

BREAKTHROUGH PRIZES

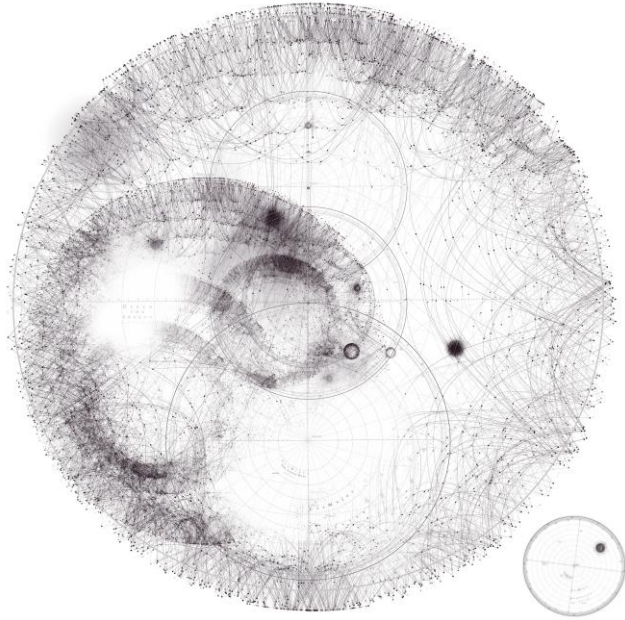
BREAKTHROUGH INITIATIVES



**BREAKTHROUGH
PRIZE**

BREAKTHROUGH PRIZE





LIFE IN THE
UNIVERSE

BREAKTHROUGH
INITIATIVES

BREAKTHROUGH INITIATIVES



BREAKTHROUGH
INITIATIVES

BREAKTHROUGH
INITIATIVES

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INITIATIVES

BREAKTHROUGH
INITIATIVES



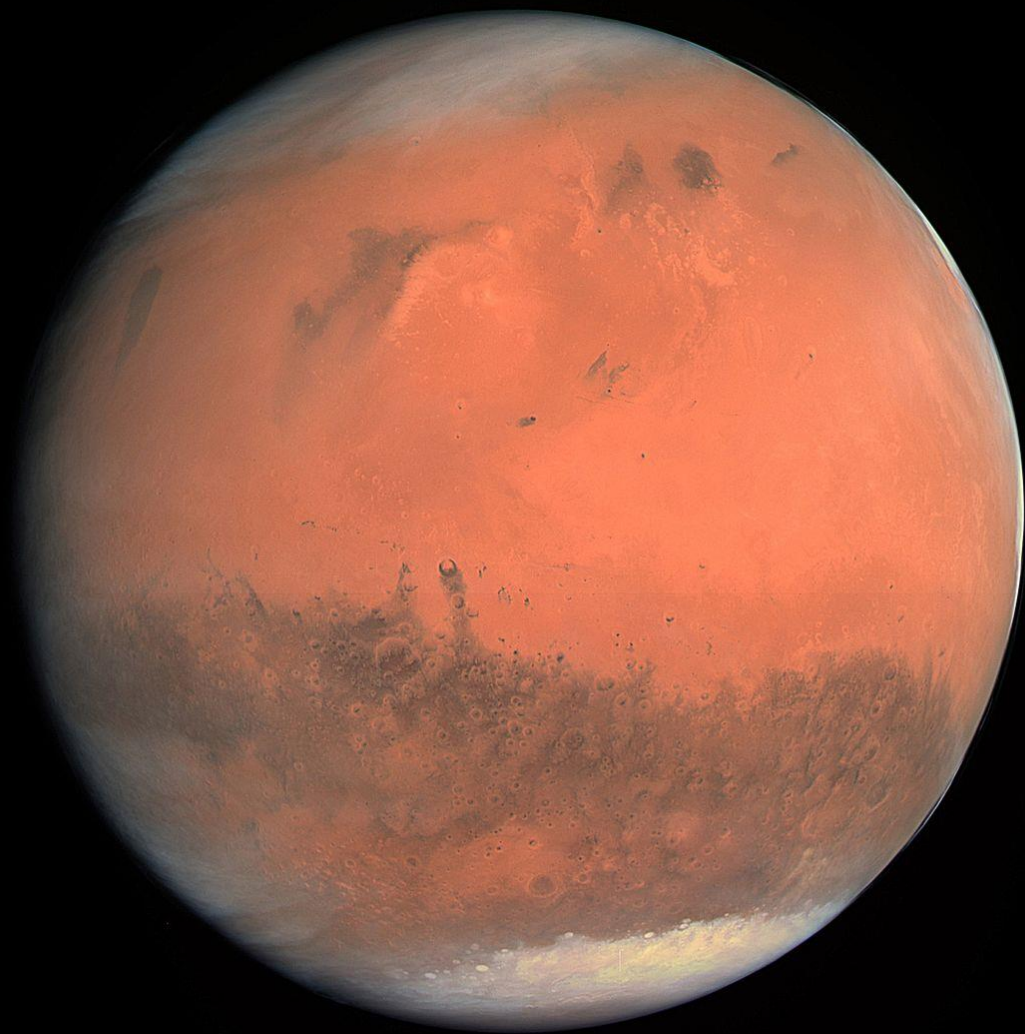
IS THERE OTHER LIFE IN THE UNIVERSE?

CAN WE TRAVEL BETWEEN STARS?

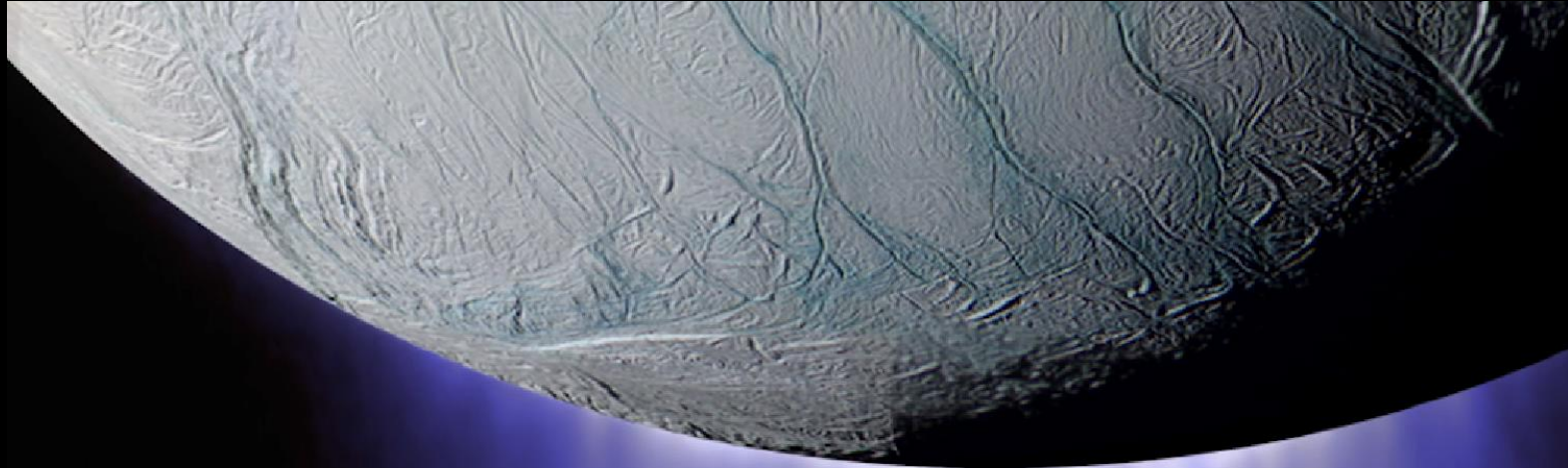
IS THERE INTELLIGENT LIFE ELSEWHERE?



BREAKTHROUGH
WATCH



ENCELADUS



Artist's concept





Alpha Centauri A



Sun



Alpha Centauri B



Proxima
Centauri



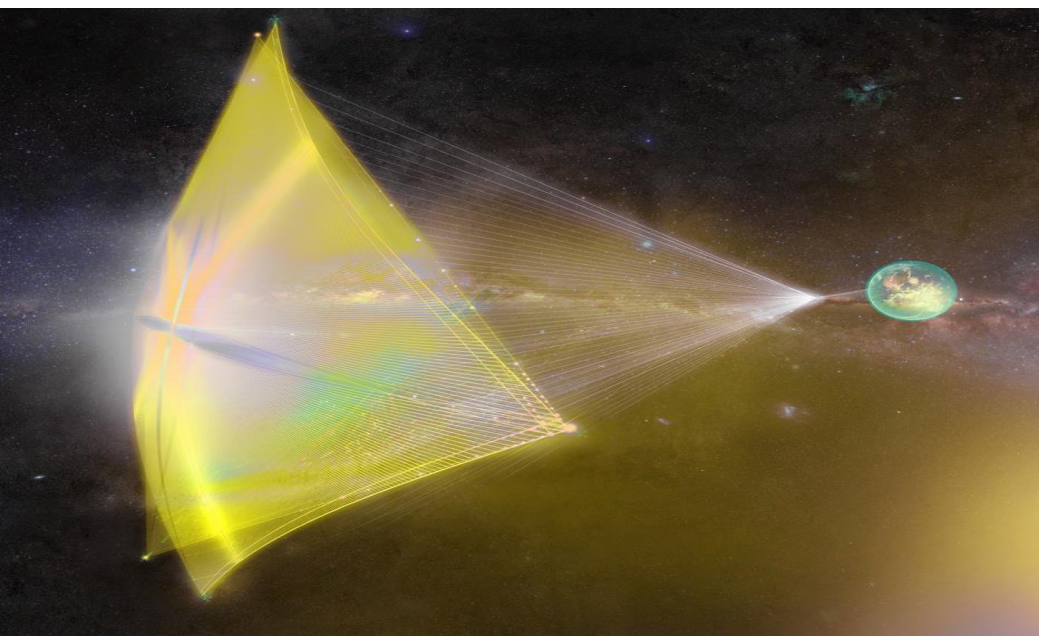




A composite image of Earth from space at night. The bottom half shows the Earth's horizon with a blue glow and numerous yellow and orange city lights. The top half shows a dark, starry sky with a blue nebula or galaxy structure. The text "BREAKTHROUGH STARSHOT" is centered in the middle of the image.

BREAKTHROUGH
STARSHOT

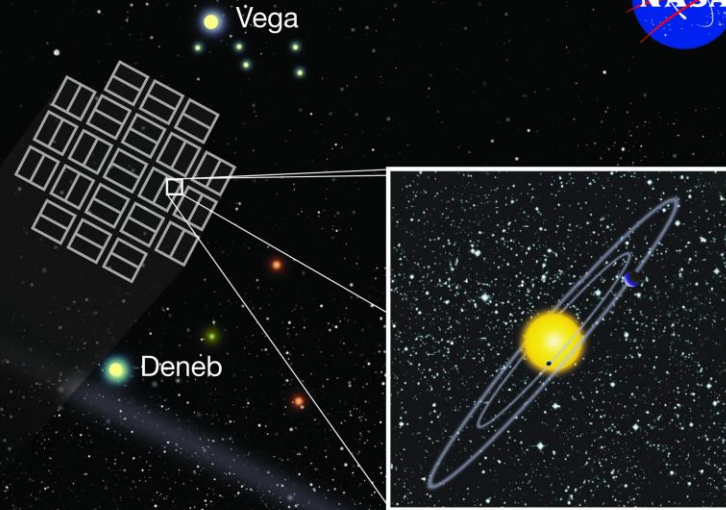
BREAKTHROUGH STARSHOT





Kepler

NASA's First Mission Capable of Finding Earth-size & Smaller Planets

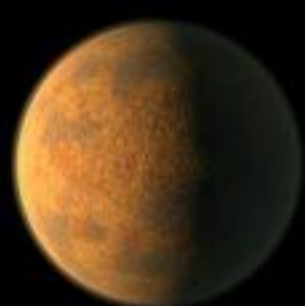


WARNING: OBJECTS IN THIS RENDITION APPEAR LARGER AND CLOSER TOGETHER THAN THEY ARE IN REALITY.

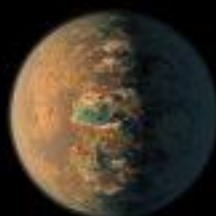
TRAPPIST-1 System



b



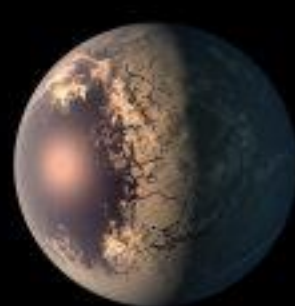
c



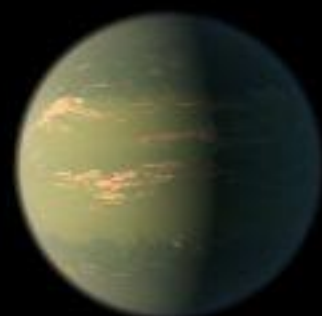
d



e



f



g



h

Orbital Period
days

1.51 days

2.42 days

4.05 days

6.10 days

9.21 days

12.35 days

~20 days

Distance to Star
Astronomical Units (AU)

0.011 AU

0.015 AU

0.021 AU

0.028 AU

0.037 AU

0.045 AU

~0.06 AU

Planet Radius
relative to Earth

1.09 R_{earth}

1.06 R_{earth}

0.77 R_{earth}

0.92 R_{earth}

1.04 R_{earth}

1.13 R_{earth}

0.76 R_{earth}

Planet Mass
relative to Earth

0.85 M_{earth}

1.38 M_{earth}

0.41 M_{earth}

0.62 M_{earth}

0.68 M_{earth}

1.34 M_{earth}

—

Solar System Rocky Planets



Mercury



Venus



Earth



Mars

Orbital Period
days

87.97 days

224.70 days

365.26 days

686.98 days

Distance to Star
Astronomical Units (AU)

0.387 AU

0.723 AU

1.000 AU

1.524 AU

Planet Radius
relative to Earth

0.38 R_{earth}

0.95 R_{earth}

1.00 R_{earth}

0.53 R_{earth}

Planet Mass
relative to Earth

0.055 M_{earth}

0.815 M_{earth}

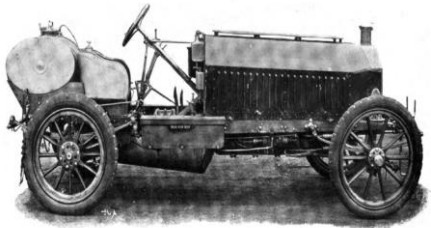
1.00 M_{earth}

0.339 M_{earth}

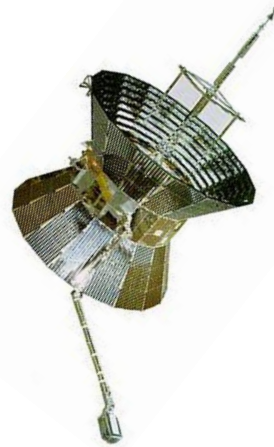


Is there a Moore's law for speed?

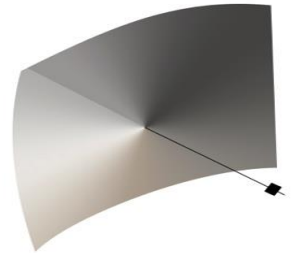
Napier Racer
1905



Helios 2
1976



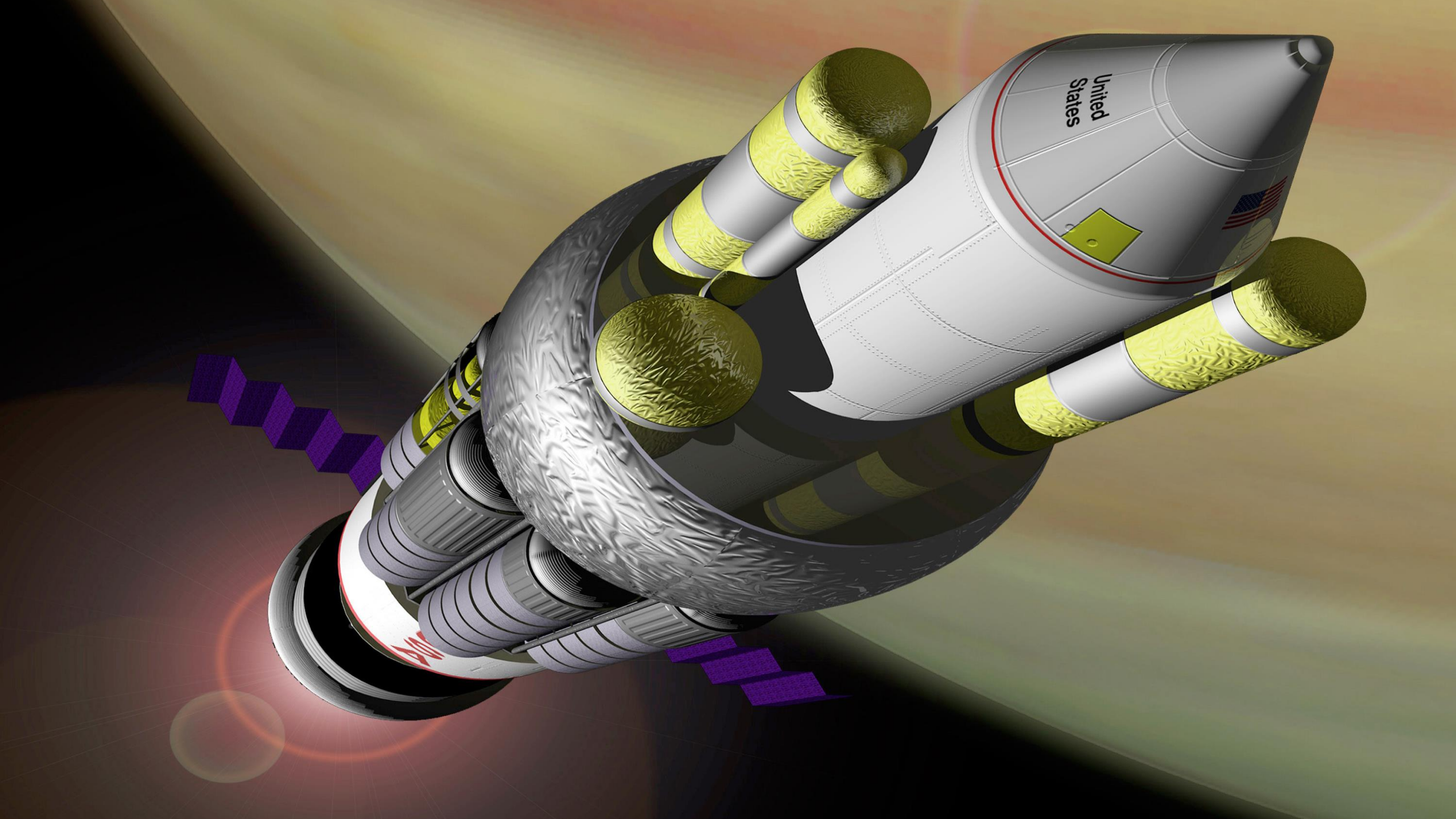
?



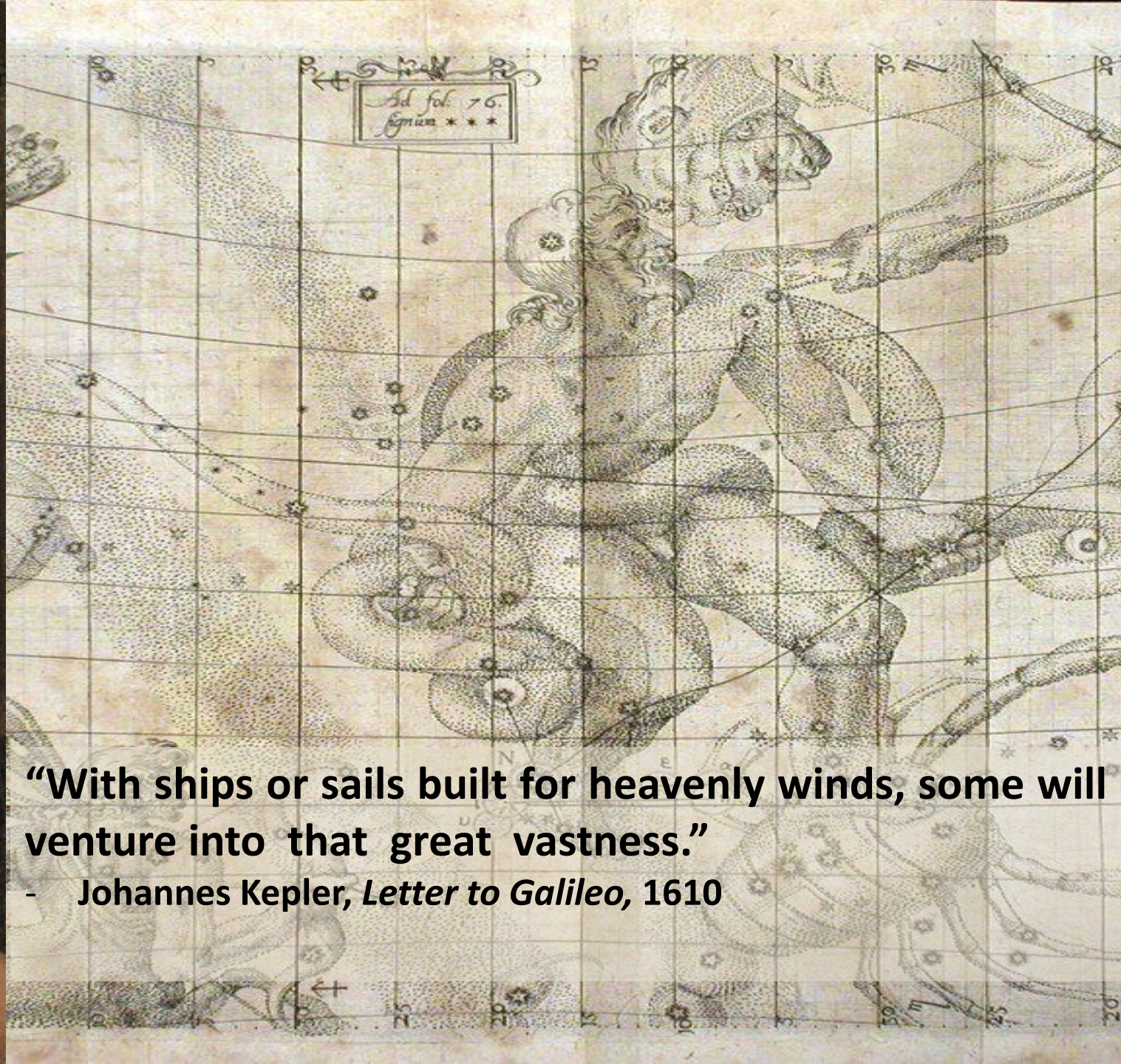
1000 times faster within 100 years

1000 times faster within ? years



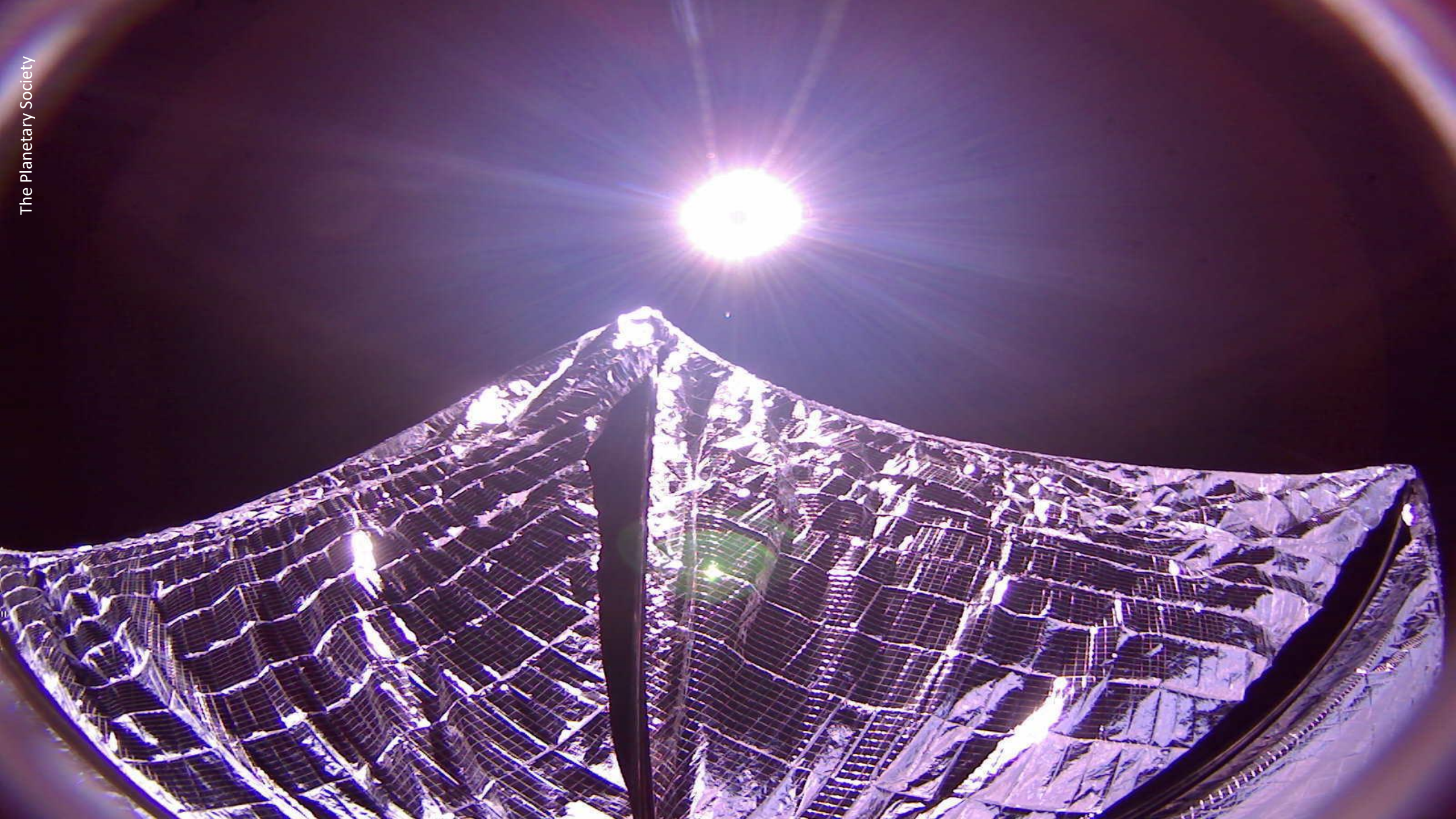




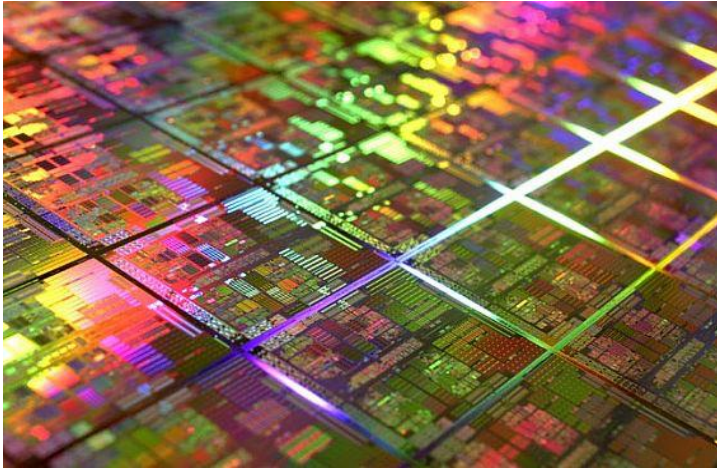


“With ships or sails built for heavenly winds, some will venture into that great vastness.”

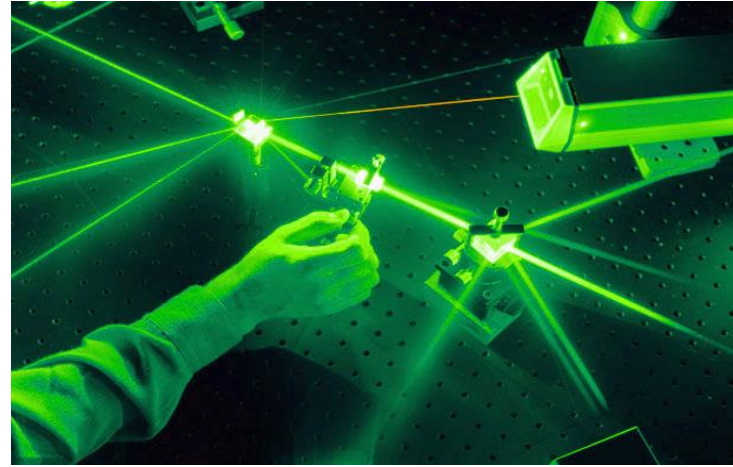
- Johannes Kepler, *Letter to Galileo*, 1610



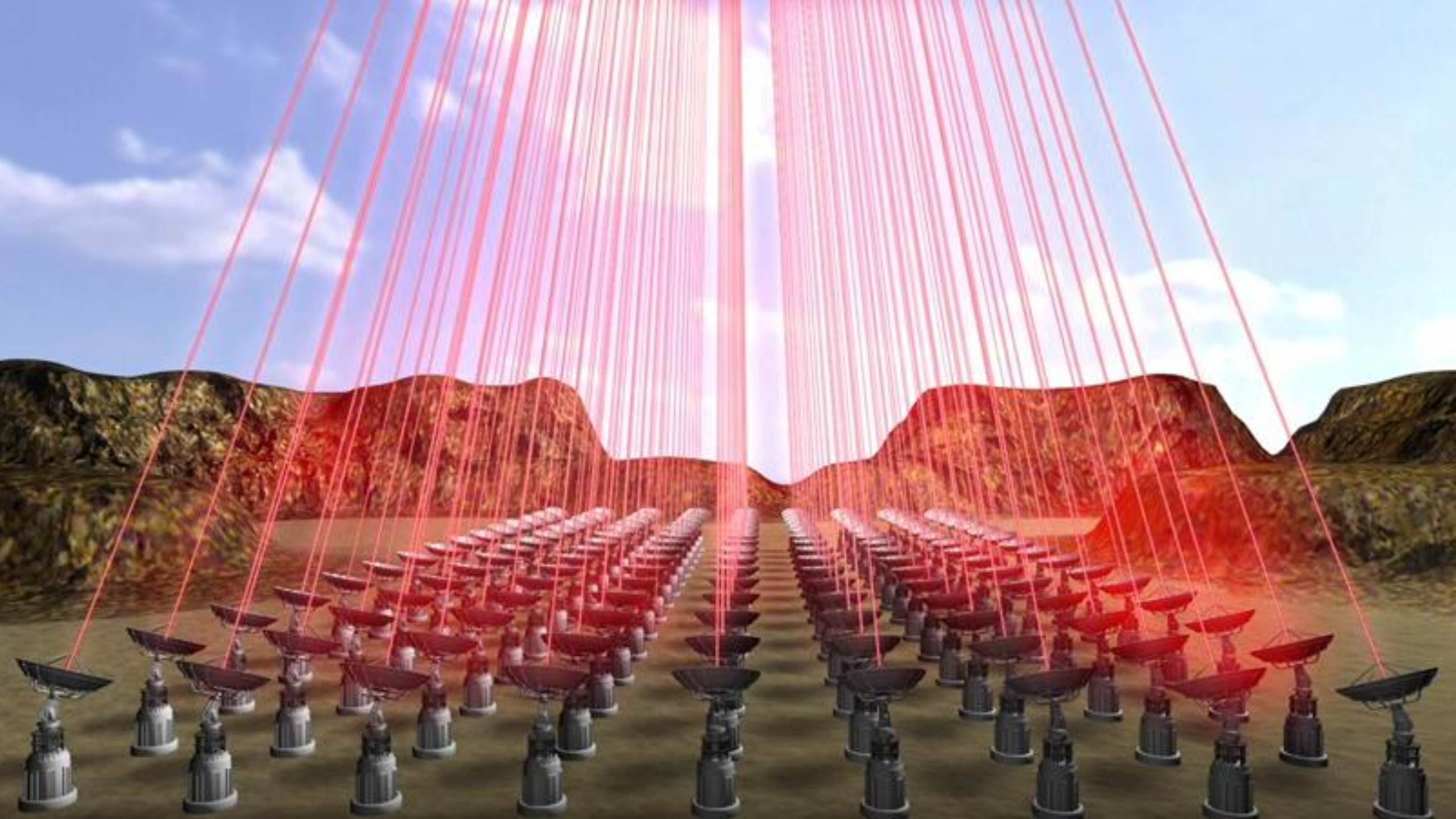
Two transformative trends



Microelectronics

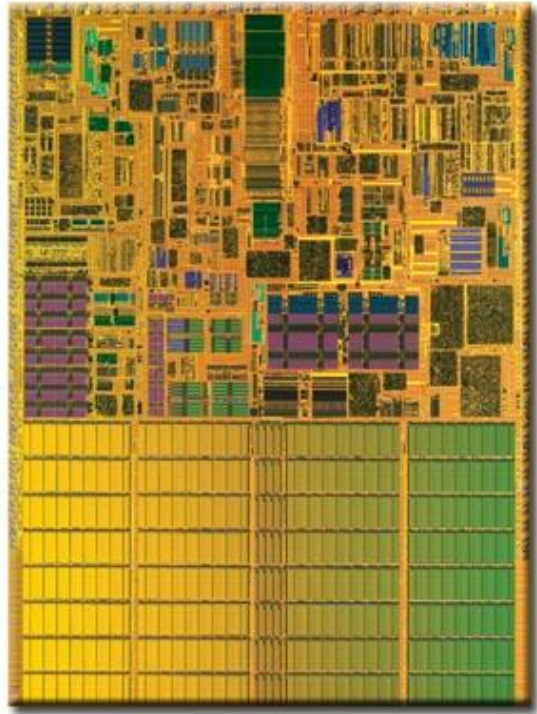


Photonics



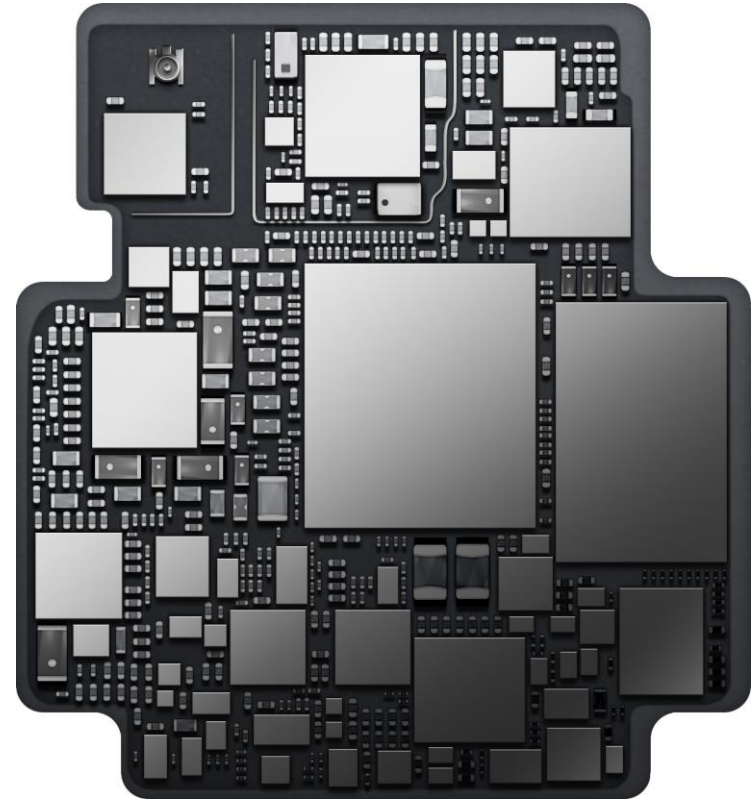


StarChip size



← 15mm →

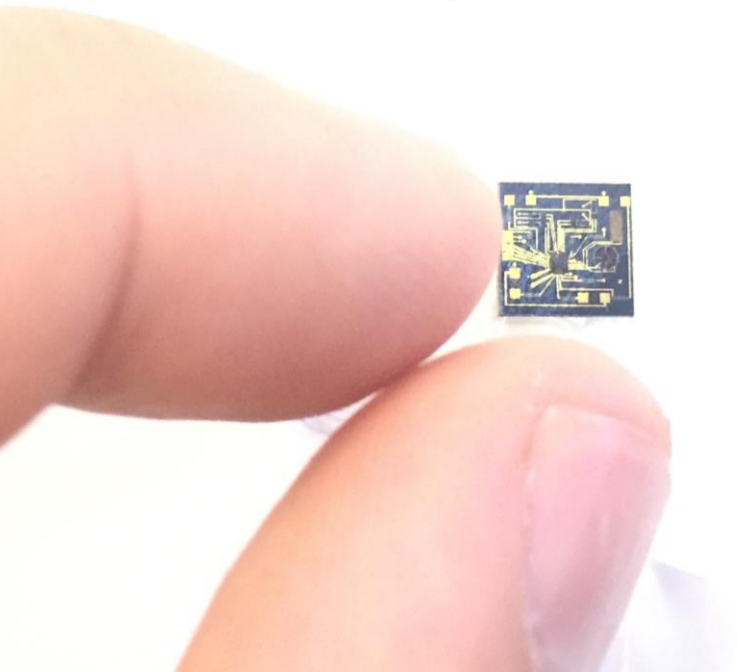
StarChip



← 25mm →

Apple Watch chip

BREAKTHROUGH STARSHOT

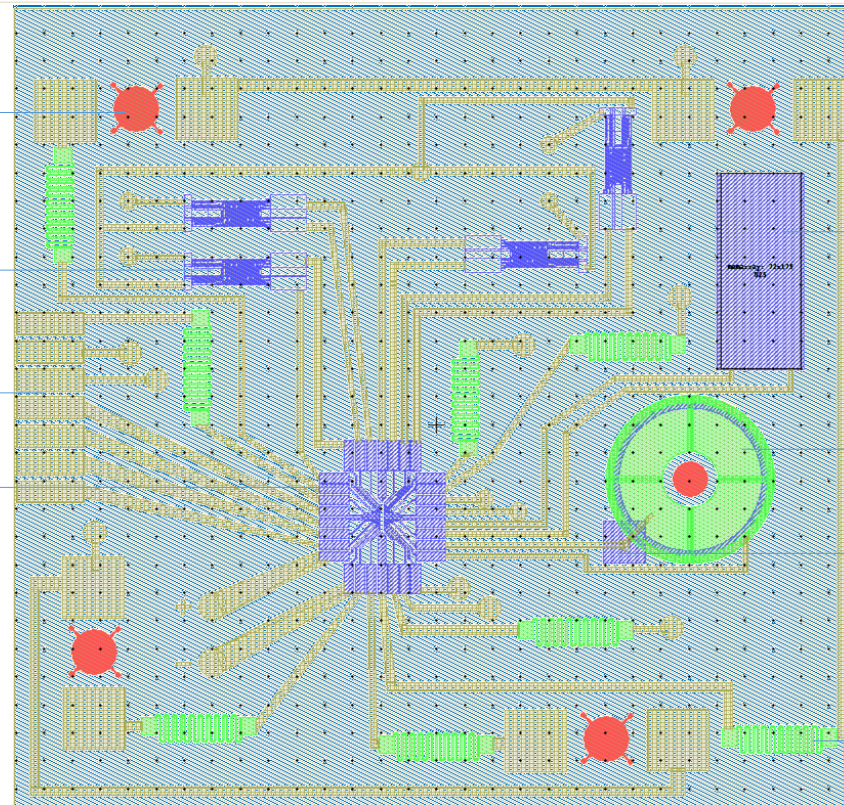


Photon Thruster
(4 pl.)

NanEye Camera
(4 pl.)

Programming
Breakout Pins

Processor IC



Si_3N_4 Substrate

Memory

1W Laser
Communications
Diode

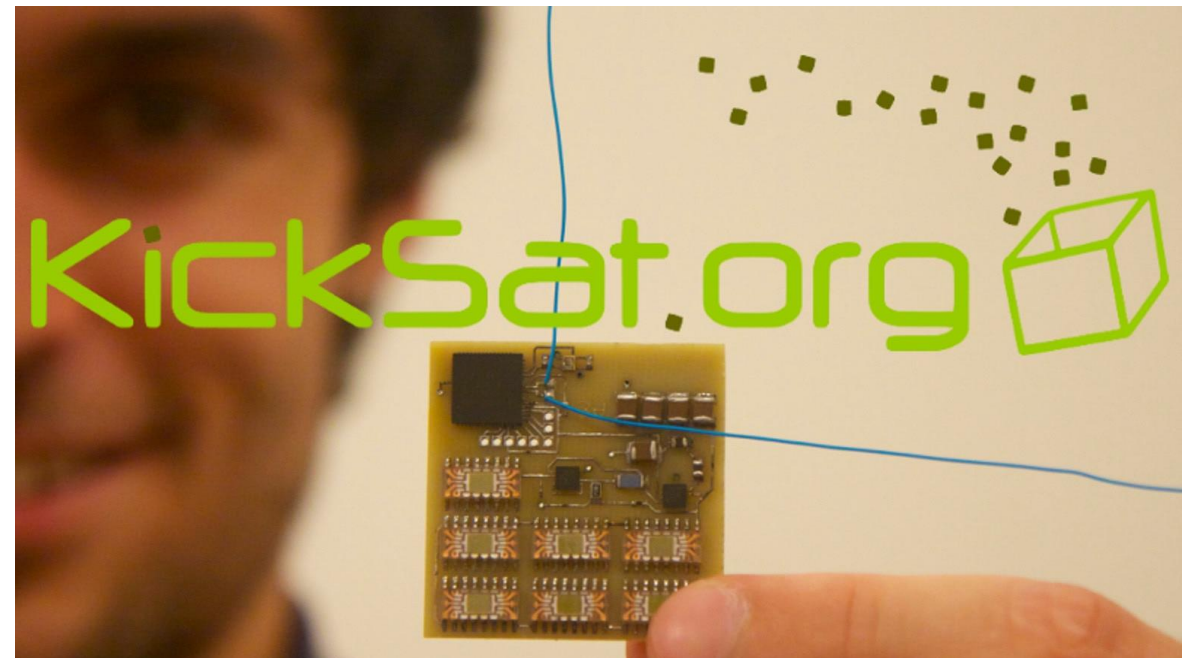
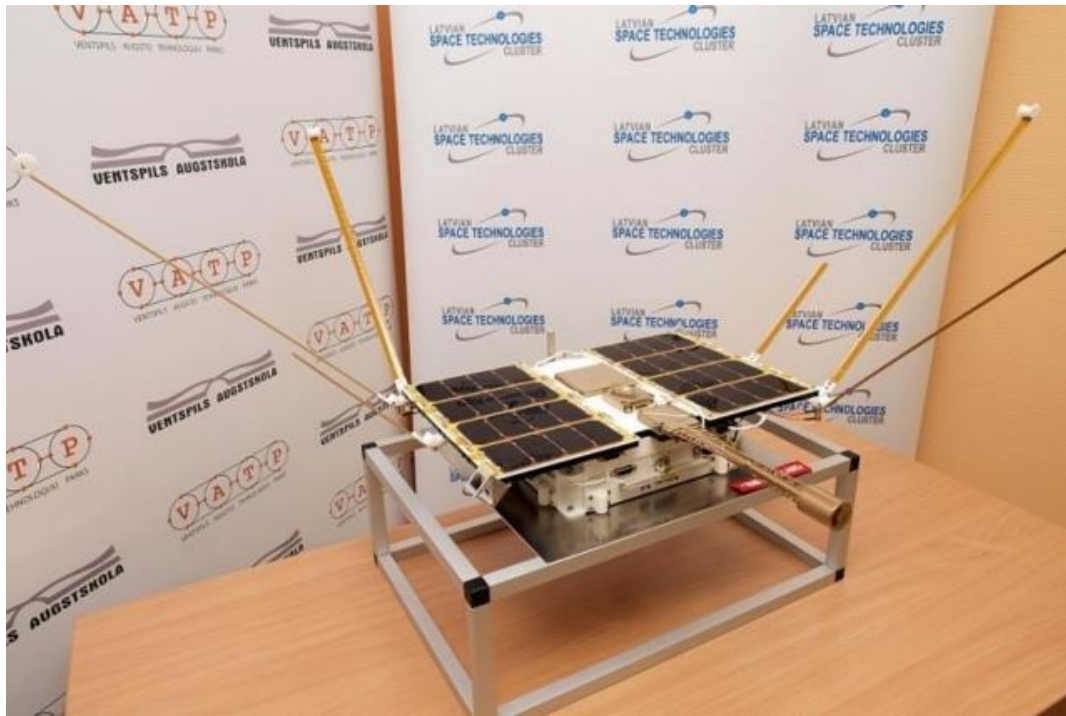
Via for power amplifier
from Betavoltaic source on
reverse

Discrete Ti
serpentine resistor
(8 pl)

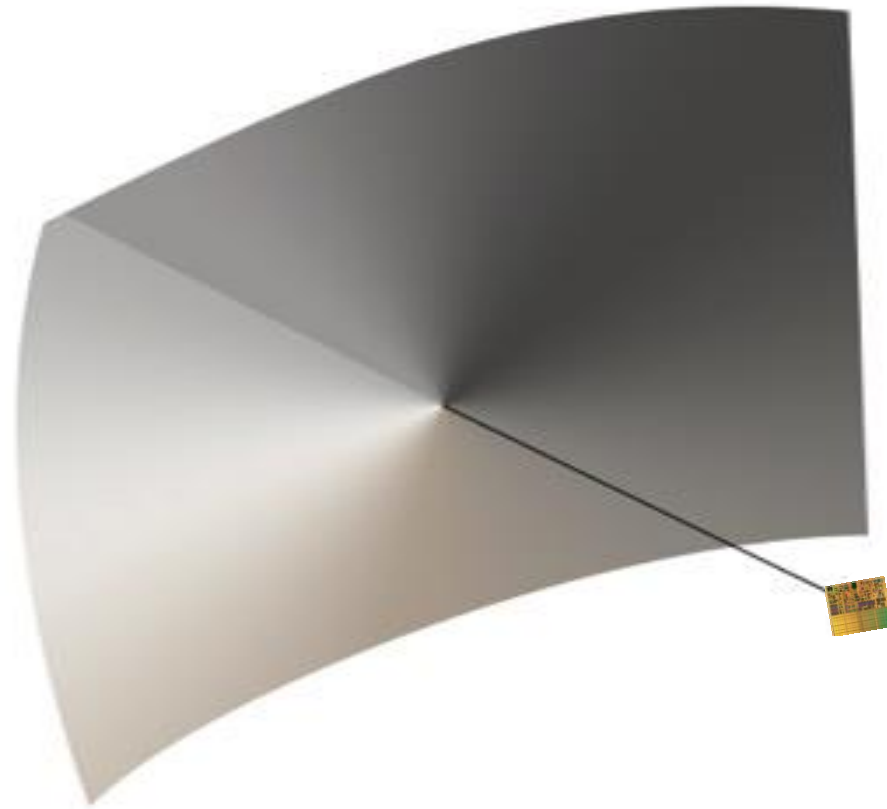
VENTA SATELLITE (LATVIA)

AND SPRITE NANOSAT (CORNELL)

Launched 23 Jun, 2017



StarChip + Lightsail: Nanocraft



CIRCA 2067



A view of Earth from space at night. The Earth's surface is visible, showing city lights and the Milky Way galaxy. The text "BREAKTHROUGH LISTEN" is overlaid in the center.

**BREAKTHROUGH
LISTEN**



**GREEN BANK, WEST VIRGINIA,
USA
100 METER RADIO TELESCOPE**

PARKES, NEW SOUTH WALES, AUSTRALIA 64 METER RADIO TELESCOPE



AUTOMATED PLANET FINDER OPTICAL TELESCOPE LICK OBSERVATORY CALIFORNIA, USA



GUIZHOU, CHINA
500 METER RADIO
TELESCOPE



**JODRELL BANK, UK
LOVELL RADIO TELESCOPE**



**SQUARE KILOMETER ARRAY-MEERKAT,
KAROO, SOUTH AFRICA
RADIO TELESCOPE**



$$N_H = 1$$
$$N_{He} = 0.0052$$

$$\frac{A_H}{A_{He}} = \frac{1}{2}$$
$$A_{He} = 2$$

$$M_{He} = \frac{1}{4}$$
$$M_{He} = 4$$

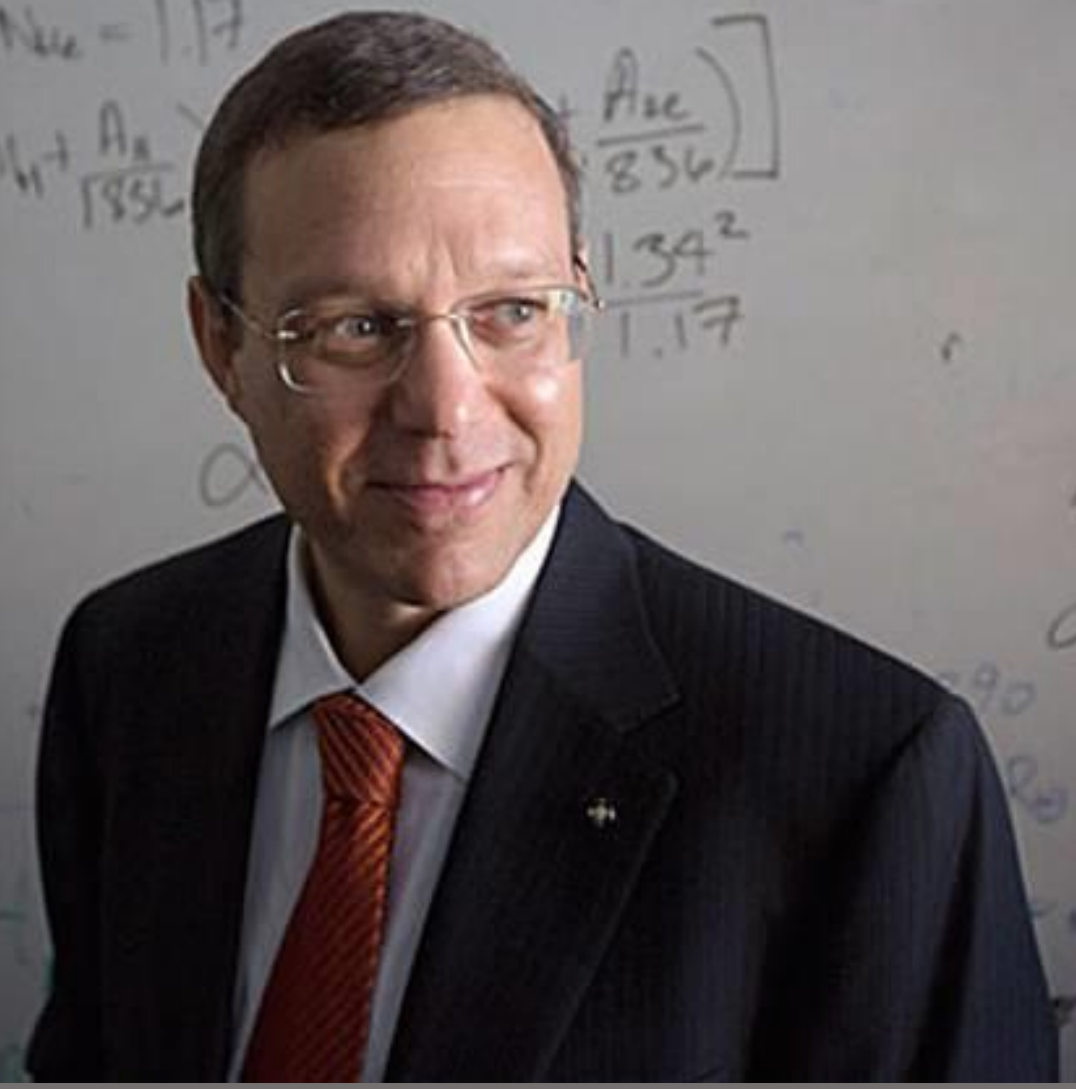
$$\alpha = \frac{\sqrt{3x^2 + \frac{3x}{2}}}{4}$$
$$\alpha = \frac{4}{\sqrt{19.5x}} = \frac{4}{\sqrt{2}x}$$

$$n_{He} = A_H N_H + A_{He} N_{He} = 1.17$$

$$\rho_g = \mu_p \left[N_H \left(N_H + \frac{A_{He}}{856} \right) + \frac{A_{He}}{856} \right]$$
$$\sim 1.34 \mu_p$$
$$\frac{1.34^2}{1.17}$$

$$N_H \left[1 + \frac{1}{2} \left(\frac{1}{\sqrt{2}} \right) \right]$$

$$\alpha = \frac{1}{\sqrt{x^2 + \frac{x(1+x)}{2}}}$$



Fast Radio Bursts from Extragalactic Light Sails

Manasvi Lingam^{1,2} and Abraham Loeb²

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[Number 2](#)



