Science, Technology, Engineering & Maths (STEM)

Mr Bateson

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Brief Introduction

- Electronic Engineering Degree, University of York, 2001-05
- RAF Engineering Officer, 2006-2011
- Cybersecurity Consultant, 2011-2016
- Head of Cybersecurity, McLaren, 2016-2020
- Information Security Manager, Slaughter and May, 2020-now





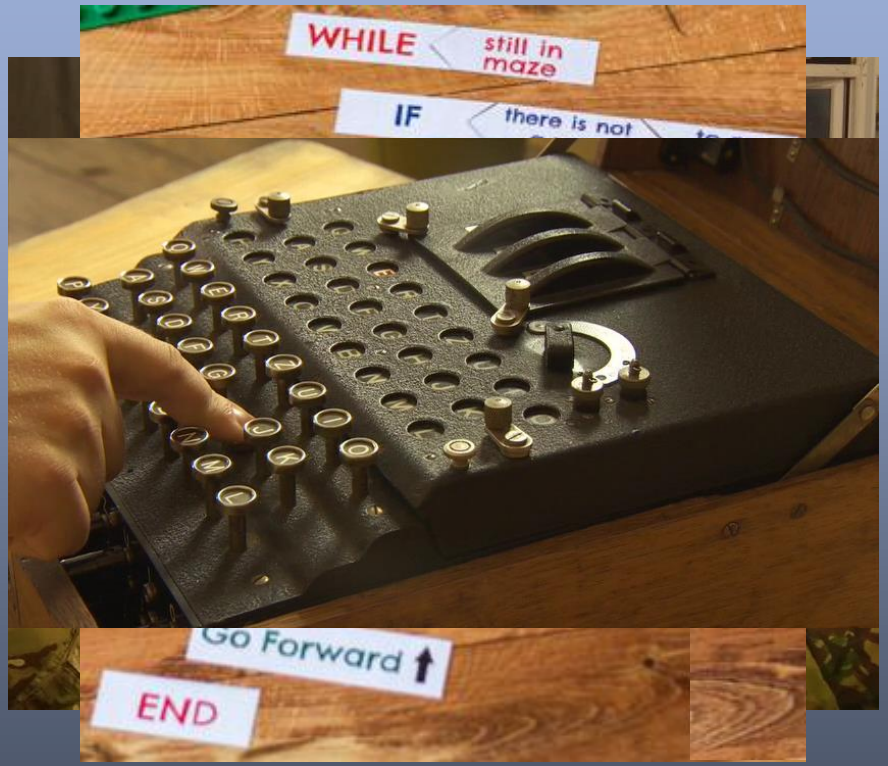


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Previous STEM Sessions

- Aug 2018:
  - Bridge and crane building
- Feb 2019:
  - Emerging technologies (AI, self-driving cars, AR)
- Aug 2019:
  - Introduction to programming
- Feb 2020:
  - Codes and codebreaking



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This Session



Space

- Why Go To Space
- Defence Uses of Space
- How To Go To Space
- How To Get Back Again

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Before We Start

- These STEM sessions aren't on any exam.
- The slides can be downloaded from www.timbateson.co.uk/rafac/

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Warm Up Exercise

- Work individually.
- You'll need pen/paper or another way of noting down ideas.
- You have 2 minutes (from "go") to write down some ideas on:

Green Flight

Why do we send people/things into space?

Red Flight

Why are the RAF/RAFAC interested in space?

- Be ready to type some ideas into the chat window *when asked*.

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2 minutes left…

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60 seconds left…

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30 seconds left…

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10 seconds left…

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Time’s up!

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Warm Up Exercise

- What did you come up with?

Green Flight

Type your ideas why we send people/things into space into the chat window *now*

Red Flight

Type your ideas why the RAF/RAFAC are interested in space into the chat window *now*

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Why Send People/Things into Space?

Satellite Communication Services	Satellite Navigation Services	Weather Monitoring & Forecasting	Scientific Research
Exploration (including SETI)	Surveillance	Defence	Challenge / Competition
Tourism*	Mining*	Colonisation*	Others?*

*: Things that might happen in future, rather than things happening now.

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Why are the RAF/RAFAC Interested?

- Space has some* military uses. E.g.:
  - Surveillance (‘spy satellites’).
  - Navigation (GPS was originally developed for weapon guidance).
  - A place to detect and potentially intercept ballistic missiles.
- Space increasingly recognised as a potential domain of conflict:
  - Russia, China and India have all tested anti-satellite weapons.
  - UK joined the US-led Operation Olympic Defender: “a multinational coalition to *deter hostile actors* in space and *reduce the spread of debris in orbit*” (Penny Mordaunt, Defence Secretary, July 2019).

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*: Some uses of space are banned by international law; such as the Space Treaty of 1967, which is monitored by the UN Office for Outer Space Affairs.

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Video 1
Space Debris (Link)

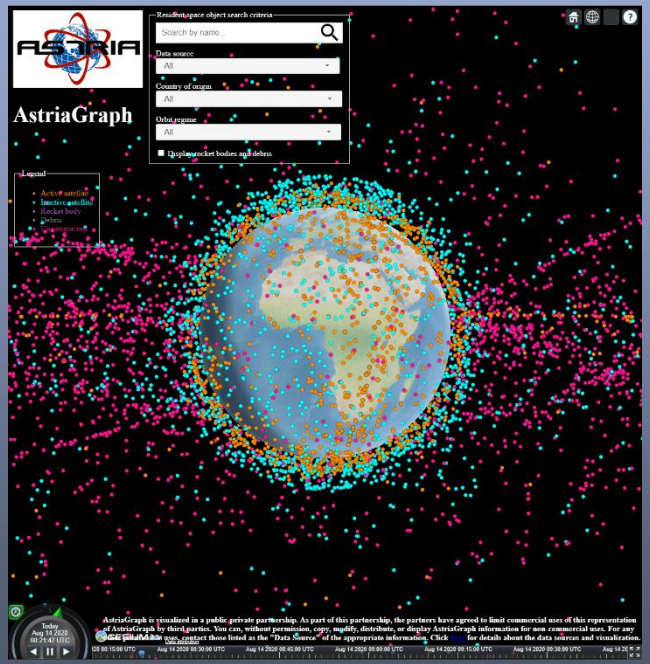
Space Debris

- Number of objects in orbit:

Diameter	No. of Objects
>1m	5,400
10cm to 1m	34,000
1cm to 10cm	900,000
1mm to 1cm	128,000,000

- Over 90% is junk.
  - Inactive satellites, discarded rocket stages, lost tools, etc.

- Live space debris tracker:

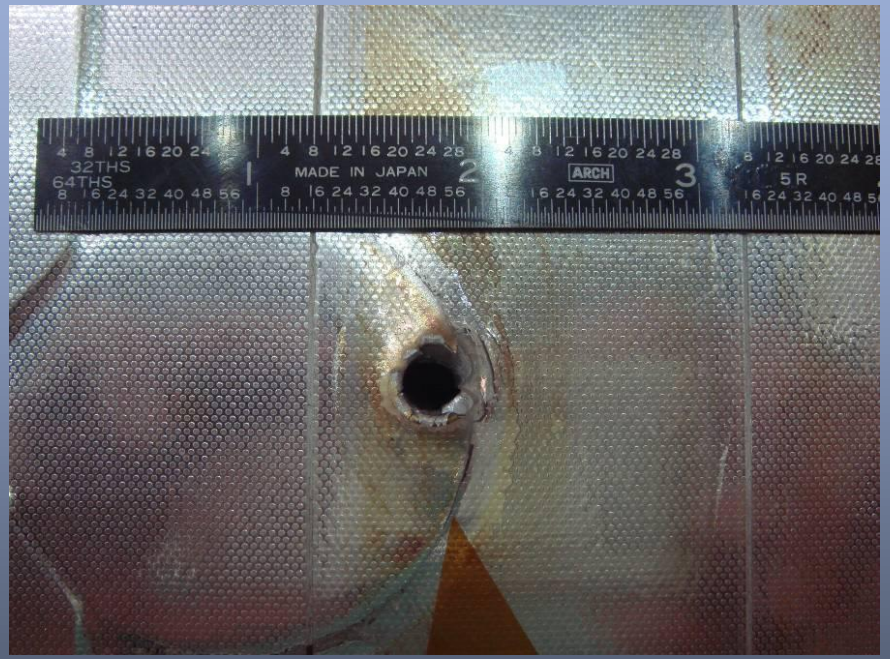


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Space Debris

- If it hits a spacecraft at a (typical) velocity of 14km/s:
  - A 1mm diameter object will punch a hole clean through most single-skin surfaces.
  - A 1cm diameter object will cause “critical damage”.
  - A 10cm diameter object will cause “catastrophic disintegration of the target”, similar to a bomb going off.



Entry hole in Space Shuttle Endeavour’s radiator panel, caused by unidentified space debris

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Video 2

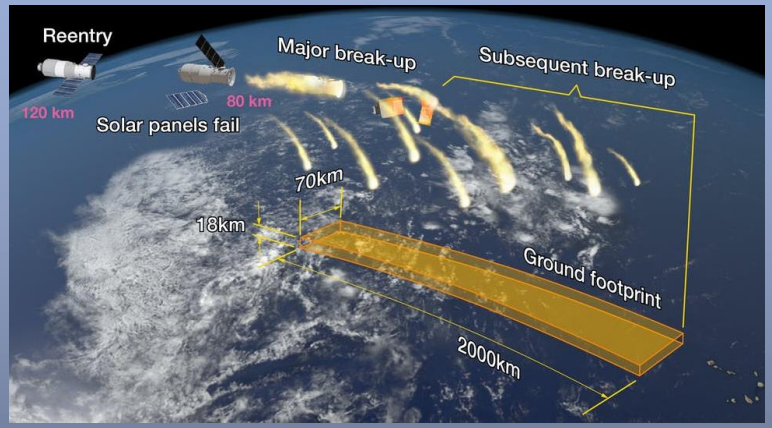
Dramatisation of Kessler Syndrome (Link)

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Space Debris

- Debris also falls to Earth.
  - Controlled de-orbit or uncontrolled de-orbit.
  - Smaller bits burn up in the atmosphere.
  - Bigger bits can hit land.
- One large, uncontrolled de-orbit every week on average.
- Between 50 and 100 tons of debris crash-land every year.



Debris footprint of China's Tiangong-1 space station



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Space Debris

- Mitigation options:
  - Reduce how much new debris is created.
    - Limit how many new spacecraft are launched (impractical).
    - Tighter regulation of spacecraft design and operation.
      - Deorbiting stages, graveyard orbits, etc.
    - Apply international pressure on countries which act irresponsibly.
  - Use Whipple shields – a multi-layer protective skin on spacecraft.
  - Track the biggest bits of debris and keep out of its way.
  - Choose different orbits, where the risk from debris is lower.
  - Active Debris Removal – remove debris using nets, lasers, etc.

Why are the RAF/RAFAC Interested?

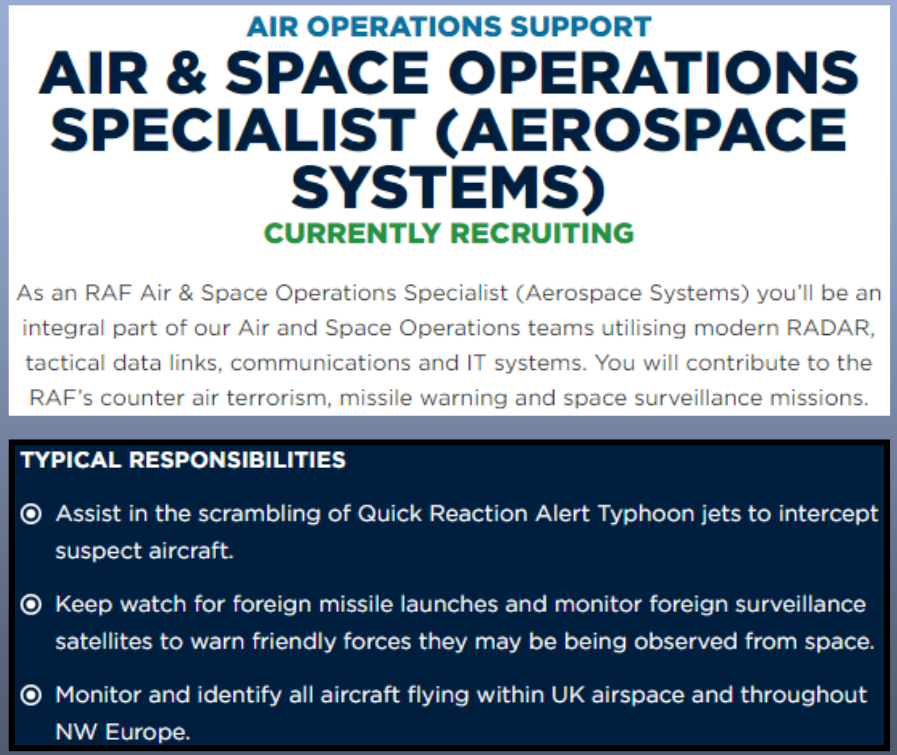
- Some militaries are creating, or already have, space units.
  - US & France have Space Commands.
  - US has a Space Force, separate from the USAF.
  - UK MOD published a space strategy in 2019.
  - UK is forming a Space Command, led by a RAF Air Vice Marshall.
  - The RAF has a ‘Space Squadron’ (23 Sqn), mainly flying satellites.
  - The RAF now has 2 ‘Air & Space Operations Specialist’ roles.
- The Space domain is adjacent to the Air domain, so many countries’ air forces are taking the lead on space operations.



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Why are the RAF/RAFAC Interested?



- "Keep watch for foreign [ballistic] missile launches".
- "Monitor foreign surveillance satellites to warn friendly forces they may be being observed from space".
- Potentially a role in avoiding collisions and debris?
- RAFAC is launching a new space syllabus next month.

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Break

- End of Part 1
  - Have briefly covered the “why” of space.
- Quick 5 minute leg-stretch.
- Part 2 will cover the “how” we go to space (and get back!).

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How Do We Put People/Things in Space*?



Rockets



Air Launch to Orbit



Space Elevators

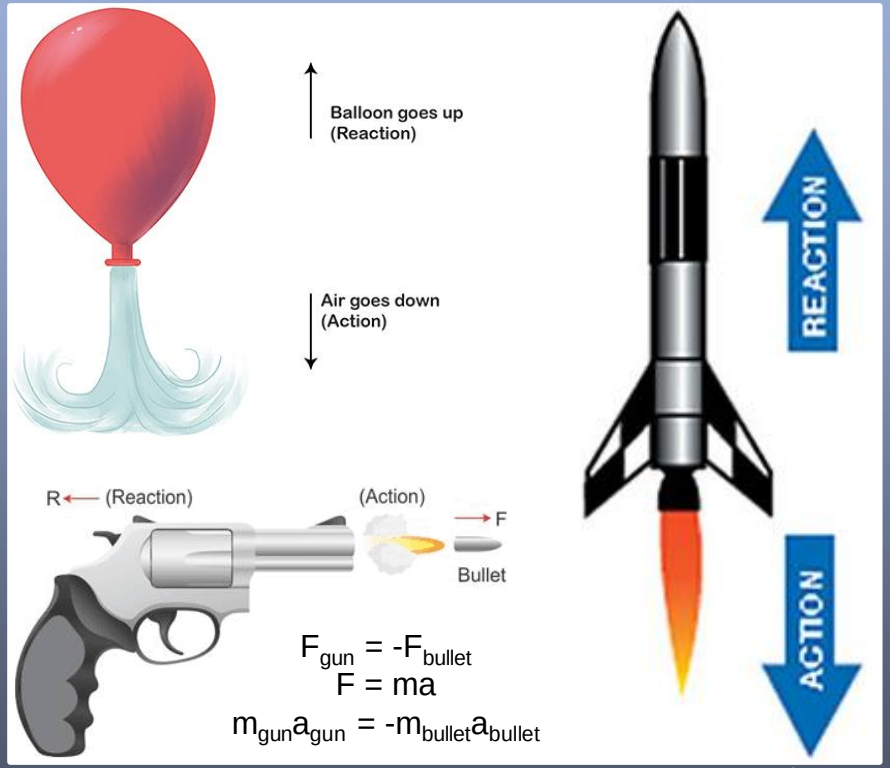
?

Other Methods

*: Space is everywhere over 100km above Mean Sea Level on Earth.

Rockets

- Utilise Newton's third law.
  - Every action has an equal and opposite reaction.
- Expel exhaust from the bottom of a rocket and the reaction will try to push the rocket upwards.
  - Need to expel exhaust fast enough to overcome gravity.
  - Relative mass is important.

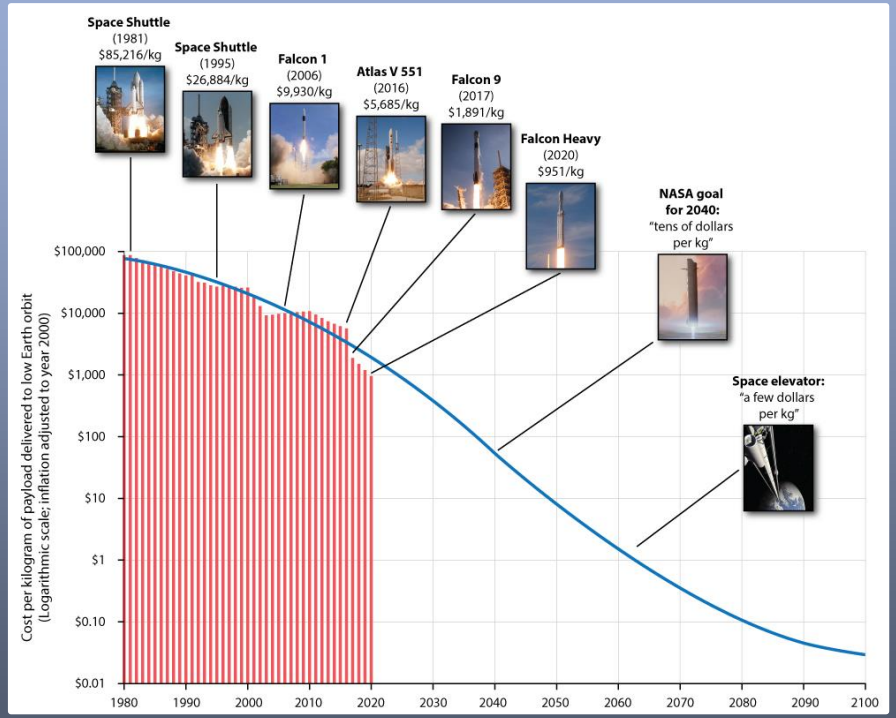


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Rockets

- There's a fundamental problem with rockets:
  - Rockets have to lift their own fuel.
- A typical (Ariane 5) rocket:
  - Burns 40kg of fuel to deliver 1kg to Low Earth Orbit.
  - Is 85% fuel, 12.5% structure and 2.5% payload at launch.
- Cost is reducing over time.



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Video 3

Elephant Rocket Fuel (Link)

Rockets

- An example:
  - There has been a guitar on the International Space Station since 2001.
  - To deliver 1kg to ISS via Space Shuttle in 2001 cost around £40,000 in 2020 £s.
  - A guitar weighs around 2kg.
  - Cost: around £80,000.
- Going to space is expensive!

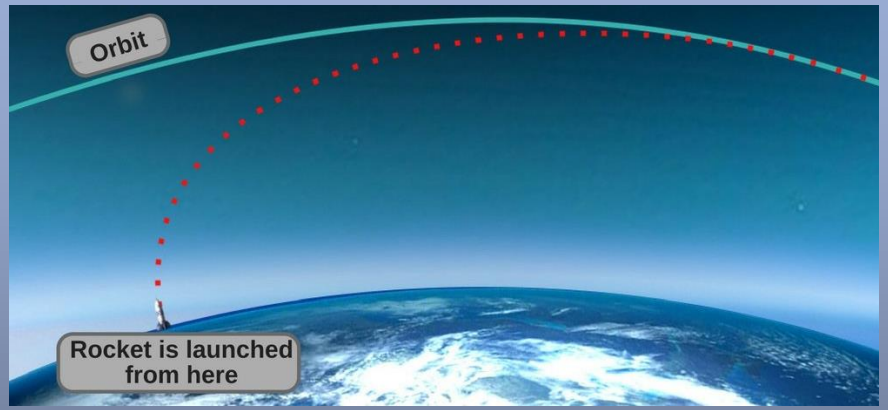


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Rockets

- Rockets don’t go straight up.
- *Getting* to space isn’t the problem – *staying there* is.
- Need to go ‘sideways’ fast enough that *Earth curves away beneath you* as fast as gravity pulls you down.
  - This happens at around 18,000 mph (29,000kph), for Low Earth Orbit.





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Air Launch to Orbit

- If we need to go sideways, why don't we just take off from a runway like a plane?
  - Air is thicker at low altitude.
  - Thicker air causes more drag, slowing us down and using more fuel.
  - Solution: take off from 39,000' (13km) up!
  - Works best for low weights.

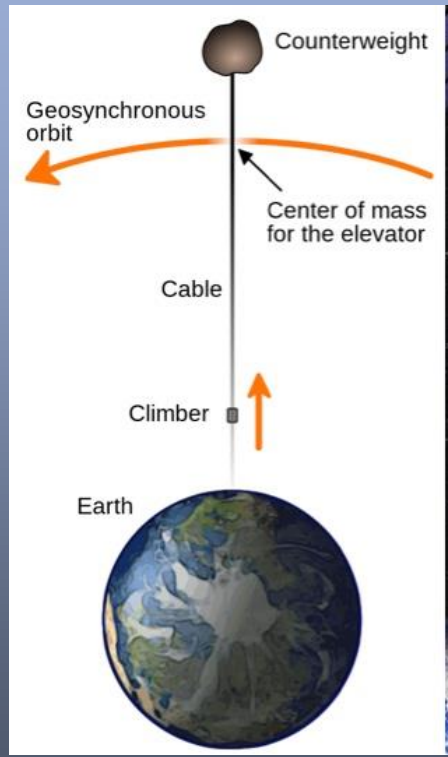


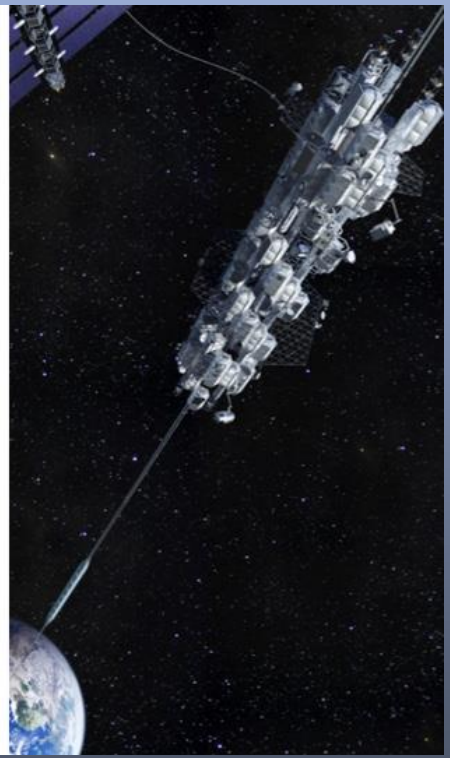
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Space Elevators

- Rockets are very inefficient – only 2.5% is useful payload.
- Could use the rotational energy of the Earth to hold a tether in geostationary orbit – a *space elevator*.
- Very expensive to build (the biggest infrastructure project in human history); but 100x more efficient if we can do it.





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Video 5

Space Elevator (Link)

How Do We Get Back Again?

- If we reduce our orbital speed:
  - Gravity will start to pull us down faster than the Earth falls away beneath us.
  - So our altitude will start to decrease.
- As we get lower, we'll start entering the upper atmosphere.
- Atmospheric drag will slow us down (much) more.
  - Heat will become a problem!

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Video 6

Landing the Space Shuttle (Link)



Summary

- Why we go to space.
  - Communications, navigation, weather forecasting, science, etc.
- Why is the RAF interested?
  - Some military uses of space (surveillance, missile defence).
  - Potentially a domain of conflict (people might want to shoot down our satellites or missiles; we might want to shoot down theirs).
  - Space debris an increasing problem.
- How we get to space (rockets, air launches, space escalators).
- How we get back again (deorbiting, shuttle re-entry flight).

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Any Questions?

(Feel free to ask in private if you prefer)

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