

Solar sailing – an introduction

Solar sailing... once upon a time



1607

Kepler observes a comet (later to be known as Halley's comet)



"Provide ships or sails adapted to the heavenly breezes, and there will be some who will brave even that void."

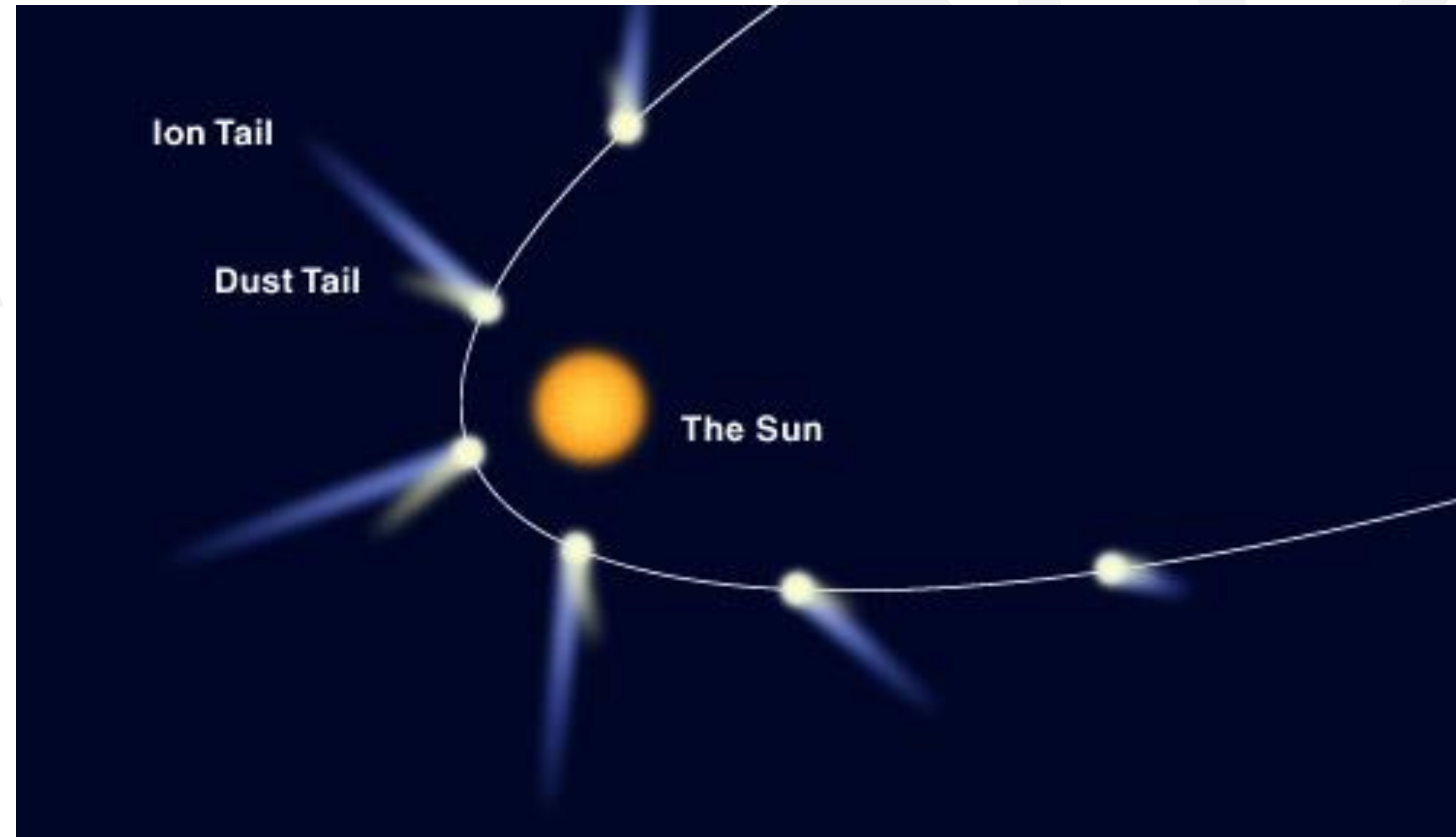
– Johannes Kepler

Solar sailing... once upon a time



1607 1619

Kepler puts forward the idea that comet's tail always points away from Sun



Solar sailing... once upon a time



1607 1619

1862

Maxwell published theoretical proof that sunlight exerts a pressure on a surface



Solar sailing... once upon a time



1607 1619

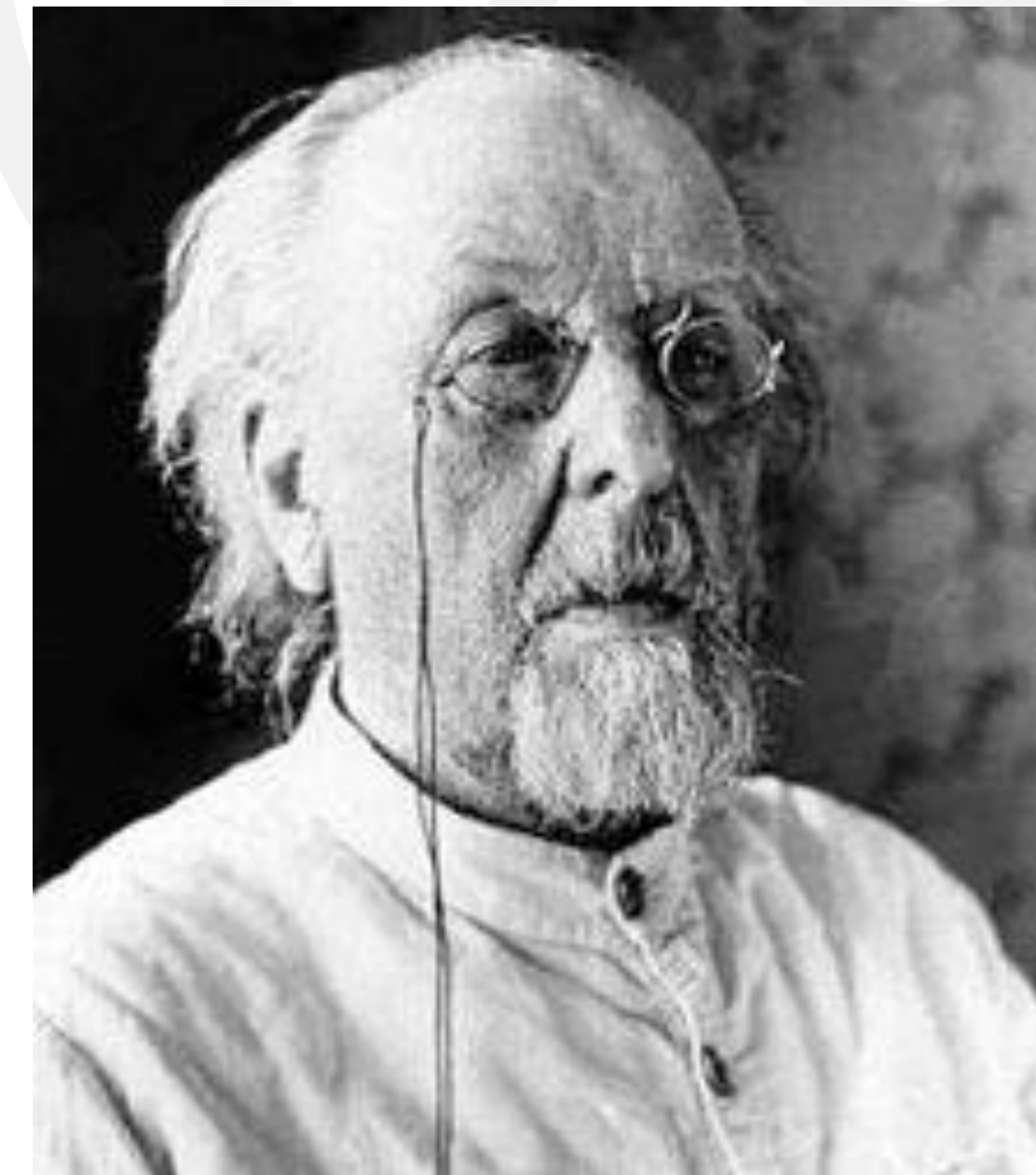
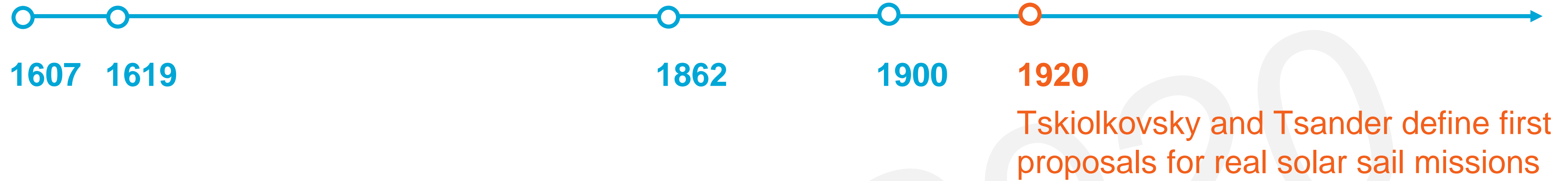
1862

1900

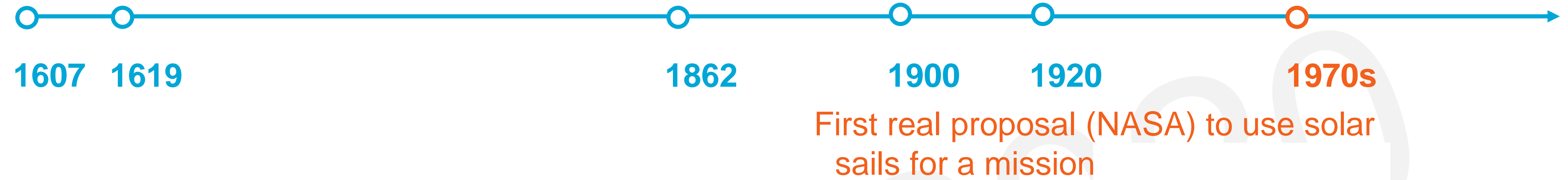
Lebedev provides experimental proof that sunlight exerts a pressure on a surface



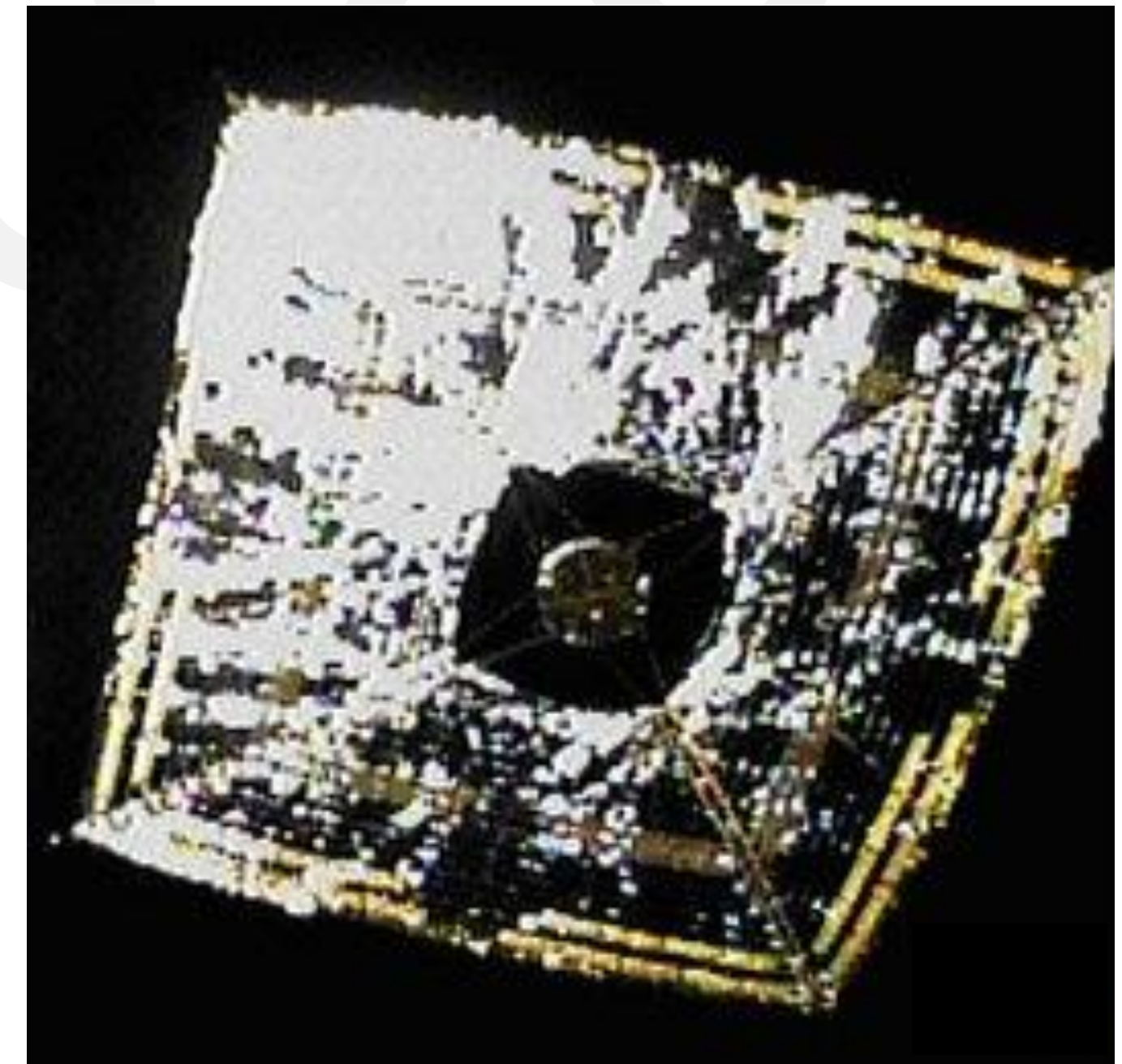
Solar sailing... once upon a time



Solar sailing... once upon a time



Solar sailing... once upon a time

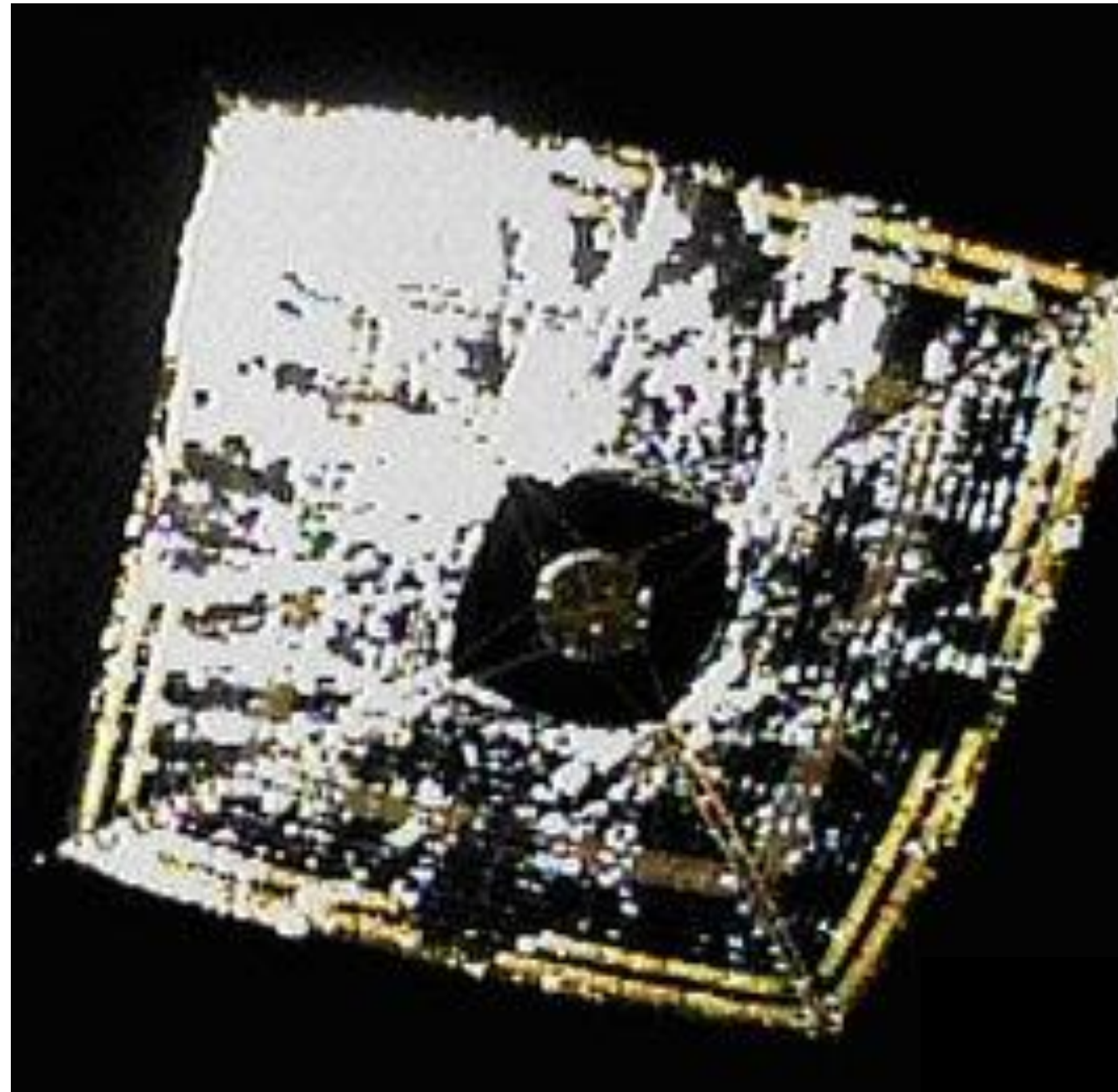


Credit: JAXA

Solar sailing... let's start a new timeline!



May 2010



Credit: JAXA

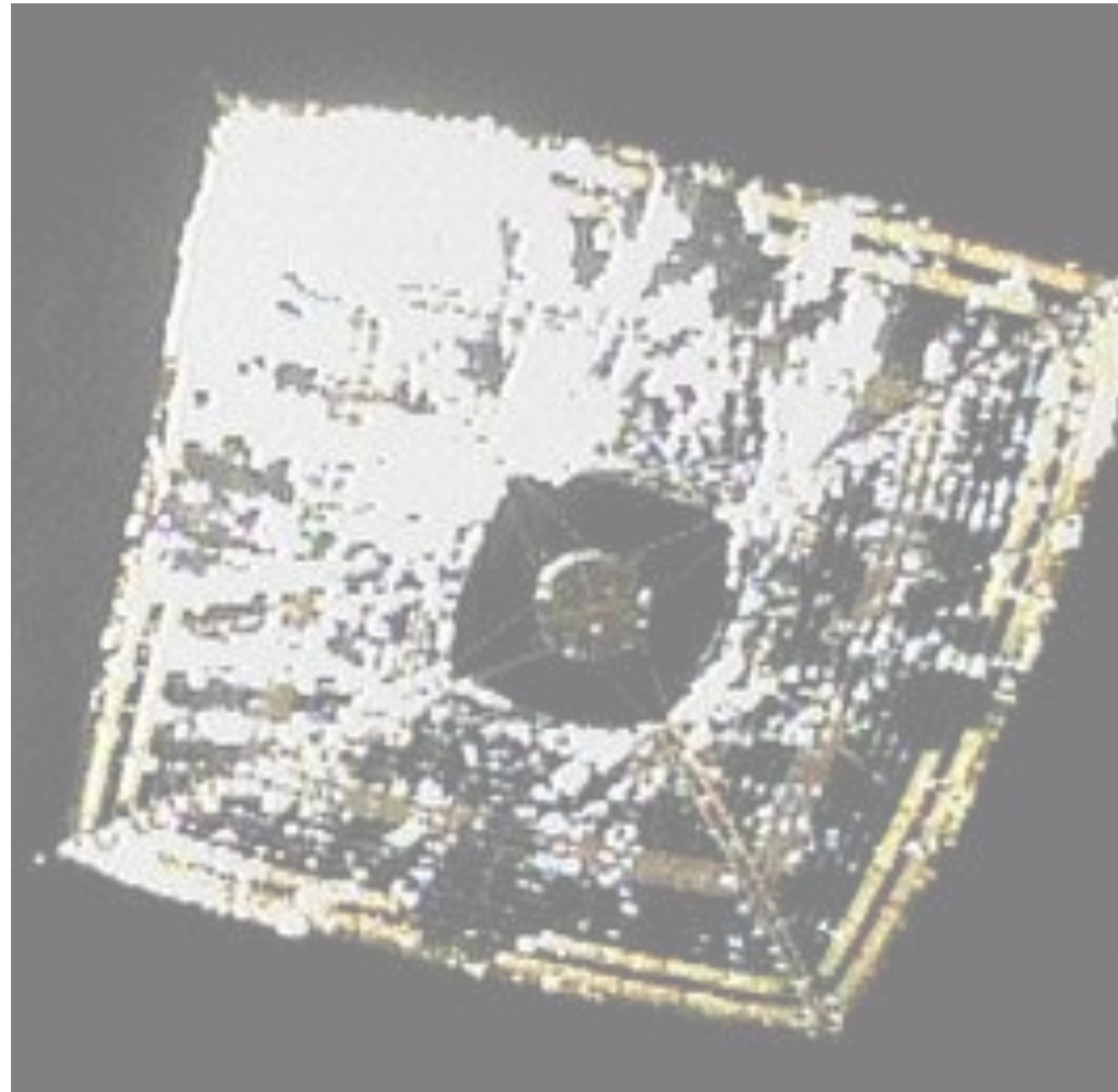
IKAROS mission

- Japan Aerospace Exploration Agency, JAXA
- Secondary payload on Venus Climate Orbiter “AKATSUKI”
- Performed fly-by of Venus and remains in heliocentric orbit
- Spacecraft mass: 307 kg

Solar sailing... let's start a new timeline!



May 2010



Credit: JAXA

IKAROS mission

- Japan Aerospace Expl
- Secondary payload on
- Performed fly-by of Ve
- Spacecraft mass: 307

Quiz question

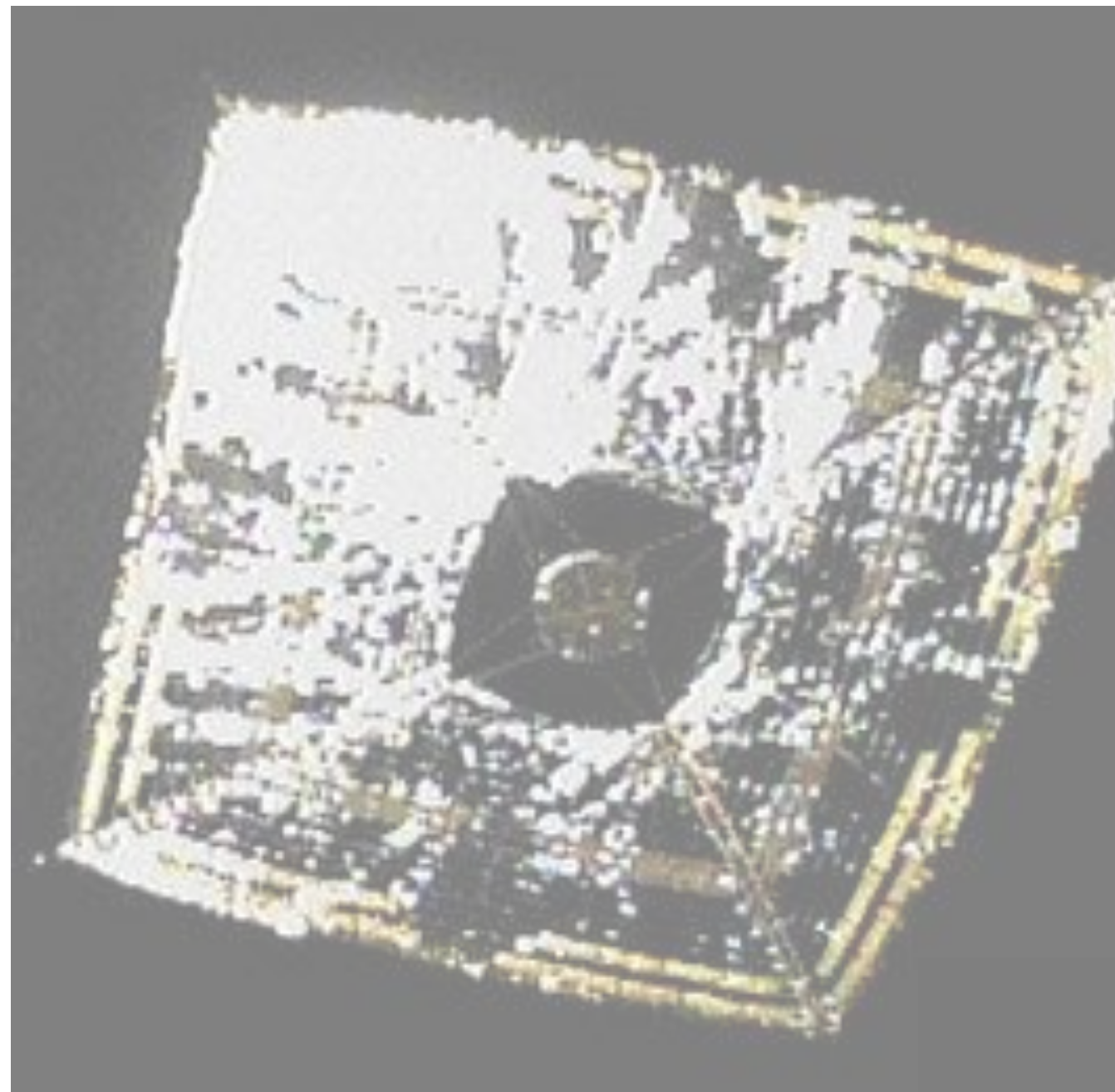
How big (approximately) do you think the IKAROS solar sail was/is?

- a) $1 \times 1 \text{ m}^2$
- b) $15 \times 15 \text{ m}^2$
- c) $30 \times 30 \text{ m}^2$
- d) $100 \times 100 \text{ m}^2$

Solar sailing... let's start a new timeline!



May 2010



Credit: JAXA

IKAROS mission

- Japan Aerospace Exploration Agency
- Secondary payload on the Hayabusa2 mission
- Performed fly-by of Venus
- Spacecraft mass: 307 kg

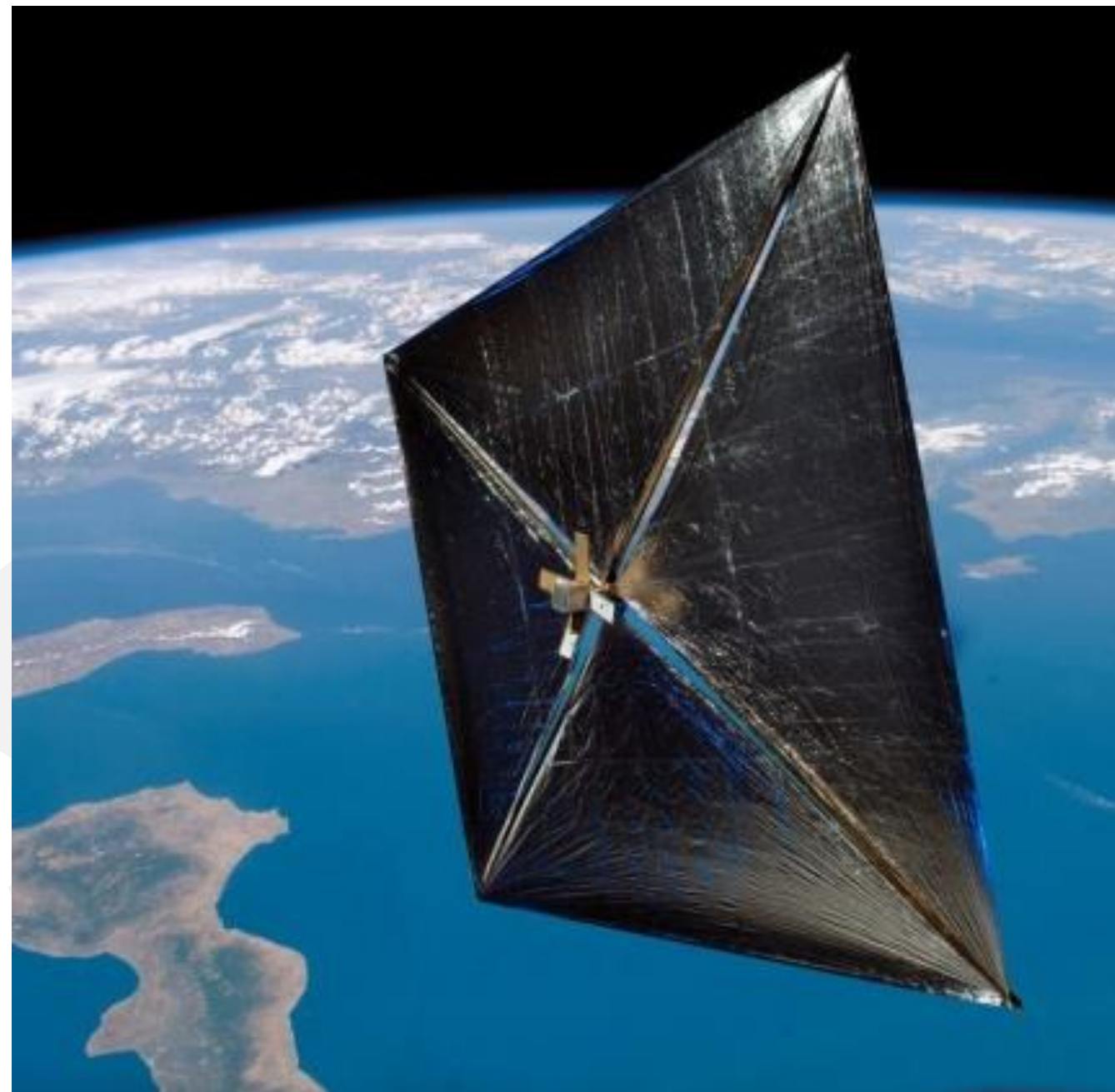
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Solar sailing... let's start a new timeline!



Credit: NASA

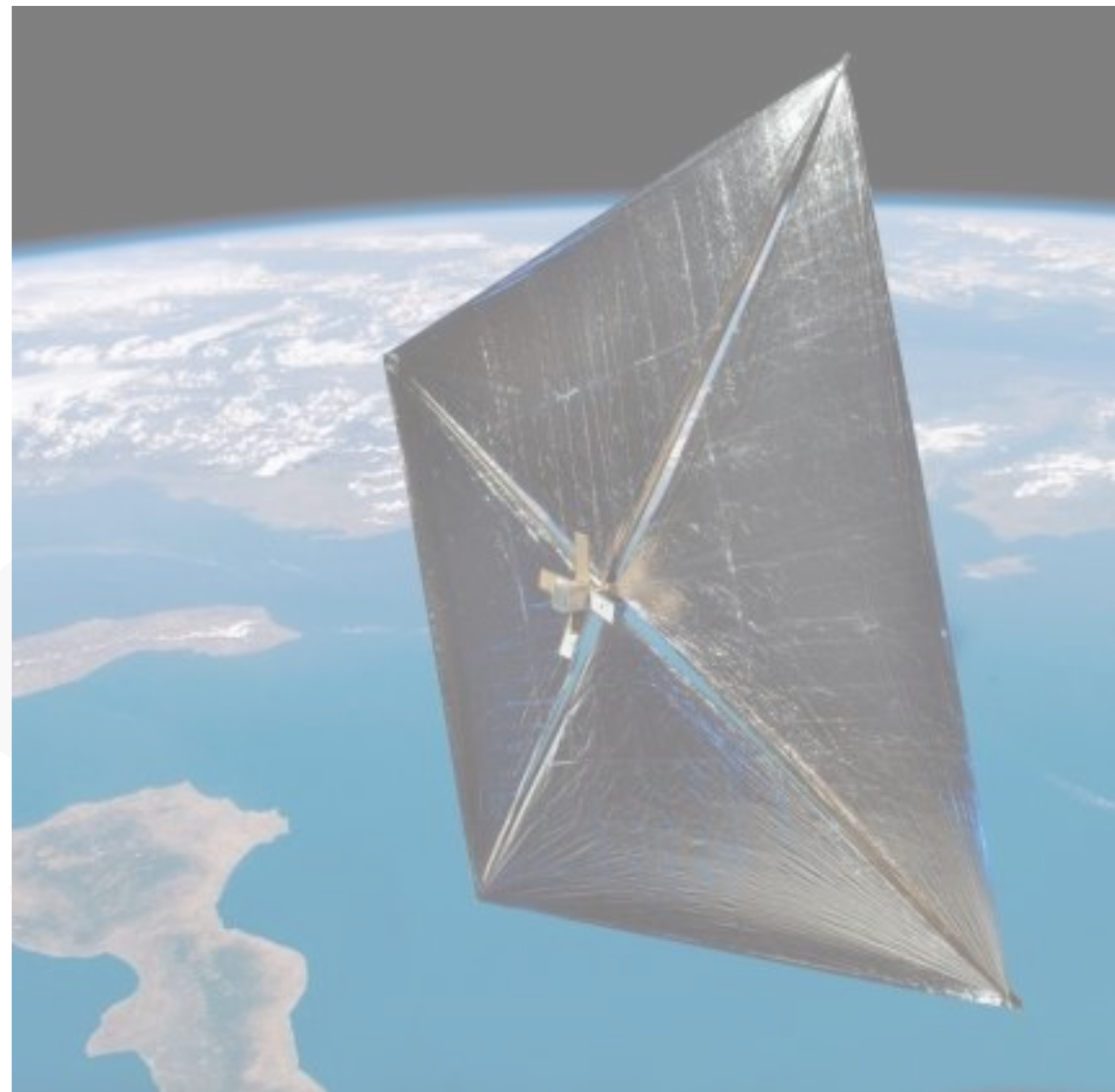
NanoSail D2 mission

- National Aeronautics and Space Administration, NASA
- Flightspare of NanoSail-D (lost on Falcon-1 launch in 2008)
- Stayed in LEO (650 km altitude) and deorbited after 240 days
- Spacecraft mass: 4 kg (3U CubeSat)
- Sail size: 3.2 x 3.2 m²

Solar sailing... let's start a new timeline!



May 2010 Dec 2010



Credit: NASA

NanoSail D2

- National Aeronautics and Space Administration (NASA)
- Flightspan: 27 months
- Stayed in orbit for 27 months
- Spacecraft: NanoSail D2
- Sail size: 270 m²

Quiz question

How thick (approximately) do you think the NanoSail D2 solar sail was?

a) Thicker than 0.2 mm

b)  0.2 mm

c)  40 – 100 μm

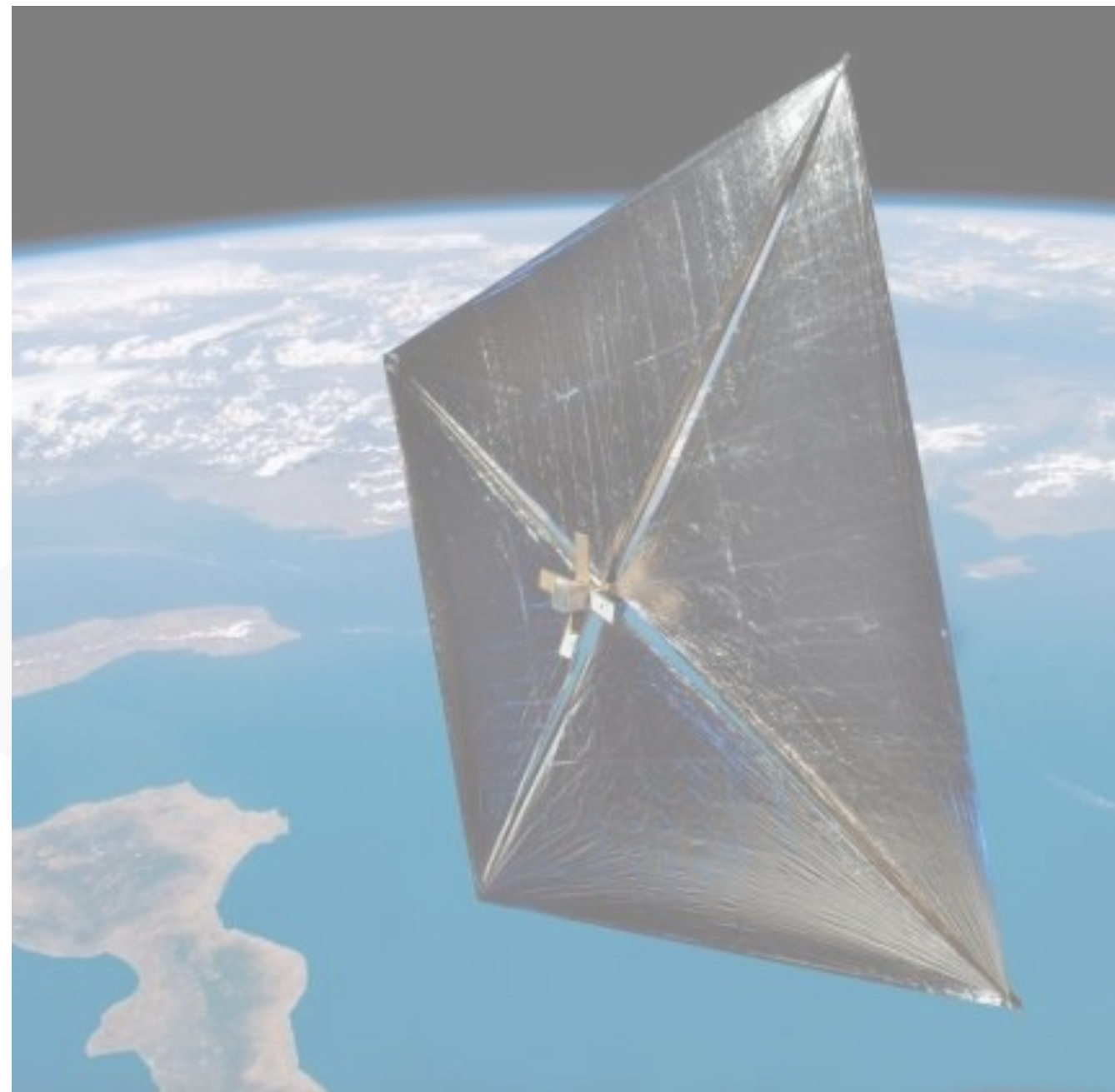
d)  16 μm

e) Thinner than 16 μm

Solar sailing... let's start a new timeline!



May 2010 Dec 2010



Credit: NASA

NanoSail D2

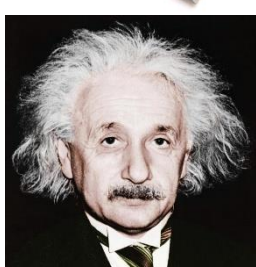
- National Aeronautics and Space Administration (NASA)
- FlightSpace Systems
- Stayed in orbit for 18 months
- Spacecraft
- Sail size: 270 m²

Quiz question

How thick (approximately) do you think the NanoSail D2 solar sail was?

a) Thicker than 0.2 mm

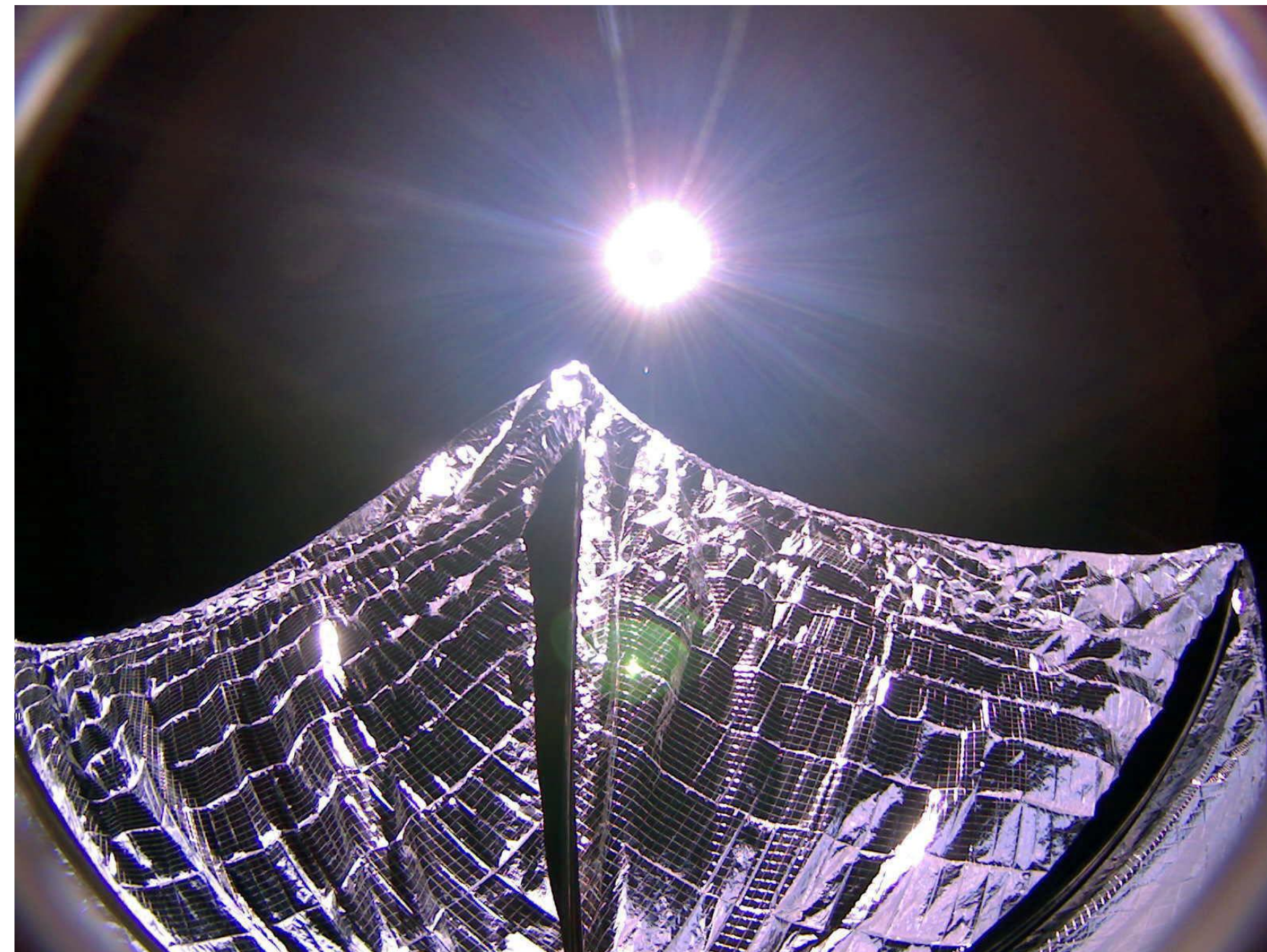
b)  0.2 mm

c)  40 – 100 μm

d)  16 μm

e) Thinner than 16 μm @7.5 μm

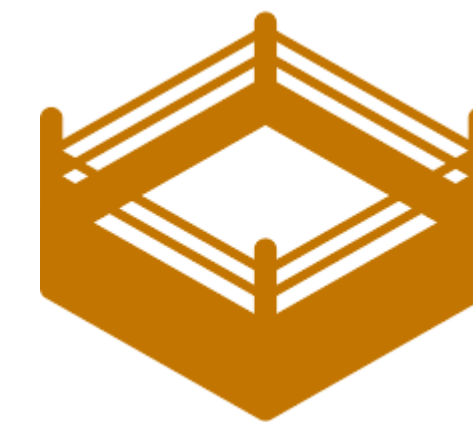
Solar sailing... let's start a new timeline!



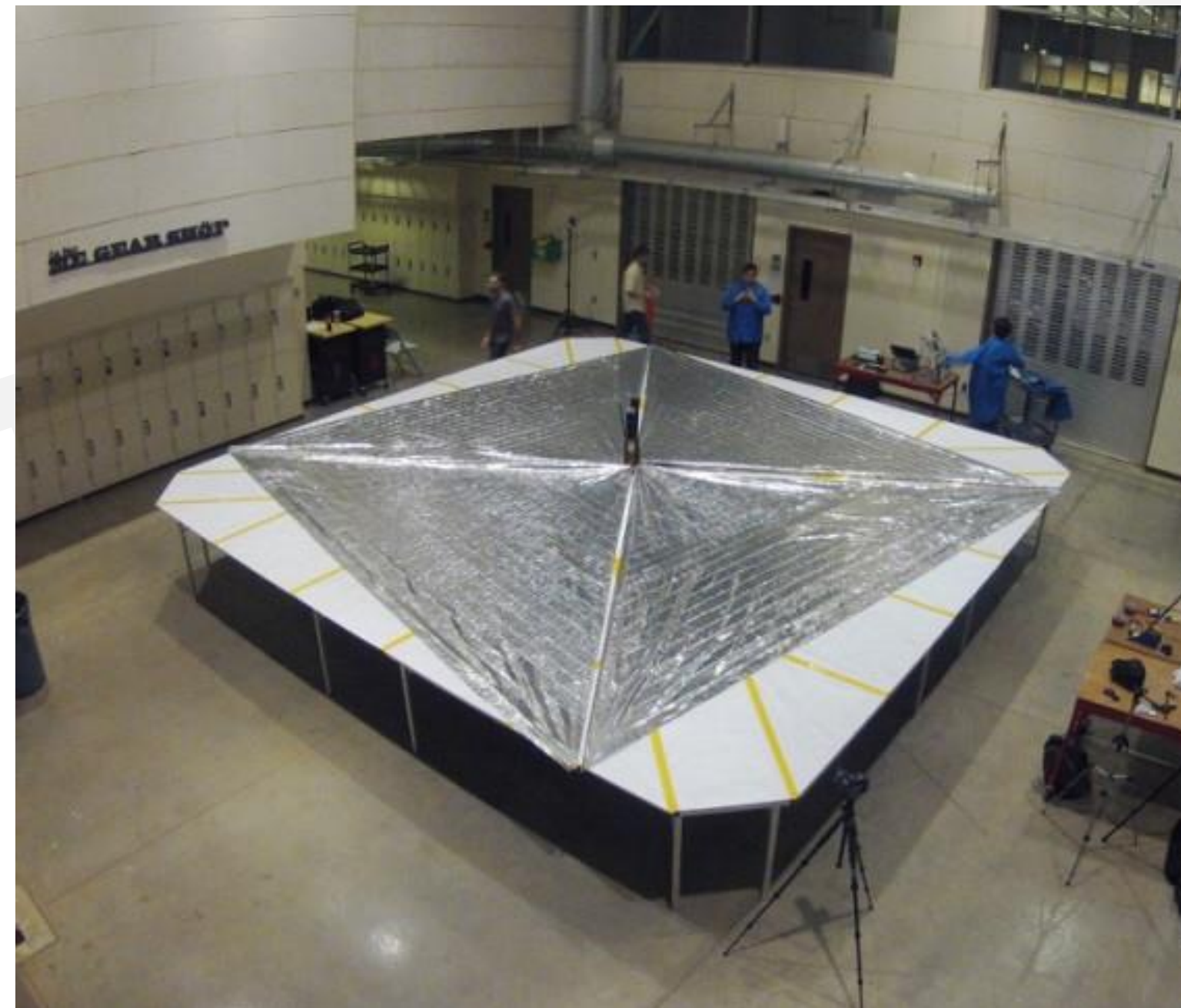
Credit: The Planetary Society

LightSail 1

- The Planetary Society
- Paid for by membership fees and private donations
- Stayed in LEO (800 km altitude)
- Spacecraft mass: 4.5 kg (3U CubeSat)
- Sail size: $5.5 \times 5.5 \text{ m}^2$



Solar sailing... let's start a new timeline!

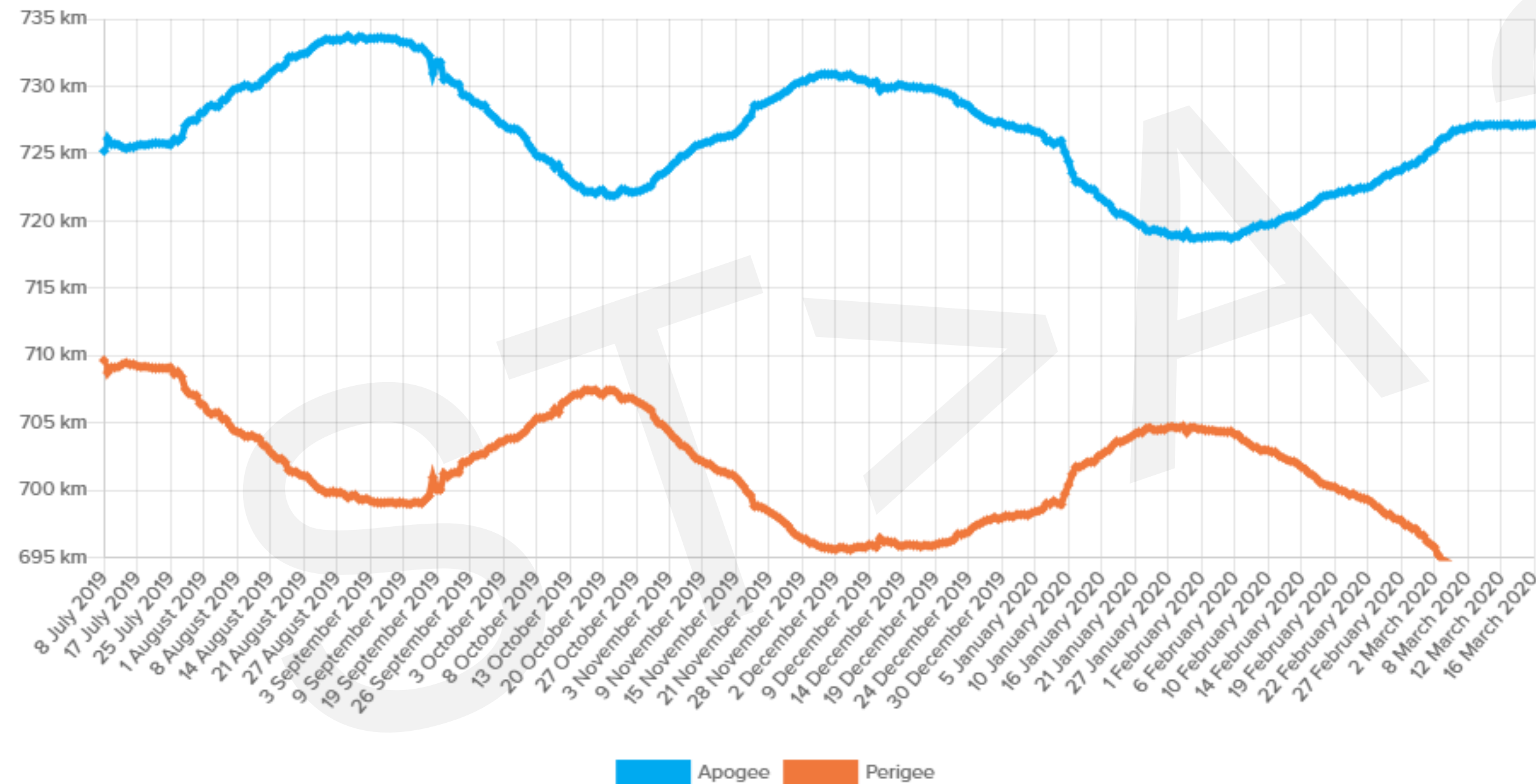


Credit: The Planetary Society

LightSail 2

- The Planetary Society
- Paid for by membership fees and private donations
- In LEO (starting altitude ± 720 km)
- Spacecraft mass: 5 kg (3U CubeSat)
- Sail size: 5.5×5.5 m²

Solar sailing... let's start a new timeline!

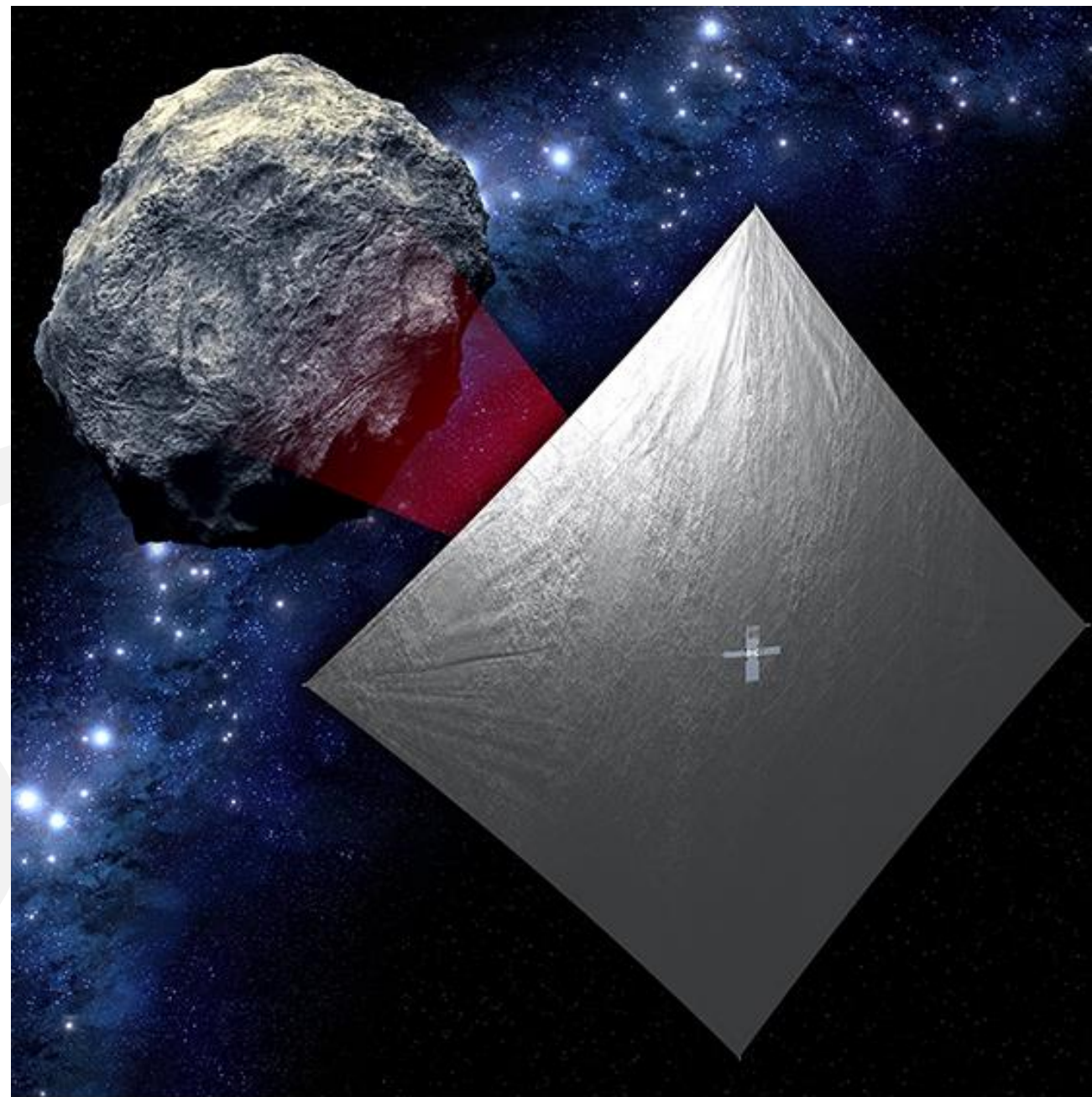


LightSail 2

- The Planetary Society
- Paid for by membership fees and private donations
- In LEO (starting altitude ± 720 km)
- Spacecraft mass: 5 kg (3U CubeSat)
- Sail size: 5.5×5.5 m²
- **First solar sail to demonstrate orbit raising**

Credit: The Planetary Society

Solar sailing... let's start a new timeline!

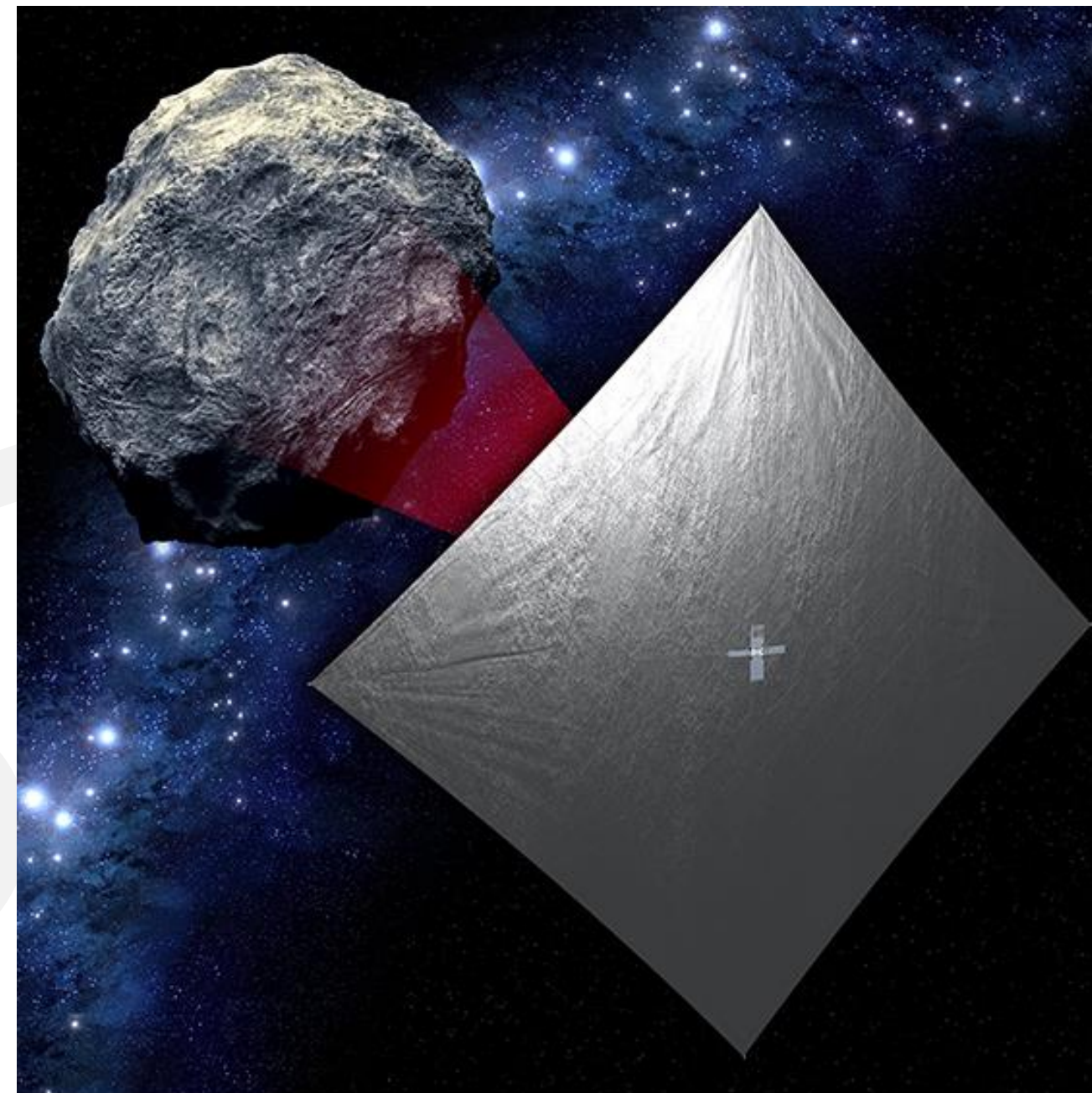


Credit: NASA

NEA Scout

- National Aeronautics and Space Administration, NASA
- Visit near-Earth asteroid 1991 VG
- Spacecraft mass: 14 kg (6U CubeSat)
- Sail size: 9 x 9 m²

Solar sailing... let's start a new timeline!

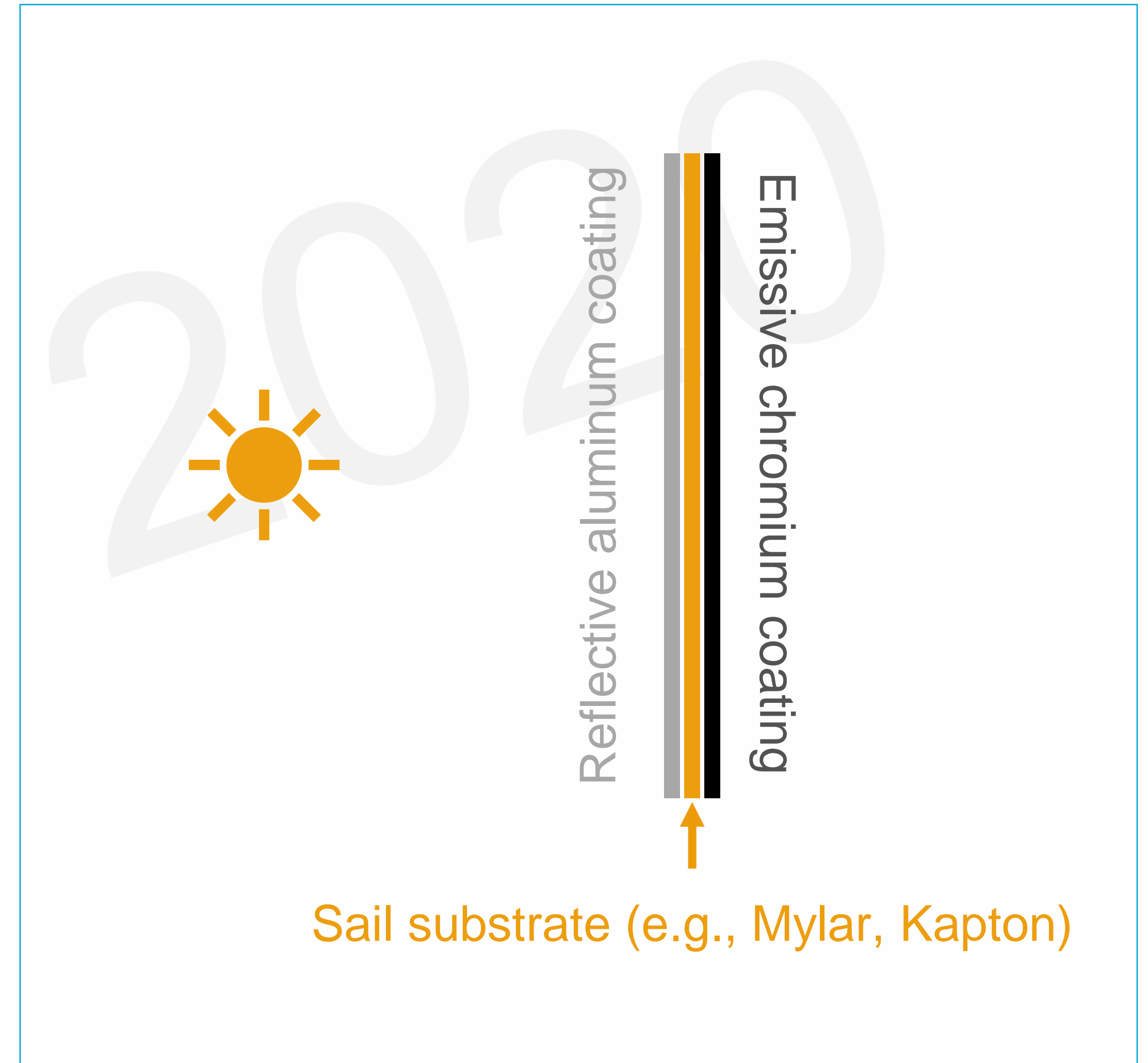
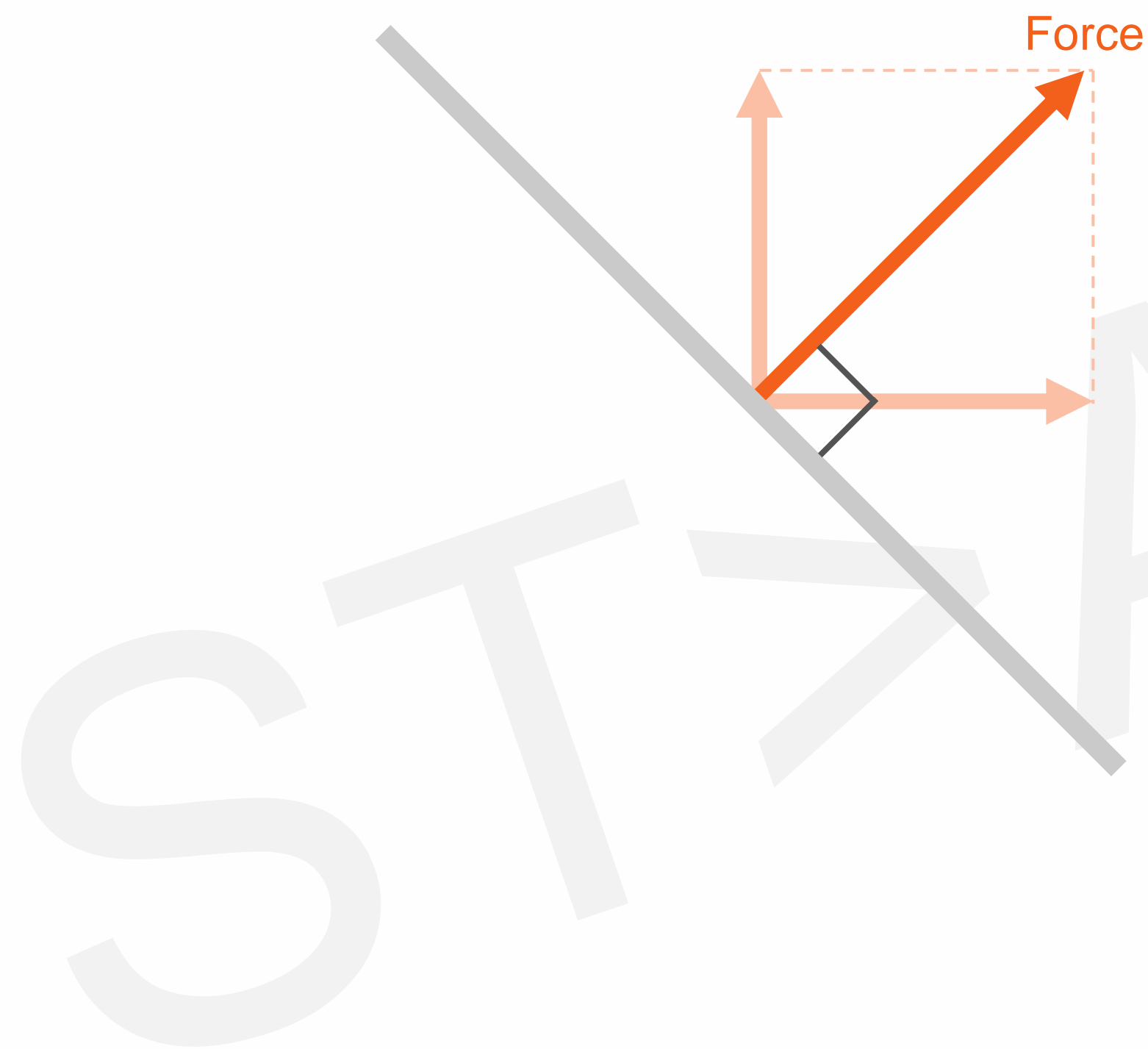


Credit: NASA

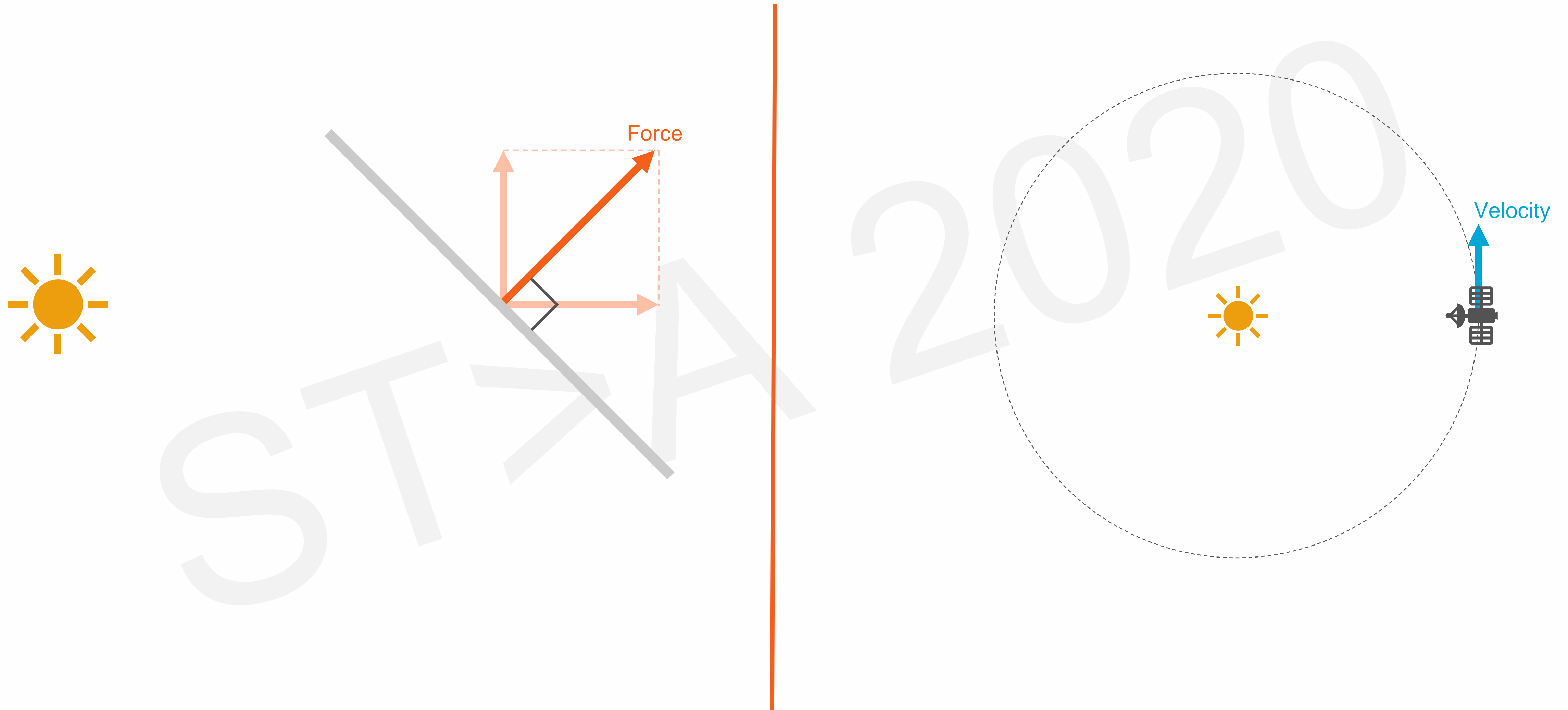
NEA Scout

- National Aeronautics and Space Administration, NASA
- Visit near-Earth asteroid 1991 VG
- Spacecraft mass: 14 kg (6U CubeSat)
- Sail size: 9 x 9 m²
- **First scientific solar-sail mission**

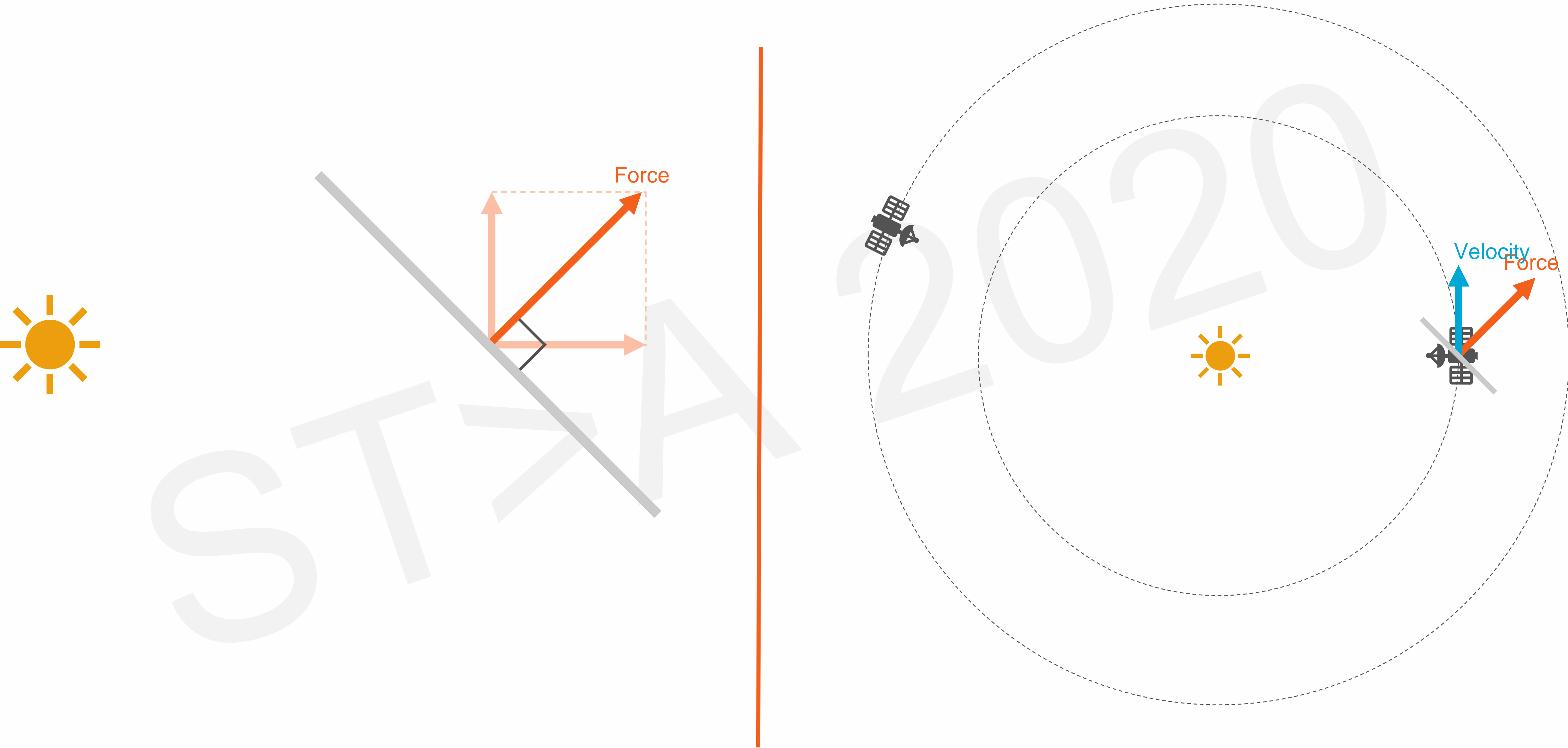
Solar sailing – how does it work?



Solar sailing – how does it work?



Solar sailing – how does it work?

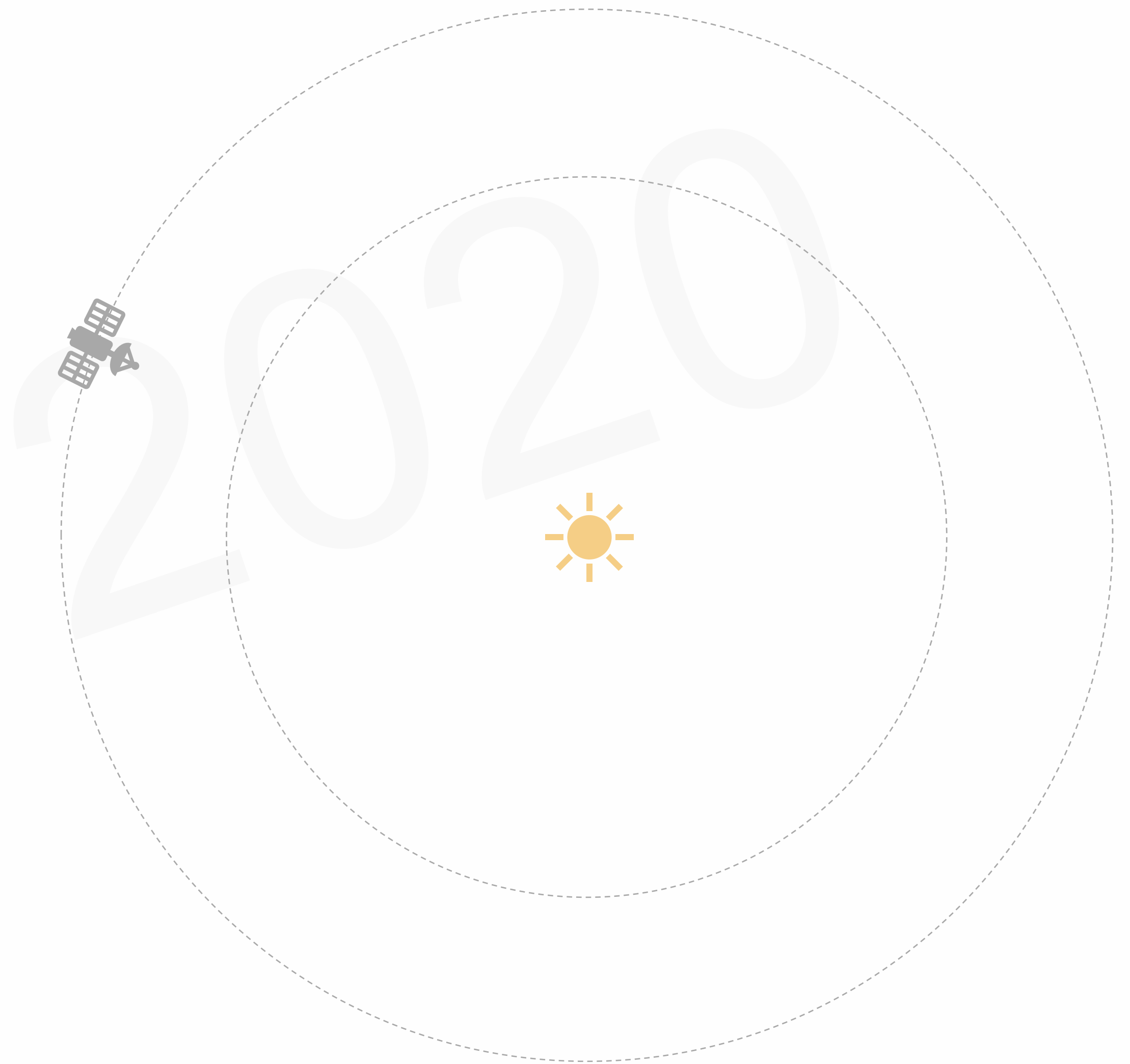


Solar sailing – how does it work?

Quiz question

Do you think it is also possible to use solar-sail propulsion to transfer the spacecraft to an orbit **closer** to the Sun?

- a) Yes
- b) No



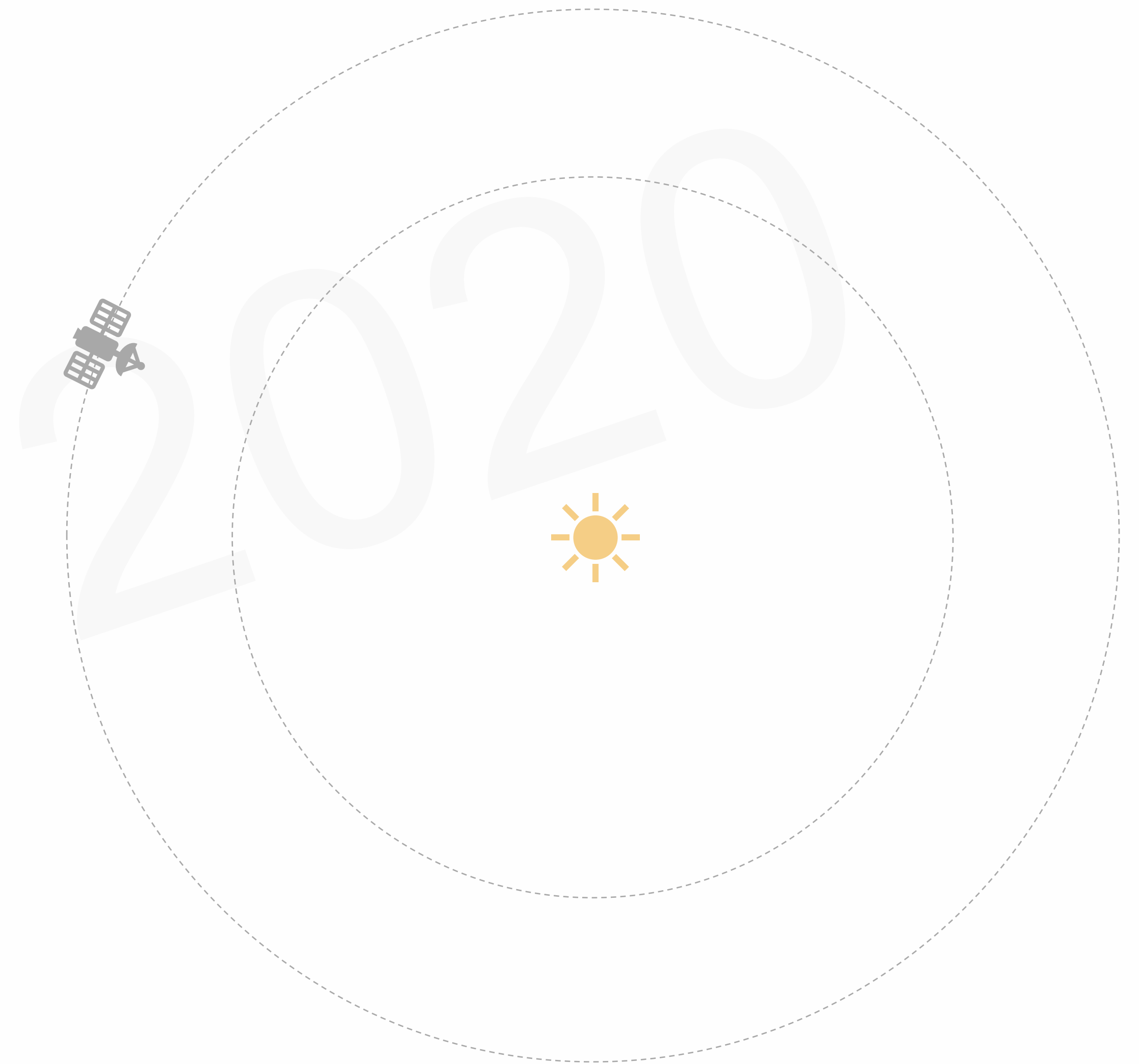
Solar sailing – how does it work?

Quiz question

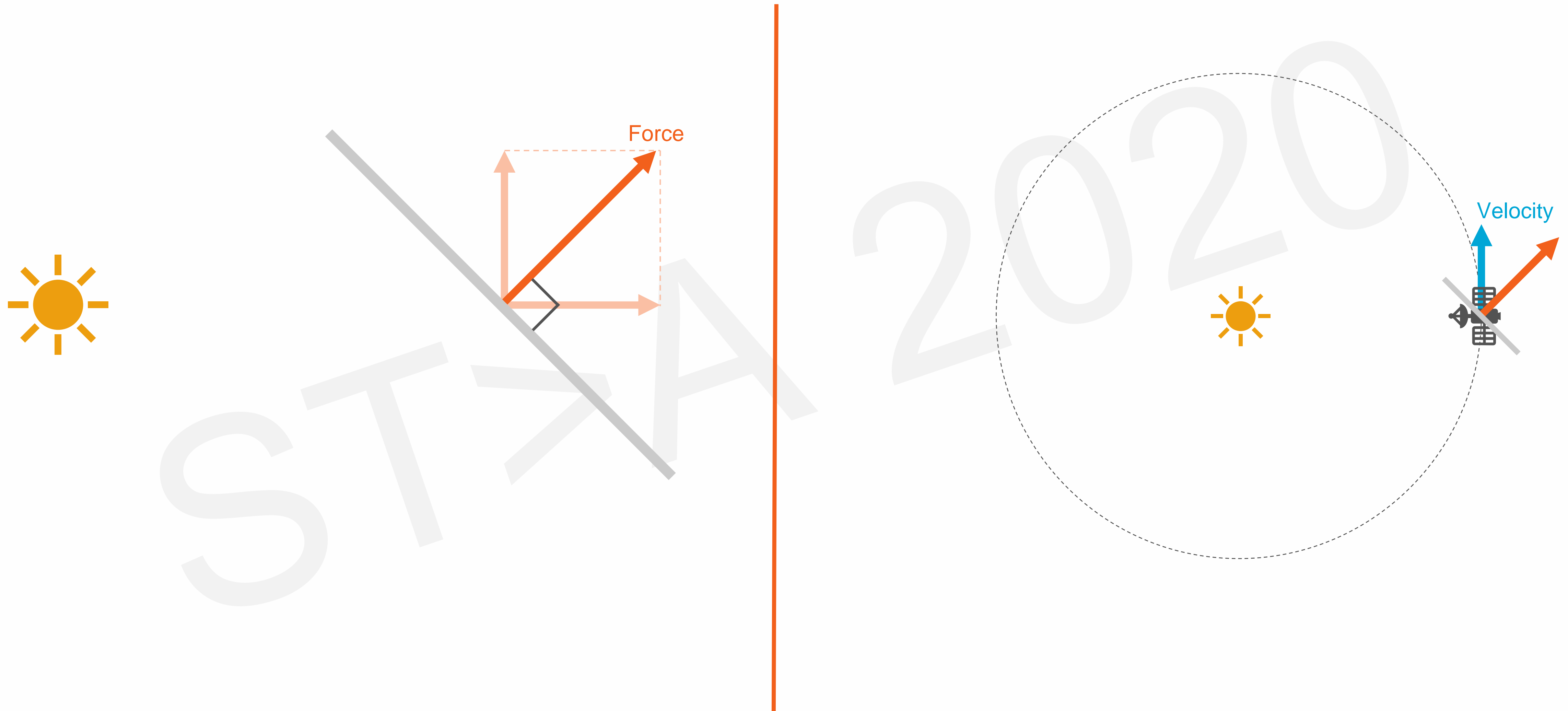
Do you think it is also possible to use solar-sail propulsion to transfer the spacecraft to an orbit **closer** to the Sun?

a) Yes

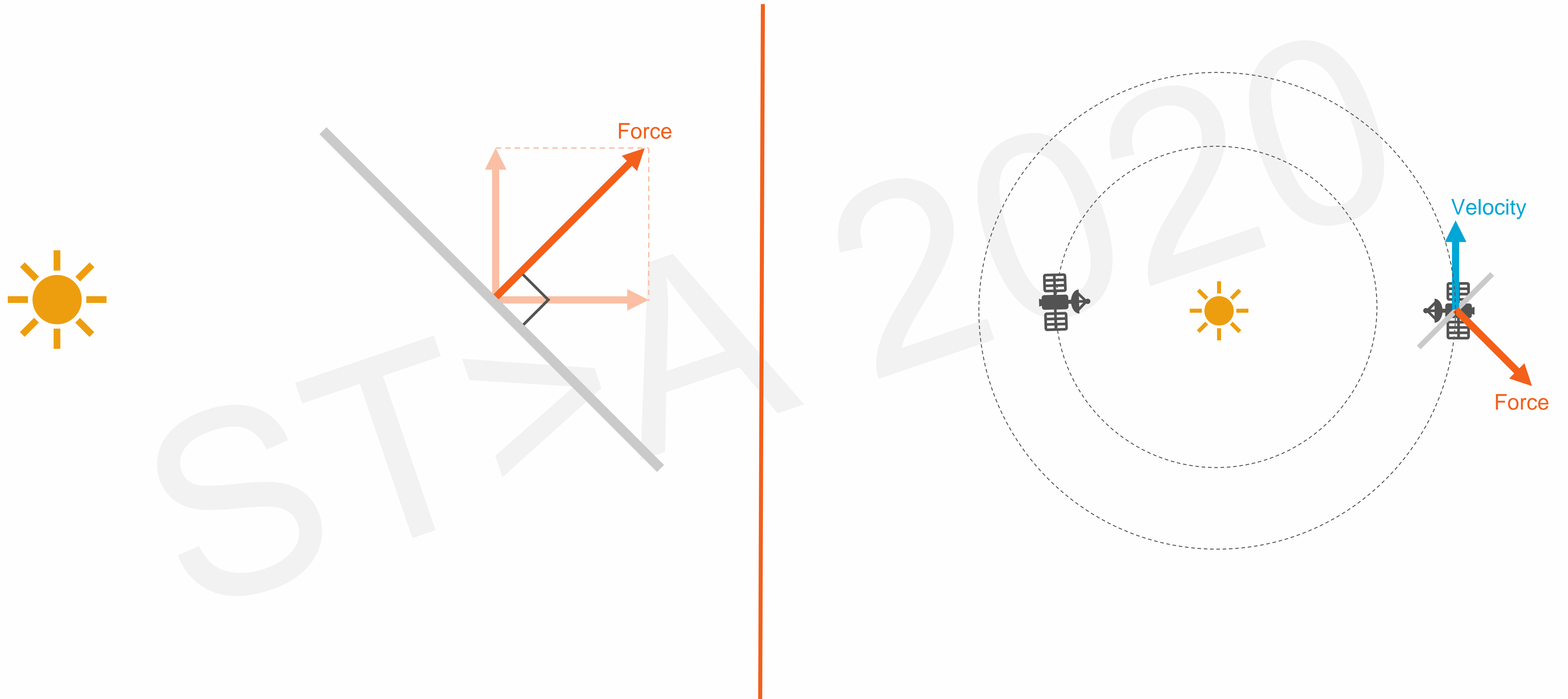
b) No



Solar sailing – how does it work?

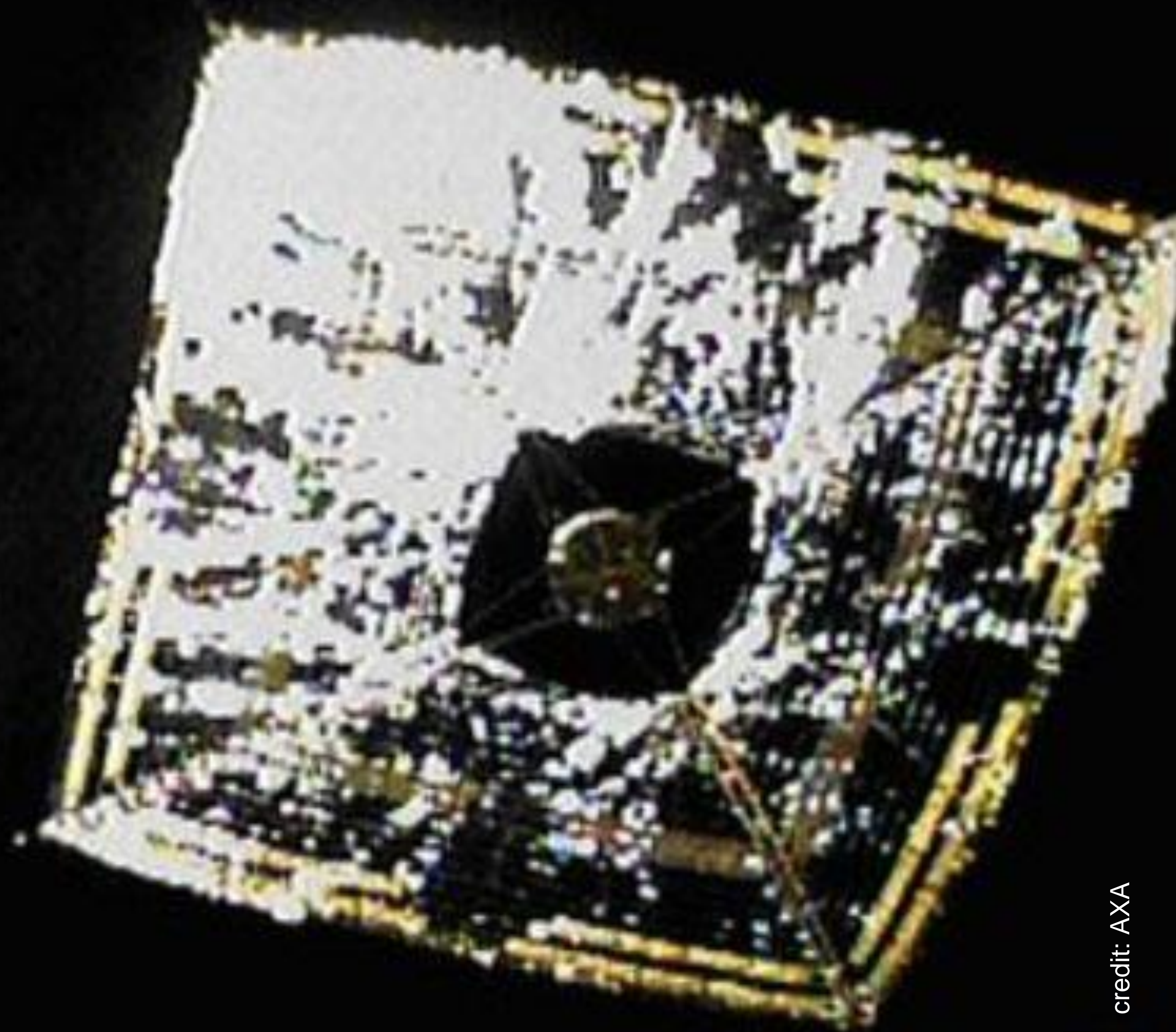


Solar sailing – how does it work?



Solar sailing - unique selling point

- No need for propellant
- Never run out of propellant
- Never-ending thrust capabilities



End of video