Space and Orbits

Learning Objectives

In this lecture you will learn

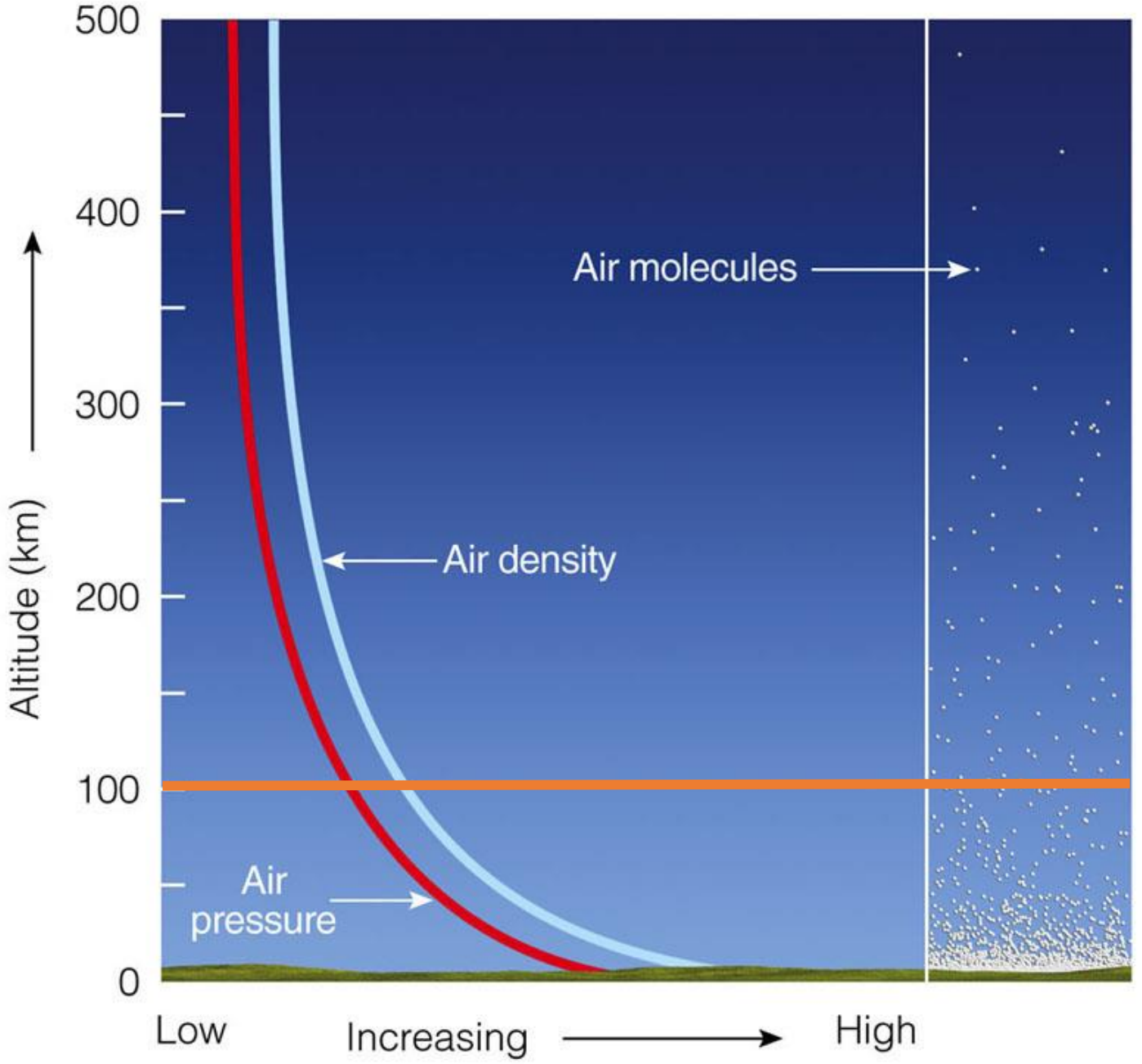
- What is Space?
- What makes an orbit and basic orbital mechanics
- Different types of orbits and their applications
- Space junk issues and solutions

What is space?

- How do you define space?
- How far is space?

- Satellites are generally at least 400-500km altitude

- The Karman line at 100km altitude is an arbitrary boundary of the atmosphere and space
  - Recognized by the (Federation Aeronautique Internationale) FAI



What is space?

- The atmosphere extends for 480 km and continues to merge with space as air pressure approaches a vacuum
- There is no distinct boundary between Earth and space

Orbits

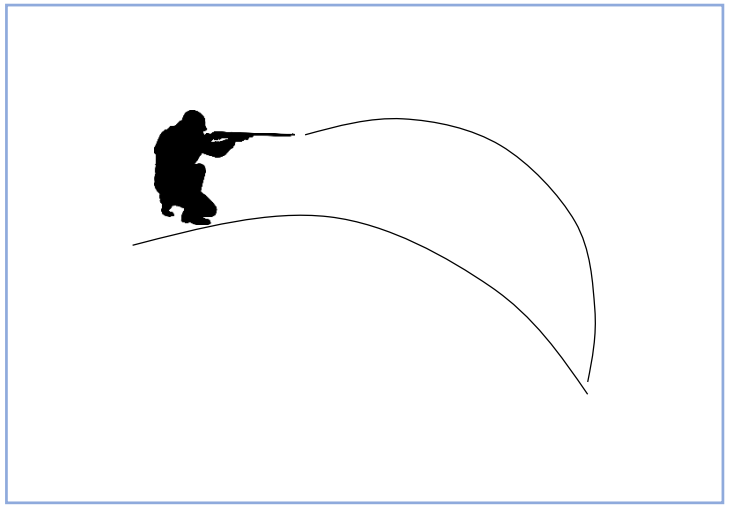
Orbit:

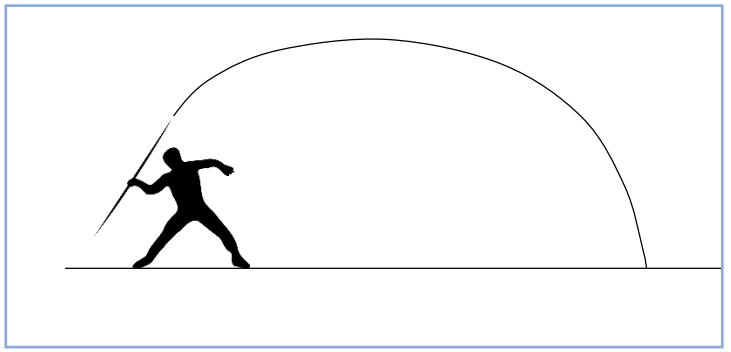
-curved path around a celestial object

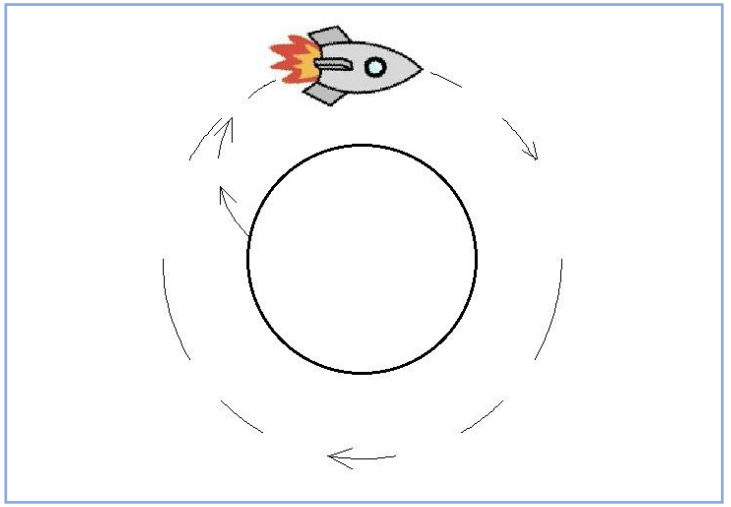
Path:

-created from gravitational attraction between the two objects

The orbit is the effect of continuously falling towards the object…



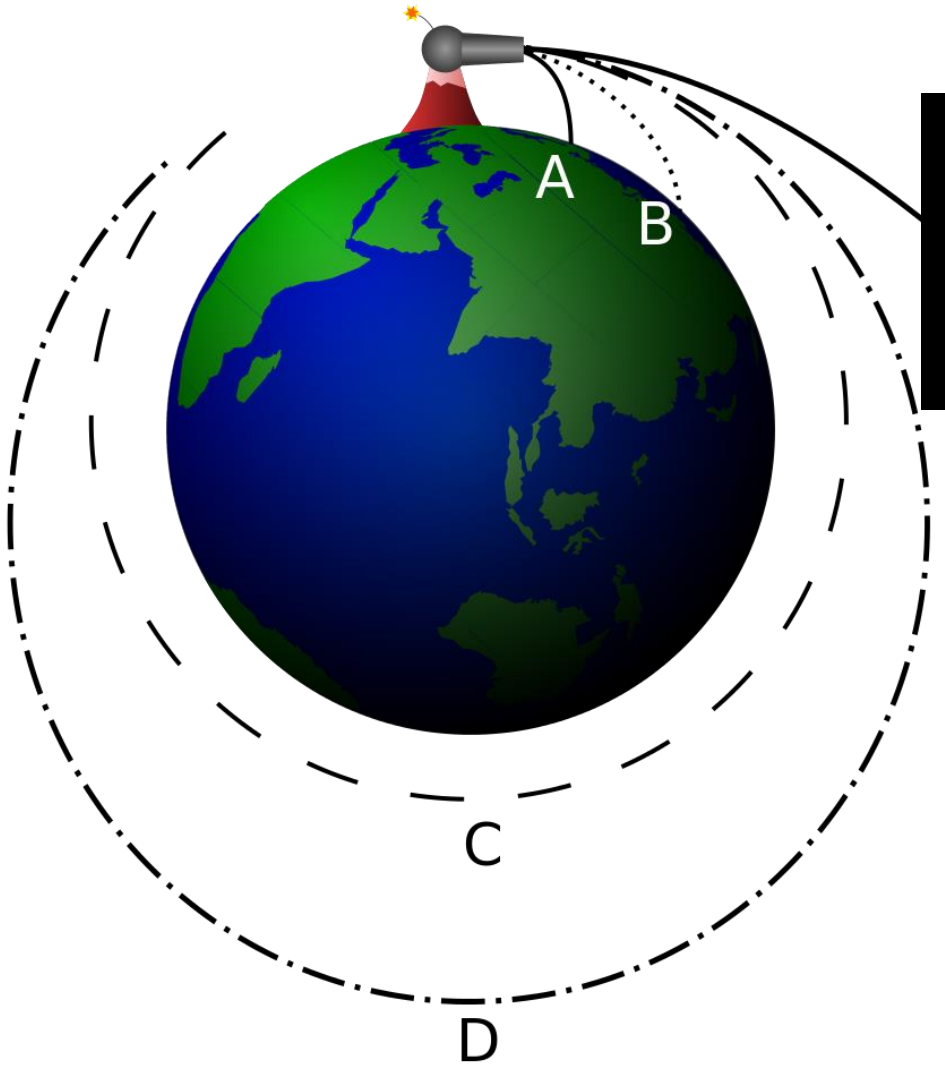




Orbits

Newton's cannonball experiment:

- Newton deduced:
  - significant thrust
  - enough altitude (from lift)
  - cannonball can maintain:
    - circular orbit around Earth



Newton Cannon (Source: Wikimedia Commons)

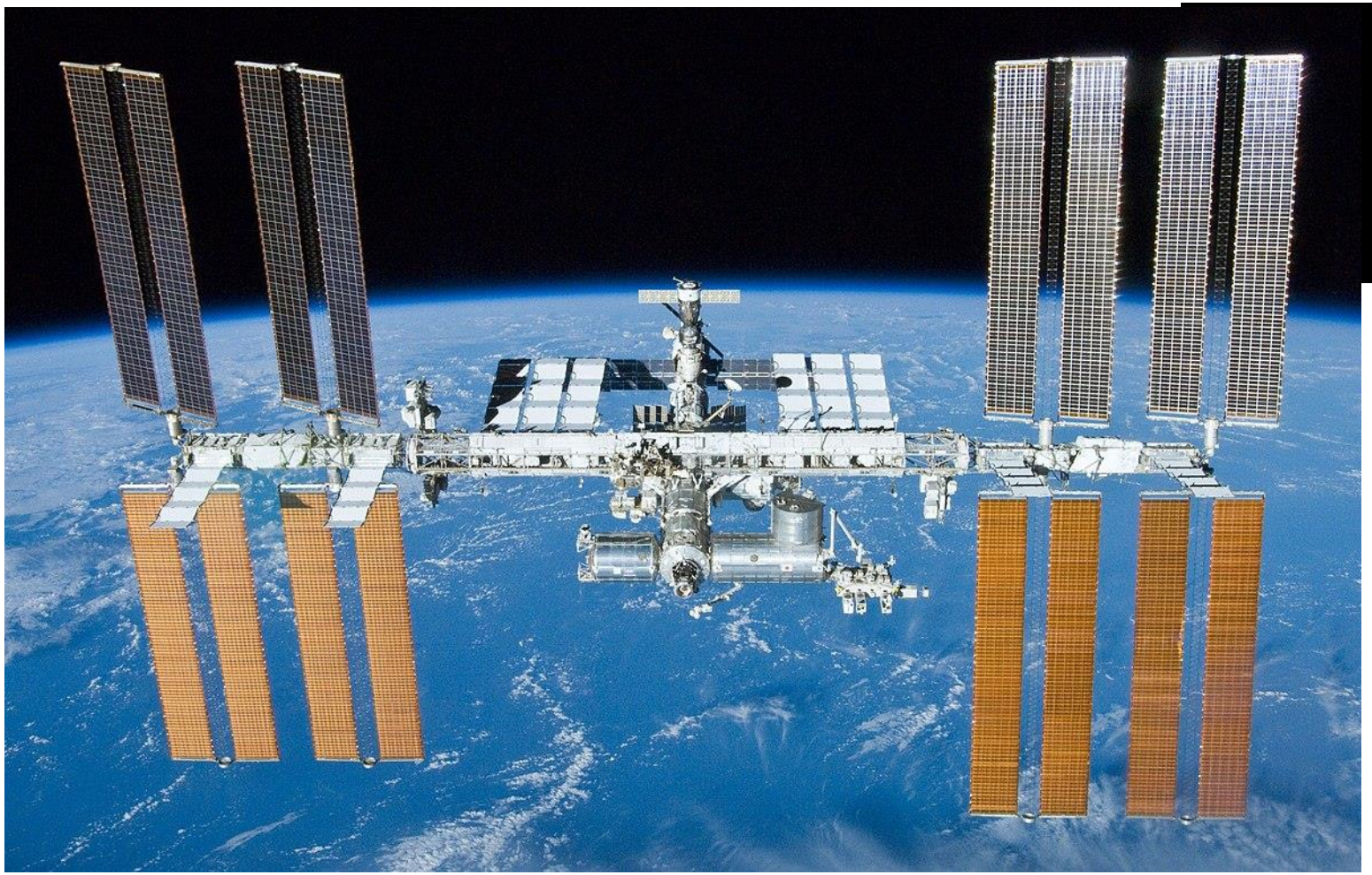
Types of orbits

- Low-Earth orbits
- Close Elliptical Orbits
- Far Elliptical Orbits
- Geostationary Orbits

Types of orbits: low-earth

Speed: 26,600 km/h

Altitude: 400 km



Applications:

-Earth observation

-human space flight

-microgravity experiments

Susceptible to:

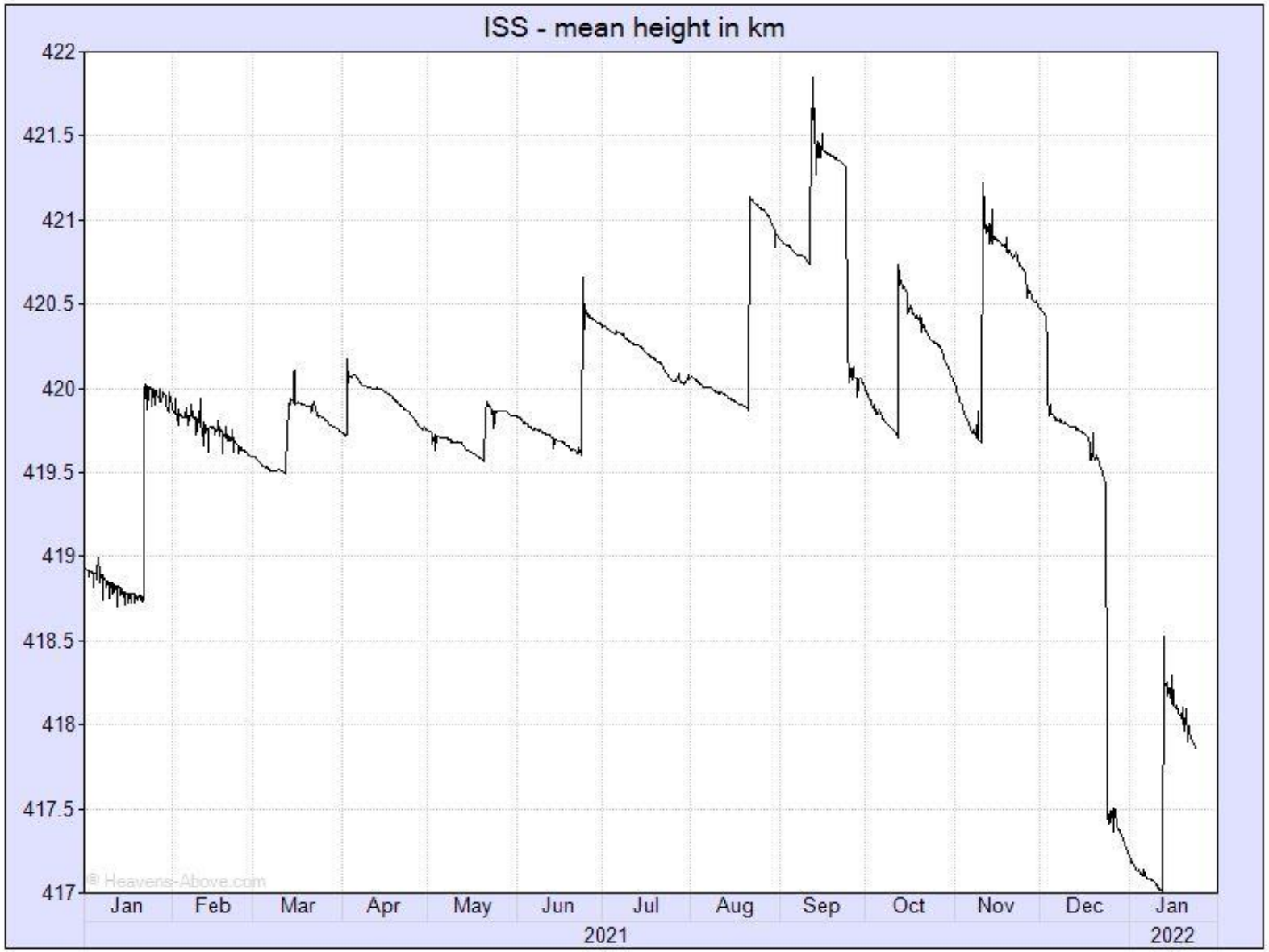
-atmospheric drag

-orbital decay

Orbits

Will the ISS eventually be forced to Earth?

Height of the ISS



This plot shows the orbital height of the ISS over the last year. Clearly visible are the re-boosts which suddenly increase the height, and the gradual decay in between. The height is averaged over one orbit, and the gradual decrease is caused by atmospheric drag. As can be seen from the plot, the rate of descent is not constant and this variation is caused by changes in the density of the tenuous outer atmosphere due mainly to solar activity.

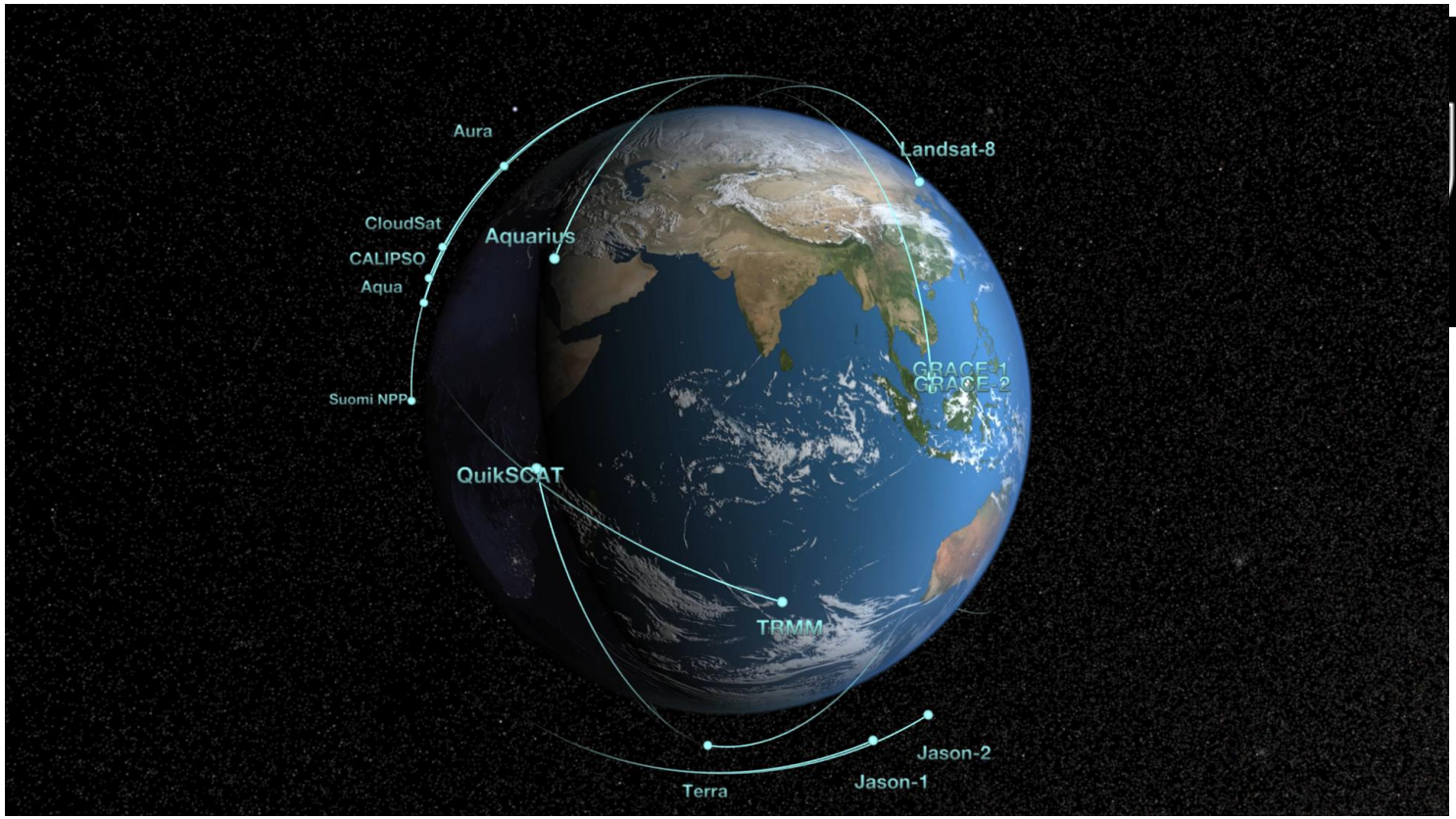
Types of orbits: close elliptical

Speed: 27,432 km/h

Altitude: 600-2000 km

Applications:

- Earth observation



HD resolution version of NASA's Earth Observing Fleet (including Landsat 8; Source: NASA)

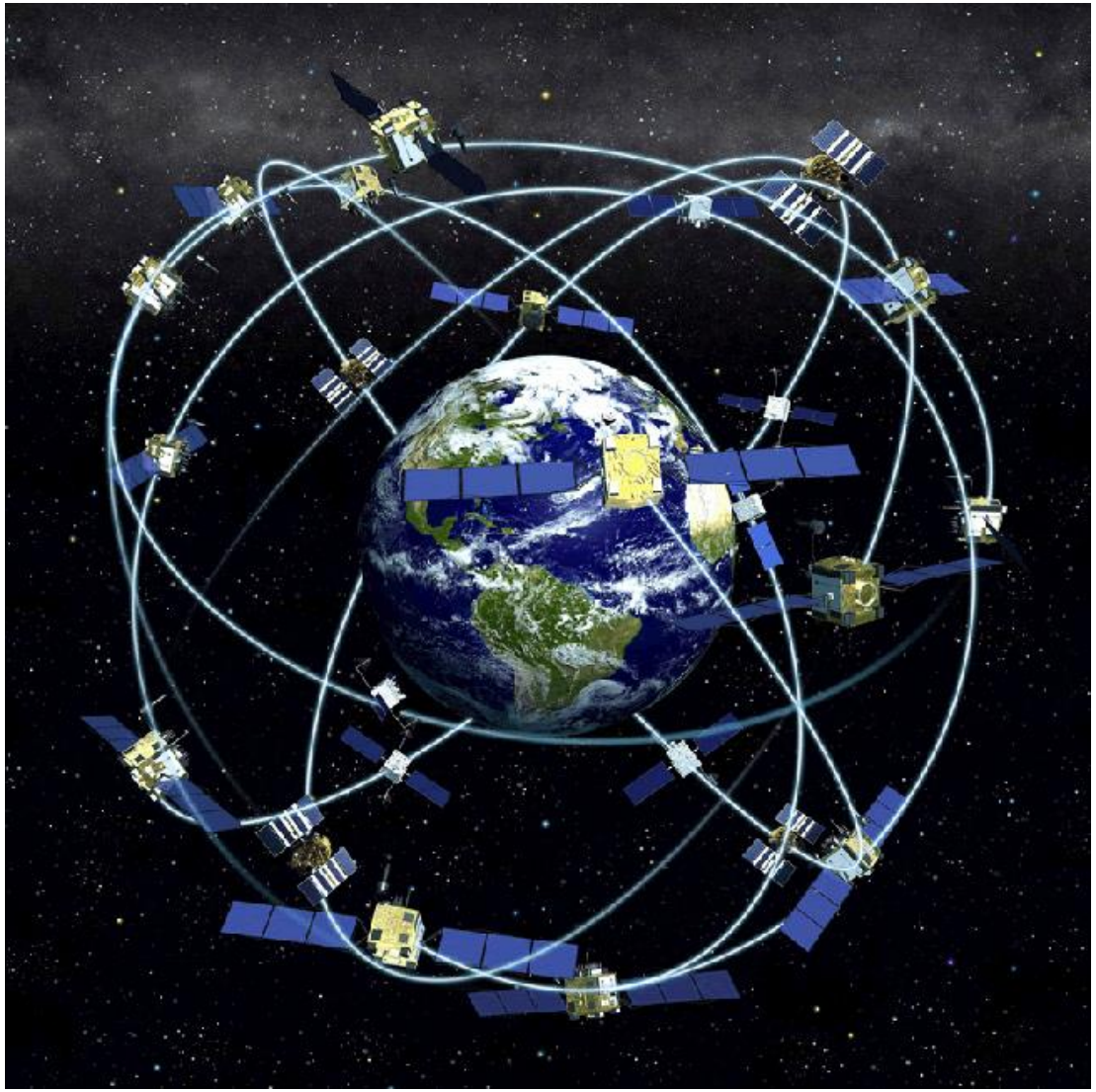
Types of orbits: far elliptical

Speed: 14,000 km/h

Altitude: 20,182 km

Applications

- Global Navigation Satellite Systems (GNSS)



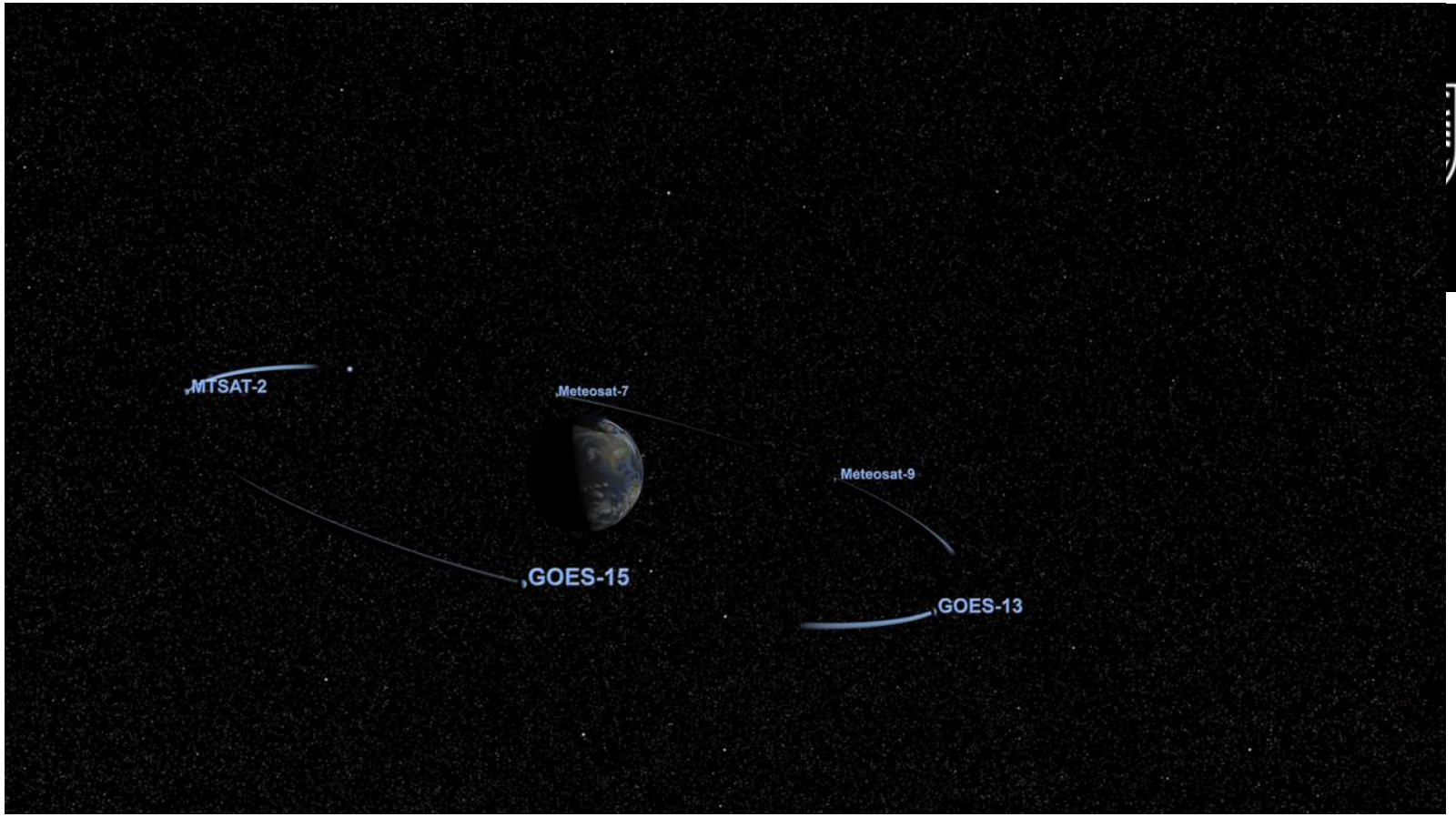
Types of orbits: Geostationary orbits

Speed: 10,080 km/h

Altitude: 35,786 km

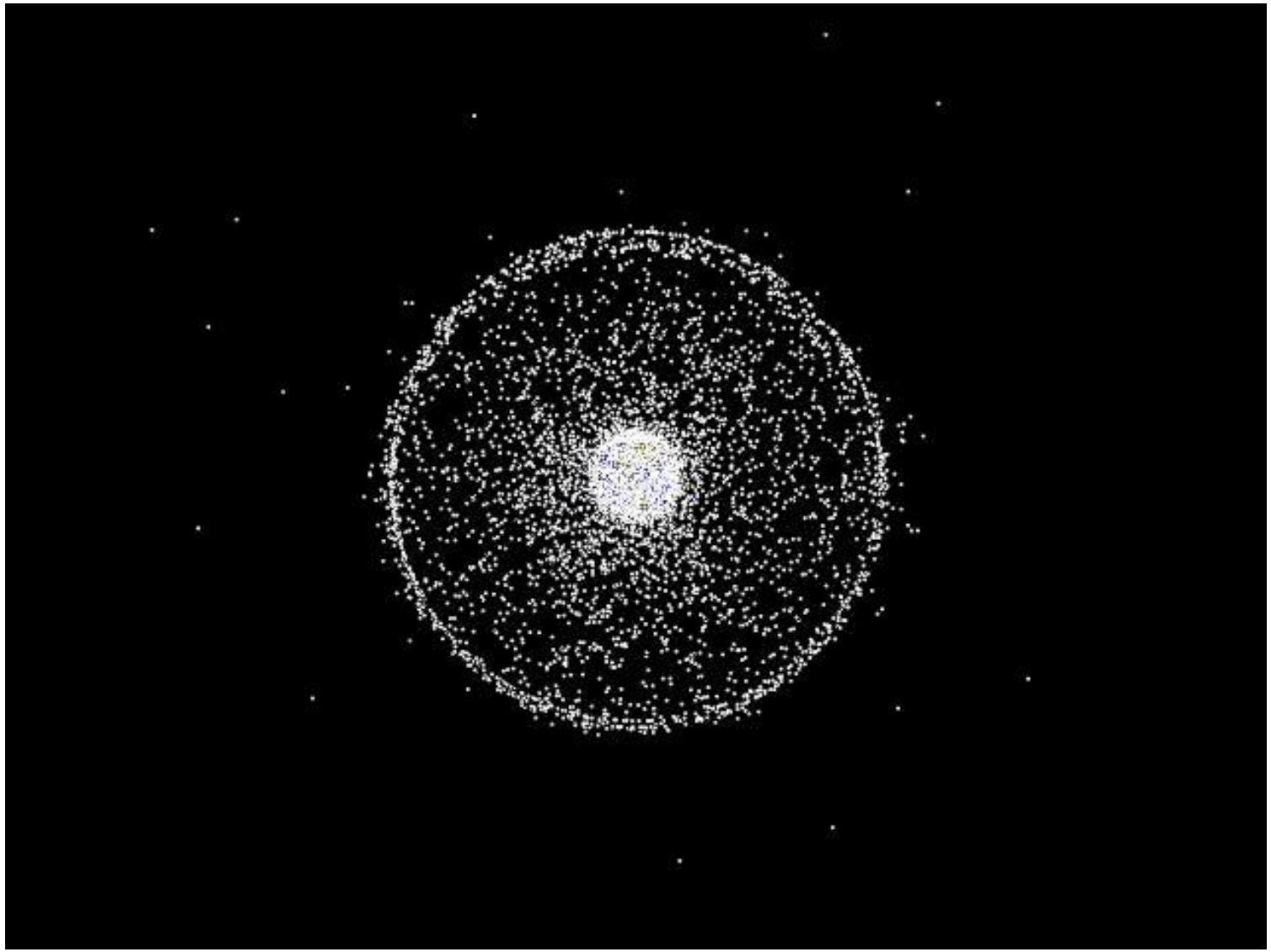
Applications:

- Weather satellites



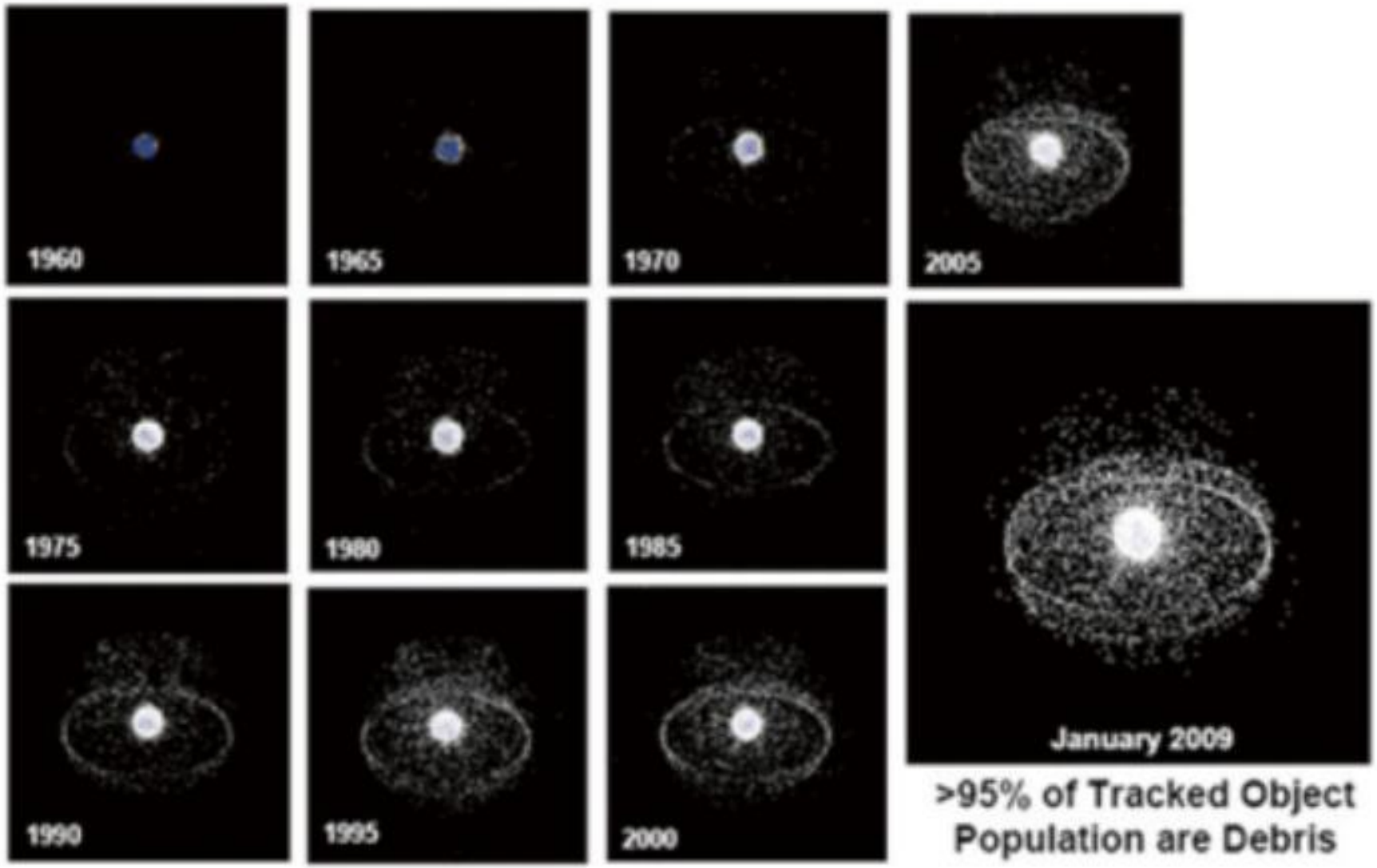
This set provides movies and frames of the Weather Satellites in Orbit visualization (Source: NASA)

Orbit of debris



National Aeronautics and Space Administration

Growth of the Satellite Population



>95% of Tracked Object Population are Debris

Risks of Space Junk

- Difficult to launch new satellites
  - They could get hit by old ones and other junk
- More dangerous/difficult for space exploration by people
  - Due to higher risk of getting hit by debris

Impacts on Earth Observation

- Exponential Growth - Kessler Effect

Scientists predict that close encounters between satellites and debris will rise by…

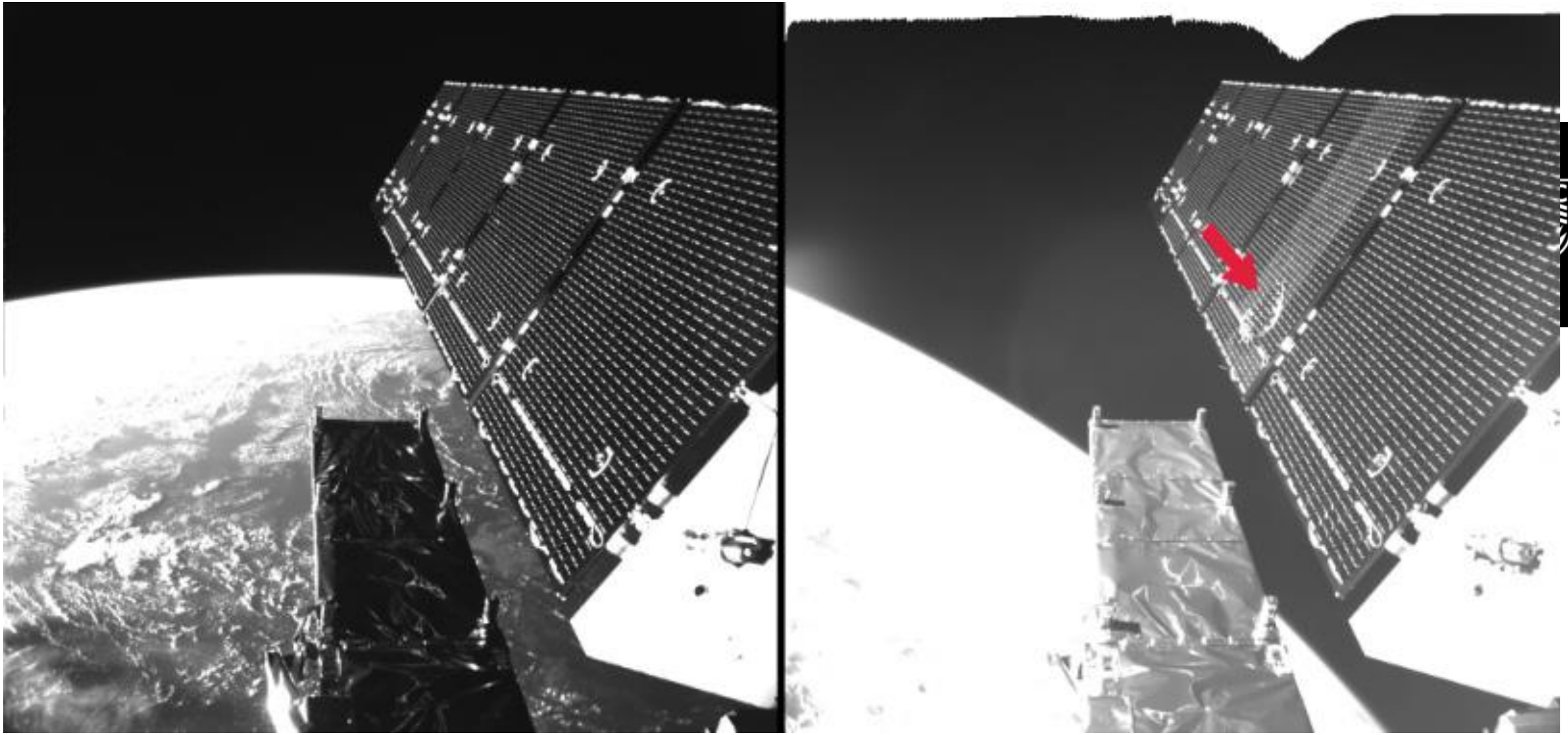
- 50% by 10 years
- 250% by 2059

- 20,000 object bigger than a softball being tracked
  - Poses danger for current satellites and future spacecraft

Image from Astronaut Tim Peake of a Chip in the windshield of the ISS caused by space junk

Hubble Telescope

Sentinel -1 Impact



What can we do?

- Debris reduction programs
  - Send satellites into space designed to reduce junk
    - Ex. Harpoon or net capture
- Develop technologies to avoid oncoming space debris
  - Ensure newly launched satellites can remove themselves from space
- Implement stronger international agreements


THE ROYAL SOCIETY
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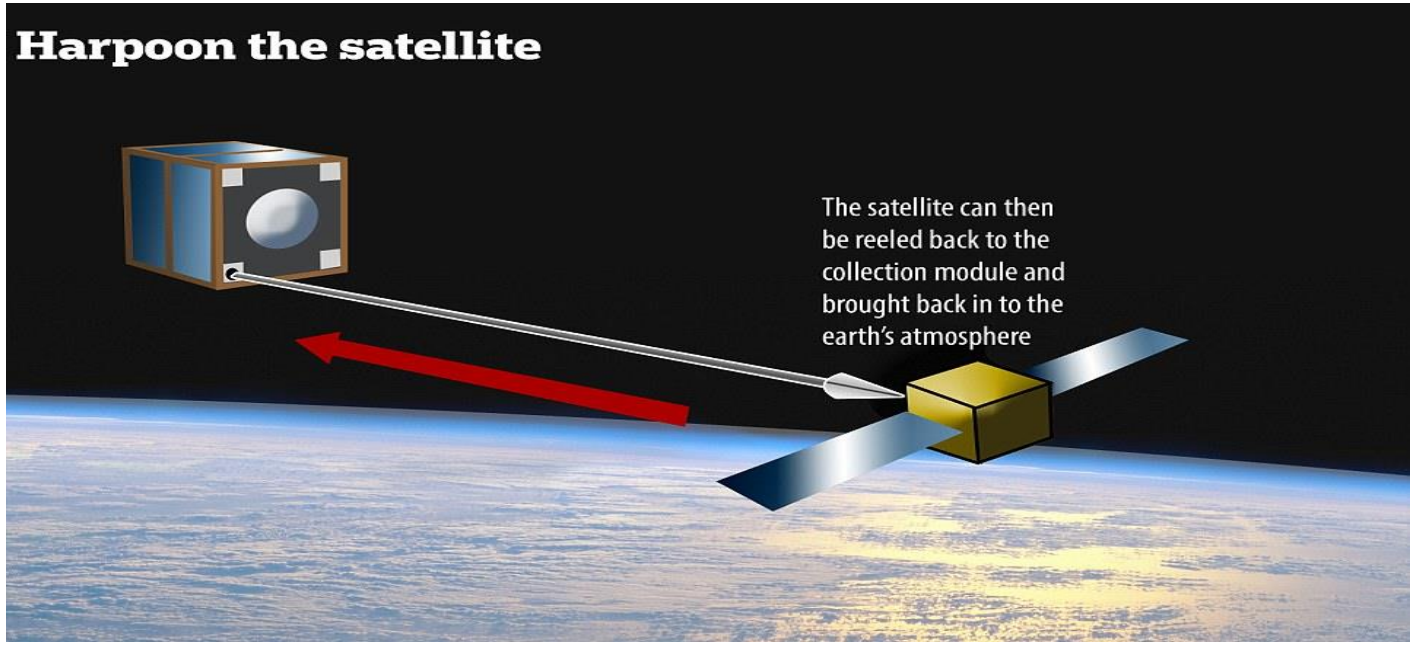
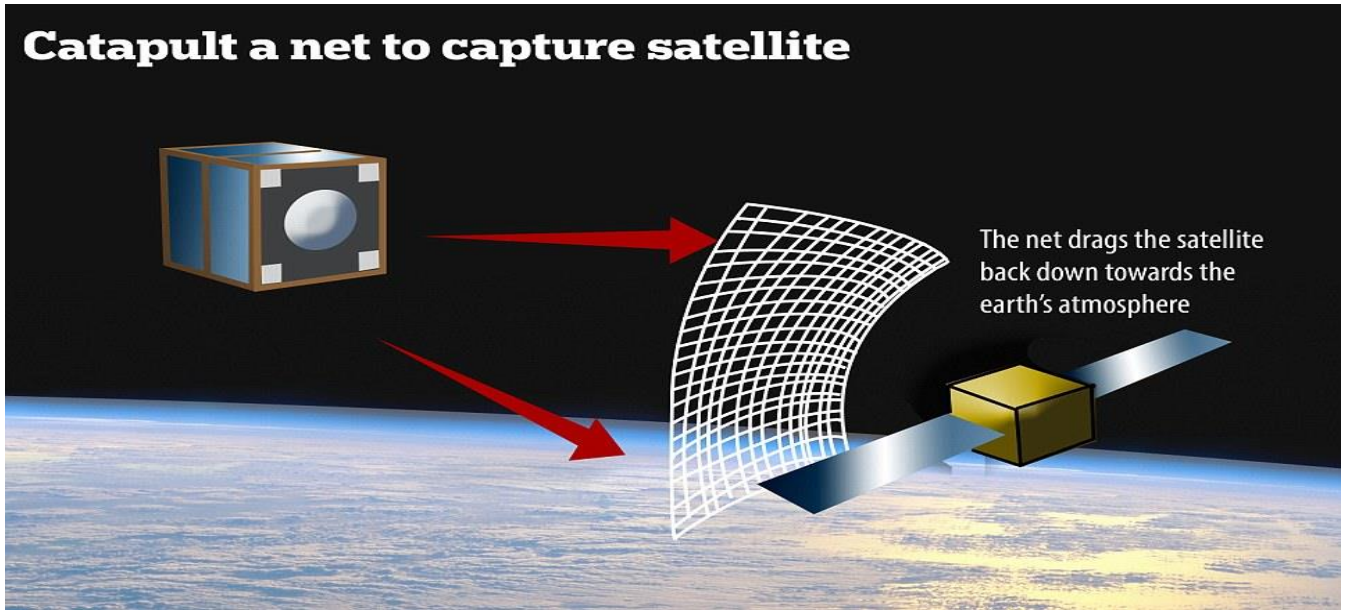
- Actively launched from a satellite to eliminate current junk
- Harpoon released from satellite and grabs the space junk
- Space junk is either reeled back into the satellite which pulls it down to the atmosphere
- OR
- Potential for the harpoon to contain a small thruster to send smaller junk into the atmosphere individually

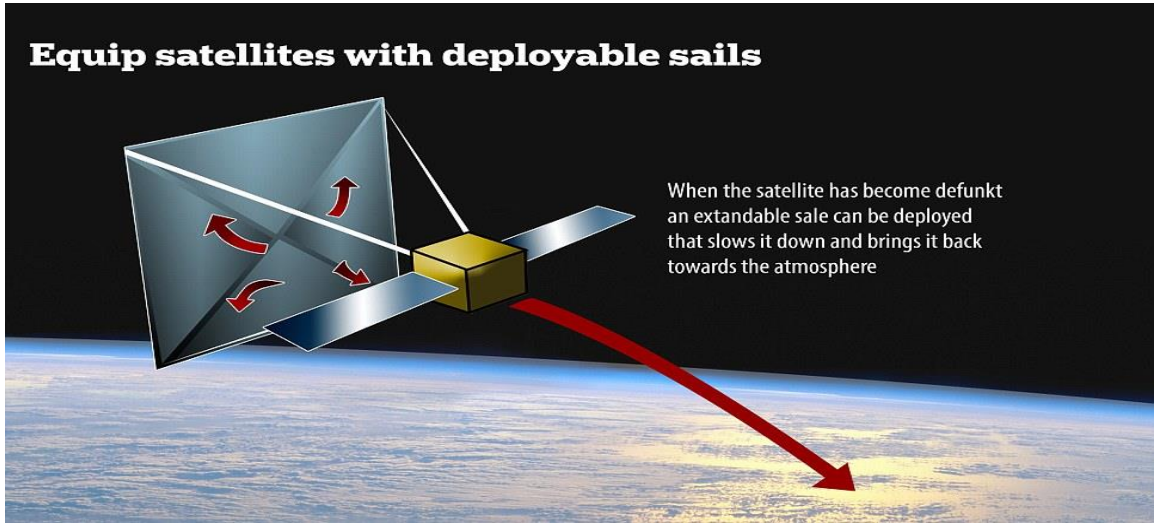


- Actively launched from a satellite to de-orbit large objects
- Launch net and capture junk
- Net (typically with attached tether) will produce enough drag to pull junk into the atmosphere



http://www.cnn.com/2017/01/18/health/space-junk-2017-cassini/

- Experiment to be placed on new satellites to dispose of themselves when missions are completed



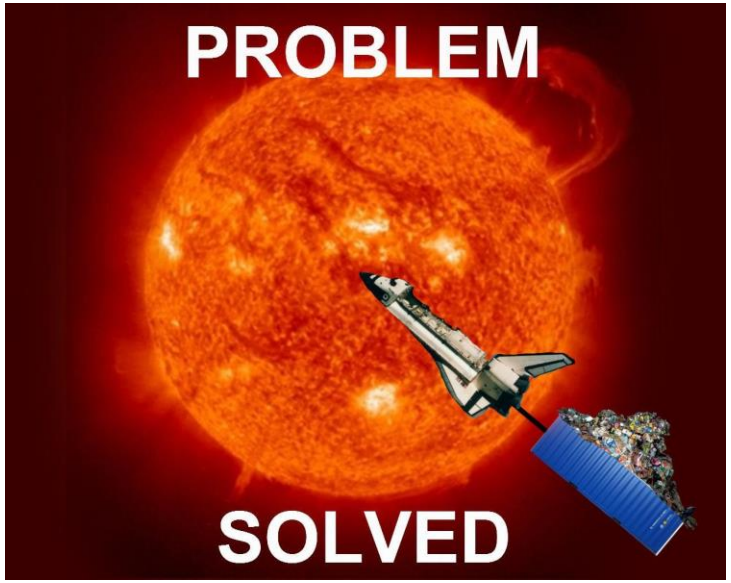
- Satellites will deploy an inflatable boom that will apply drag to the satellite
- The drag will pull the satellite down to earth quicker where it will disintegrate upon entering the atmosphere
- Will not fix current space junk problem but can help prevent it in the near future

Why not send garbage to space?

- The ISS recently dumped 2.9 tons of used nickel-hydrogen batteries
- Currently orbiting the earth at 4.8 miles/second
- Will get pulled into Earth's atmosphere
  - 2 – 4 years

Why not send garbage to space?

- The world makes about 2.6 trillion pounds of garbage per year
- That would take about 168 million rocket launches
- Which would cost about $33 quadrillion (for one year)
  - $33,000,000,000,000,000 (1500 times annual GDP of US)



Important Topics

- Where does space begin?
- What is the altitude of each orbit type?
- What are the common applications of each orbit type?
- Why is space junk a problem and how can we fix it?

Additional Resources

- Newton's cannon: http://www.school-for-champions.com/science/gravity_newtons_cannon.htm
- Types of orbits: http://www.polaris.iastate.edu/EveningStar/Unit4/unit4_sub3.htm
- Animation of travel from Sun outward at speed of light: https://vimeo.com/117815404
- Experiments on ISS: http://www.nasa.gov/mission_pages/station/research/experiments_category/#.VbFjgPmjYZw