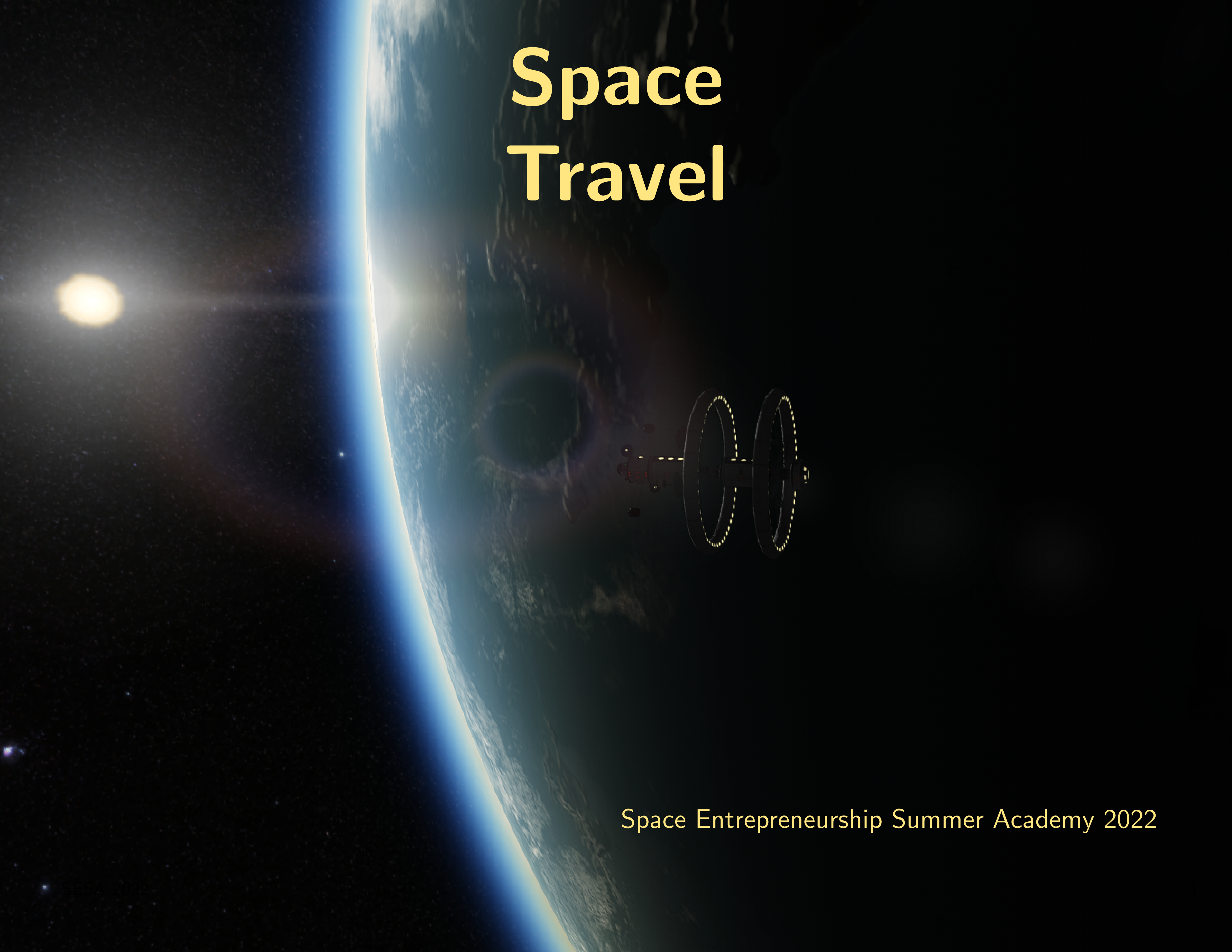

Space Travel

Space Entrepreneurship Summer Academy 2022

Newton's Law:

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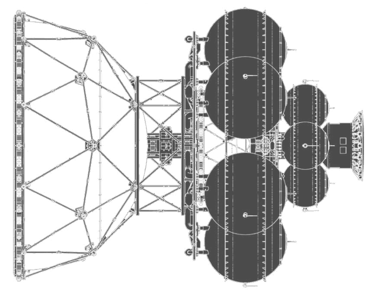

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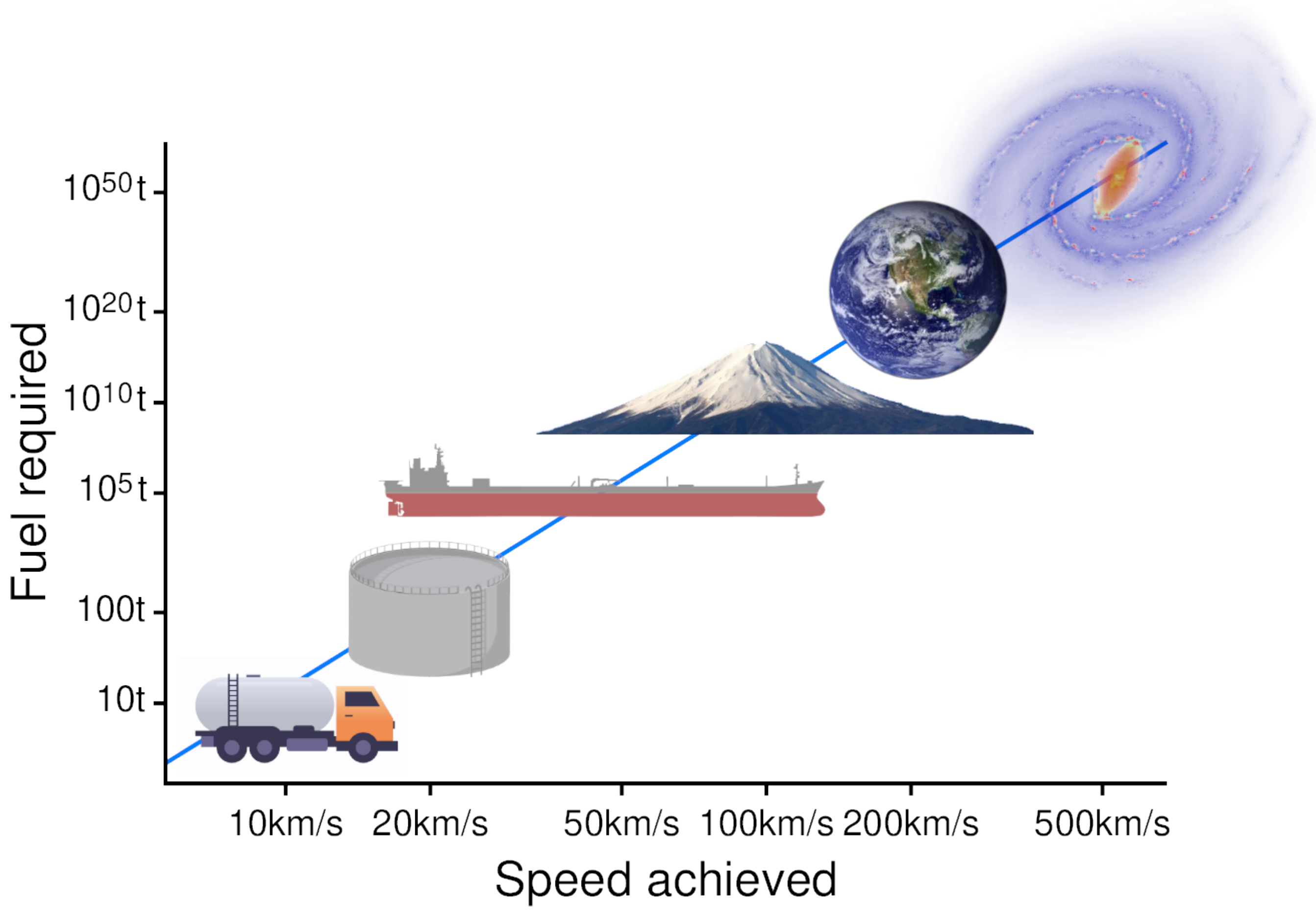

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Kerbal Space Program

Kerbal Space Program

KSP Challenge 1: Sounding Rockets

- Go to the Vehicle Assembly Building (VAB).
- Built a vessel with a rocket, fuel, and payload.
- Note the Δv listed in blue (computed by KSP).
- Launch it and see what happens!
- Compare your maximum height to the theoretical value:

$$h = \frac{v^2}{2g} = \frac{v \times v}{19.6\,\mathrm{m/s^2}}$$

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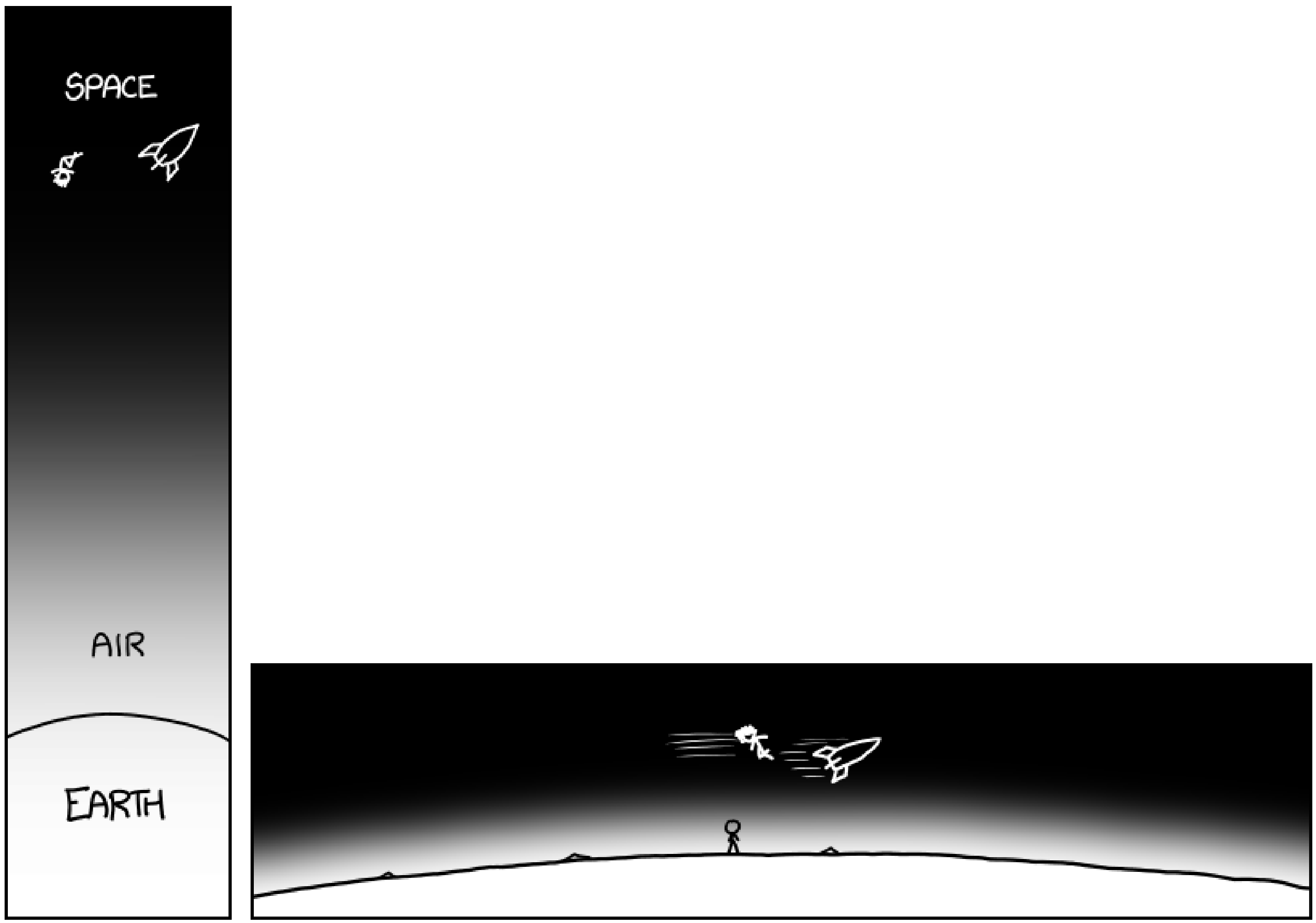
Getting into space: Space is not “up”,

You Will Go To Space Today

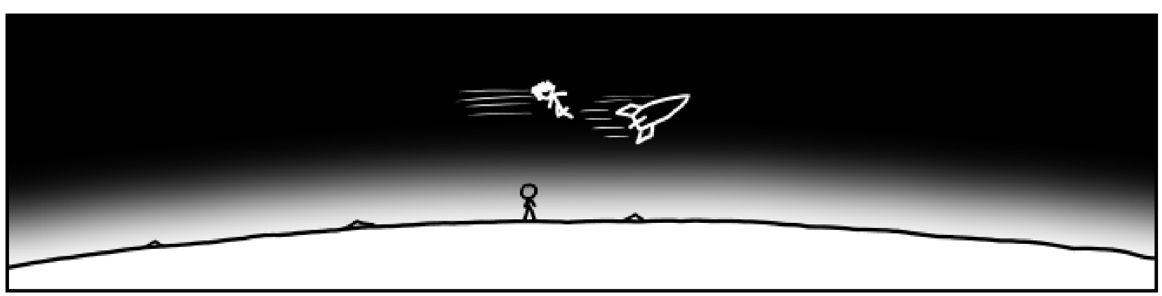
Getting into space: Space is not “up”, space is “sideways”.



You Will Go To Space Today

Getting into space: Space is not "up", space is "sideways".

Kerbin's atmosphere ends at $70\,\mathrm{km}$.



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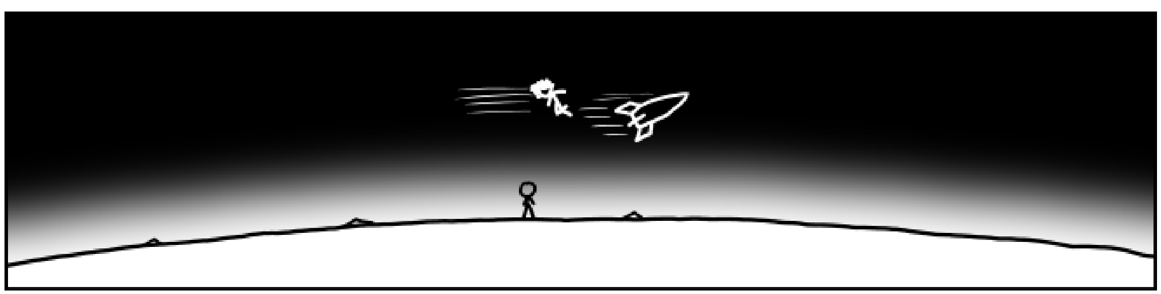
Reaching that height requires:

$$v = \sqrt{2gh}$$



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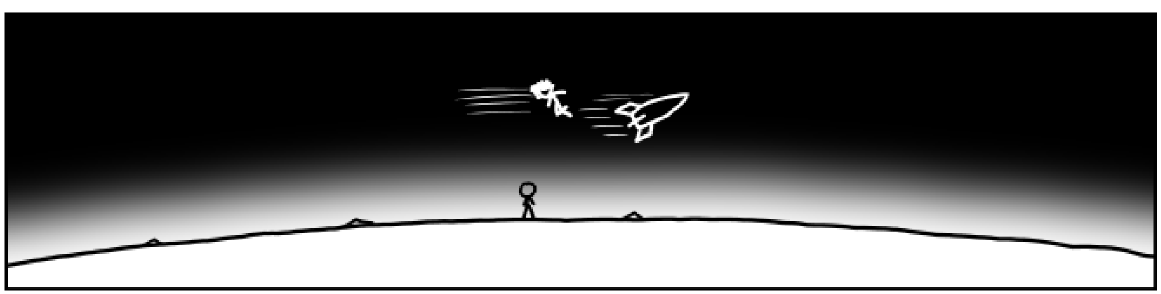

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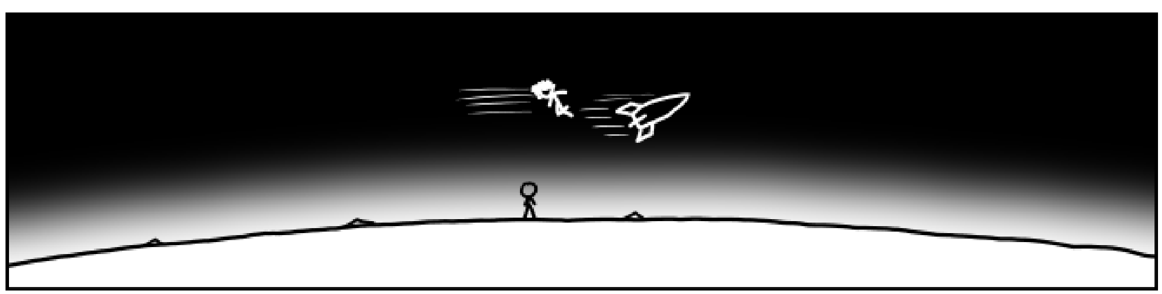
$$
\begin{aligned}
v &= \sqrt{2gh} = \sqrt{19.6\,\mathrm{m/s^2} \times 70\,000\,\mathrm{m}} \\
&= 1171\,\mathrm{m/s}
\end{aligned}
$$



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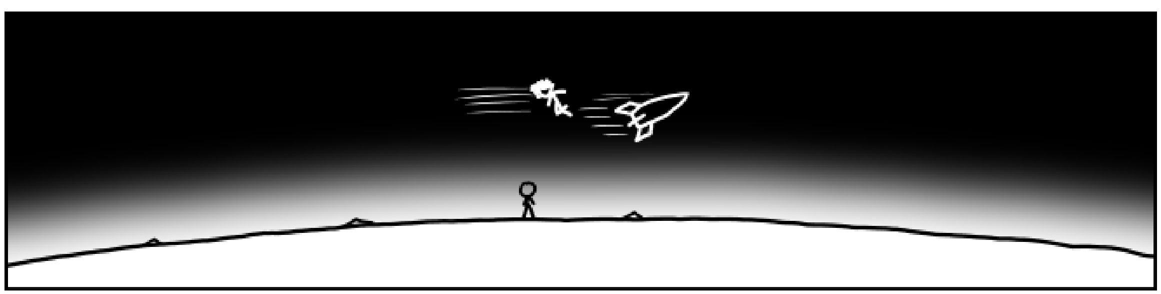
But to orbit at that altitude requires speed

$$v = 2296\,\mathrm{m/s}$$



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$\Longrightarrow$ The difficult part of space travel is not getting "into space" but achieving orbit.

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⇒ The difficult part of space travel is not getting "into space" but achieving orbit.

- This is even more true on Earth, where low-Earth orbit (LEO) requires $7800\,\mathrm{m/s}$.

You Will Go To Space Today

$\Rightarrow$ The difficult part of space travel is not getting "into space" but achieving orbit.

- This is even more true on Earth, where low-Earth orbit (LEO) requires $7800\,\mathrm{m/s}$.
- When $v_e \sim 2500\,\mathrm{m/s}$, this makes a huge difference!

You Will Go To Space Today

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$$\begin{aligned} v_e &= I_{\mathrm{sp}} \times 9.8\,\mathrm{m/s^2} \\ \Delta v &= I_{\mathrm{sp}} \times 23\,\mathrm{m/s^2} \times \log_{10}\left(\frac{m_{\mathrm{fuel+payload}}}{m_{\mathrm{payload}}}\right) \end{aligned}$$

Kerbal Space Program Rockets

Rocket	Thrust (kN)		ISP (s)		v_e (m/s)	
	Sea Level	Vacuum	Sea Level	Vacuum	Sea Level	Vacuum
Solid Fuel						
Flea	163	192	140	165	1372	1617
Hammer	198	227	170	195	1666	1911
Thumper	250	300	175	210	1715	2058
Liquid Fuel						
Terrier	15	60	85	345	833	3381
Reliant	205	240	265	310	2597	3038
Swivel	168	215	250	320	2450	3136
Non-Chemical						
NERV	14	60	185	800	1813	7840
Dawn	0.05	2	100	4200	980	41 160

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Swivel	168	215	250	320	2450	3136
Non-Chemical	Sustainer					
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Atmospheric Drag: Force required to push air out of the way.

- Reduce by keeping speed low until altitude is high

$\Rightarrow$ Vertical trajectory.

Gravity Drag: Force required to support weight of rocket.

- Reduce by increasing centrifugal force quickly

$\Rightarrow$ Horizontal trajectory.

KSP Challenge 2: Orbit

- Launch a payload to orbit!
- Rule of thumb:

1. Start vertical then tip (pitch) eastward.
2. Gravity turn: keep rocket pointing towards forward vector, which will gradually tip over.
3. Keep pitch angle above 45° until speed $> 340\,\mathrm{m/s}$ (Mach 1).
4. Thrust until highest point of trajectory (apoapsis) is above the atmosphere, then coast.
5. At apoapsis, thrust eastward until orbit is circular.

- Revert to launch as needed to try different trajectories.