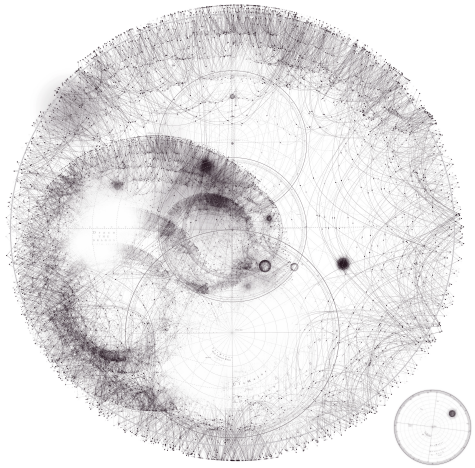
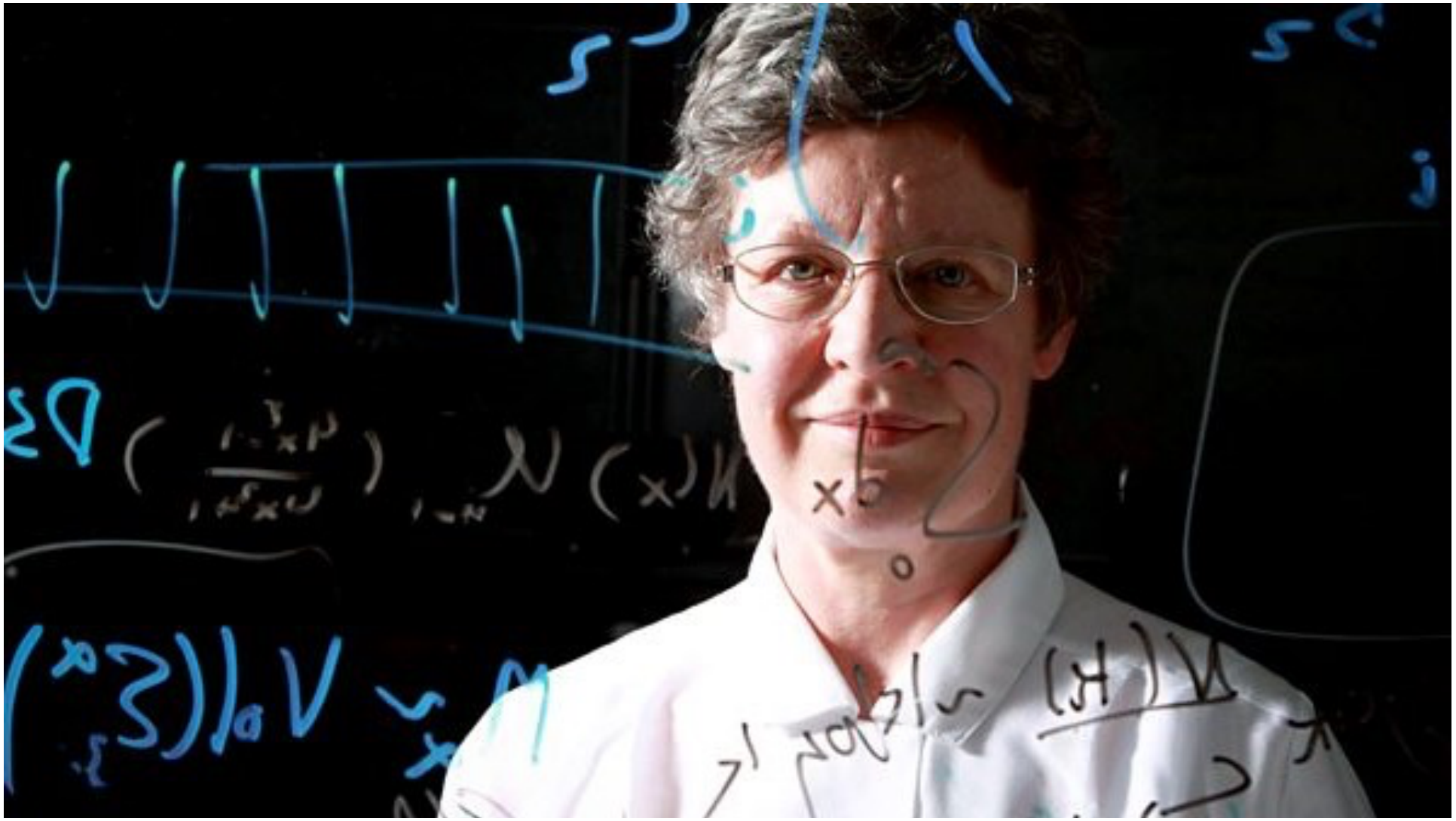


BREAKTHROUGH PRIZES
BREAKTHROUGH INITIATIVES

Dr. S. PETE WORDEN - CHAIRMAN, BREAKTHROUGH PRIZE FOUNDATION -
PETE@BREAKTHROUGHPRIZE.ORG


BREAKTHROUGH
PRIZE

BREAKTHROUGH
PRIZE



BREAKTHROUGH JUNIOR CHALLENGE

- Make a short film about a big idea in science or math
- Win a $250,000 scholarship and a brand new science lab for your school
- Your favorite teacher get's $50,000
- Join the superstars of science – prize presented at a live televised ceremony
- www.breakthroughjuniorchallenge.org

KHAN ACADEMY

NATIONAL GEOGRAPHIC CHANNEL

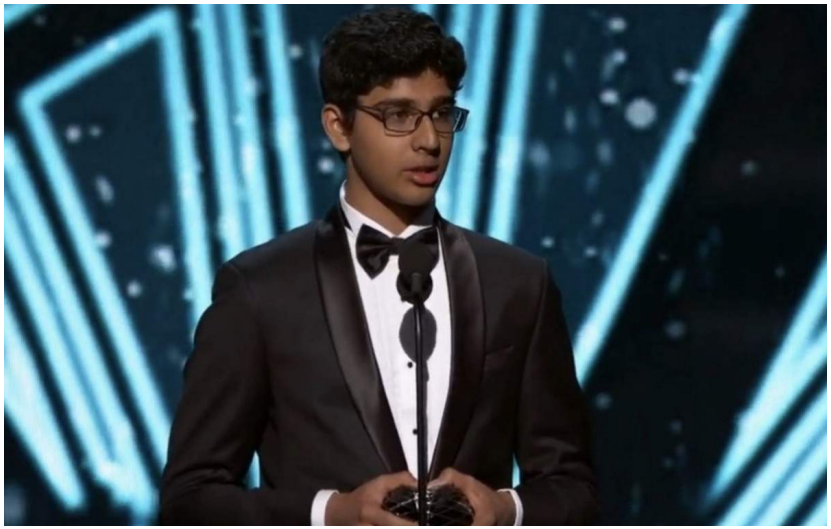
CSH Cold Spring Harbor Laboratory

Ryan Chester 18, USA, 2016

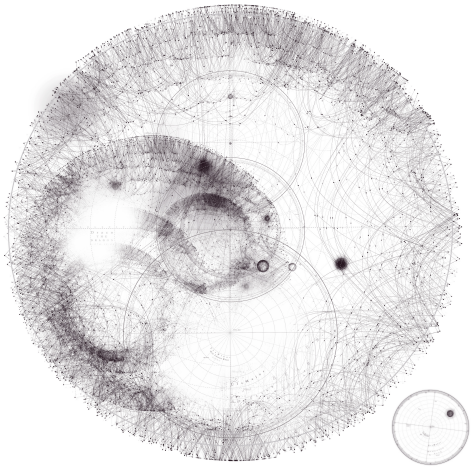
Deanna See 17, Singapore, 2017

Antonella Masini, 18, Peru, 2017

Hillary Diane Andales, 18, Philippines, 2018



Samay Godika, 16, India, 2019



LIFE IN THE UNIVERSE

BREAKTHROUGH INITIATIVES

Dr. S. PETE WORDEN - CHAIRMAN, BREAKTHROUGH PRIZE FOUNDATION -
PETE@BREAKTHROUGHPRIZE.ORG

IS THERE OTHER LIFE IN THE UNIVERSE?

IS THERE INTELLIGENT LIFE ELSEWHERE?

CAN WE TRAVEL BETWEEN STARS?


BREAKTHROUGH
INITIATIVES
BREAKTHROUGH
INITIATIVES
BREAKTHROUGH
INITIATIVES
BREAKTHROUGH
INITIATIVES
intel


BREAKTHROUGH
LISTEN


GREEN BANK, WEST VIRGINIA
© NRAO


PARKES, NEW SOUTH WALES
© CSIRO


APF,
CALIFORNIA
© Laurie Hatch

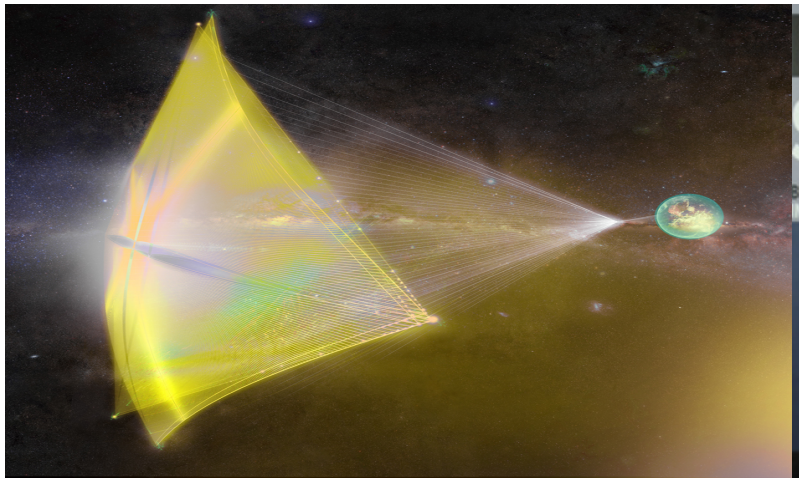

GUIZHOU, CHINA

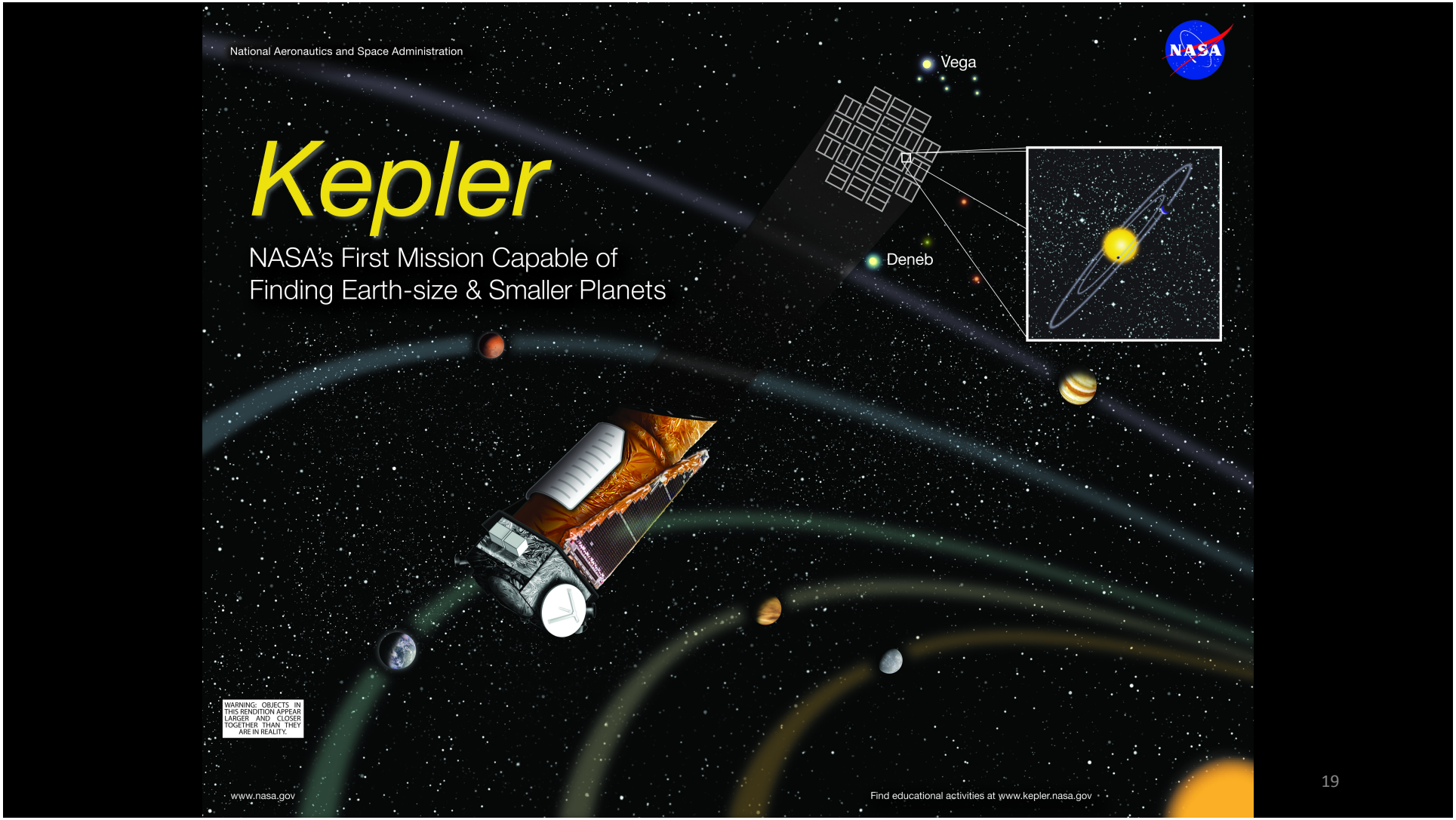

JODRELL BANK, UK

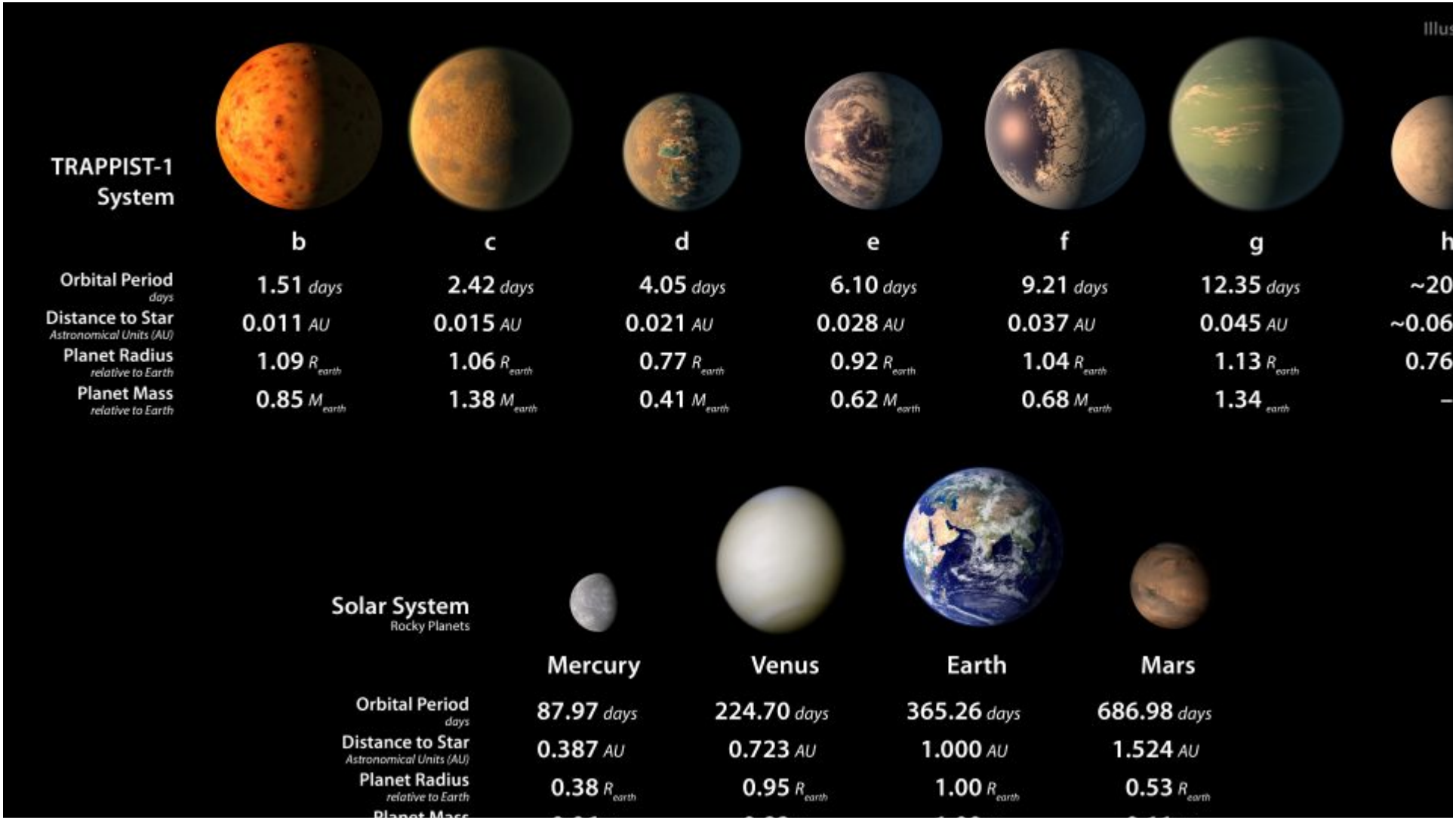

SKA-MeerKAT, Karoo, South Africa


BREAKTHROUGH
STARSHOT

BREAKTHROUGH
STARSHOT




National Aeronautics and Space Administration
Vega
Deneb
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.
www.nasa.gov
Find educational activities at www.kepler.nasa.gov

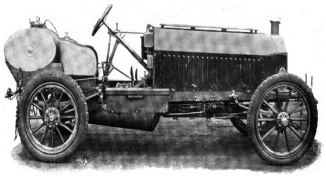

TRAPPIST-1 System
b
c
d
e
f
g
h
Orbital Period
days
1.51 days
2.42 days
4.05 days
6.10 days
9.21 days
12.35 days
~20
Distance to Star
Astronomical Units (AU)
0.011 AU
0.015 AU
0.021 AU
0.028 AU
0.037 AU
0.045 AU
~0.06
Planet Radius
relative to Earth
1.09 R earth
1.06 R earth
0.77 R earth
0.92 R earth
1.04 R earth
1.13 R earth
0.76
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 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


NASA


Starshot Objectives
1. Send a spacecraft to nearby stars with planets in the habitable zone within 5 Parsecs of earth
2. Take Science Data of star system focused on planets and beam data ~~back~~ to Earth
3. Launch within 30 years, at an affordable cost
4. Go FAST

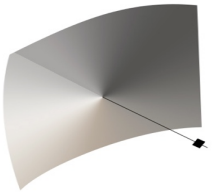
Is there a Moore's law for speed?

Napier Racer
1905



Helios 2
1976

?



1000 times faster within 100 years

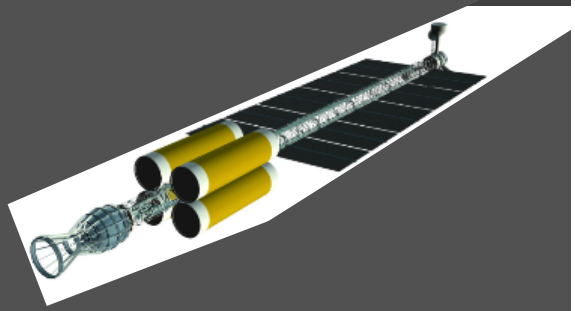
1000 times faster within ? years


Breakthrough Starshot
Pete Worden, Executive Director
Pete Klupar, Project Manager
STARSHOT ADVISORY COMMITTEE
Avi Loeb, Harvard, Chairman
Stephen Chu*, Stanford
Saul Perlmutter*, Berkeley
Freeman Dyson, Princetion
Ann Druyan
Lord Martin Rees, Astronomer Royal
Ed Turner, Princeton
Bruce Drain, Princeton
Mason Peck, Cornell
Phil Lubin, UCSB
Jim Benford, µWave Sciences
Lou Friedman, Planetary Society
* Nobel Laureate
Giacario Genta, Polytechnic Univ of Turin
Olivier Guyon, Univ of Arizona
Mae Jemison, Astronaut, 100 Year Starship
Geoff Landis, NASA Glenn
Kelvin Long, J. British Interplanetary Soc.
Zac Manchester, Harvard
Greg Matloff, NYC College of Technology
Kaya Nobuyuki, Kobe University
Kevin Parkin, Parkin Research
Bob Fugate, NM Tech (Emeritus)
Mark Spencer, AFRL/RDL
Wesley Green, SETA

Considered Many Different Approaches

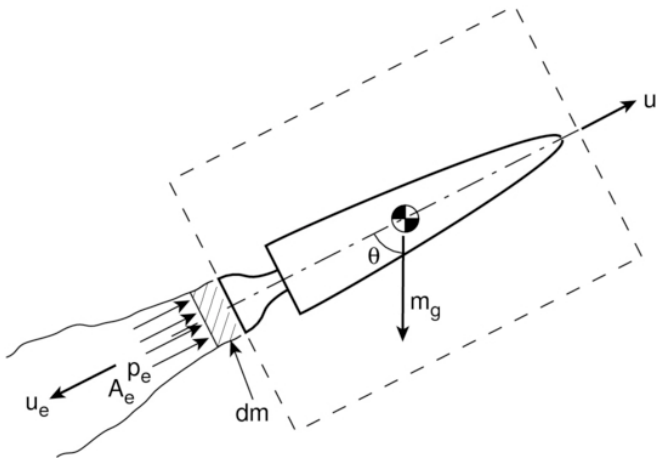
- Laser Thermal
- Solar Thermal
- Plasma Drive
- Solar Sail
- Laser Sail
- Fission
- Fusion
- Nuclear Pulse
- Antimatter
- Interstellar Ram Jets
- VASMIR
- E-Sail
- Von Neuman Machines

- Warp Drive
- Worm Holes
- Time Machines
- Zero Point Energy
- Casmir Effect
- Vacuum Energy
- Dark Energy
- EM Drive
- Pitch and Bias
- Diametric
- Disjunction
- Alcubierre
- Krasnikov tube



Chemical 13 MJ/Kg
Fission $82*10^6$ MJ/Kg
Fusion $350*10^6$ MJ/Kg
Antimatter $90*10^9$ MJ/Kg

ROCKET PROPULSION



$$(v_{bo} - v_o) = gI_{\text{sp}} \left[\ln \frac{m_o}{m_{bo}} - \frac{1}{R}(1 - \frac{m_{bo}}{m_o}) \right], \text{where}$$

g = gravity acceleration field at sea level

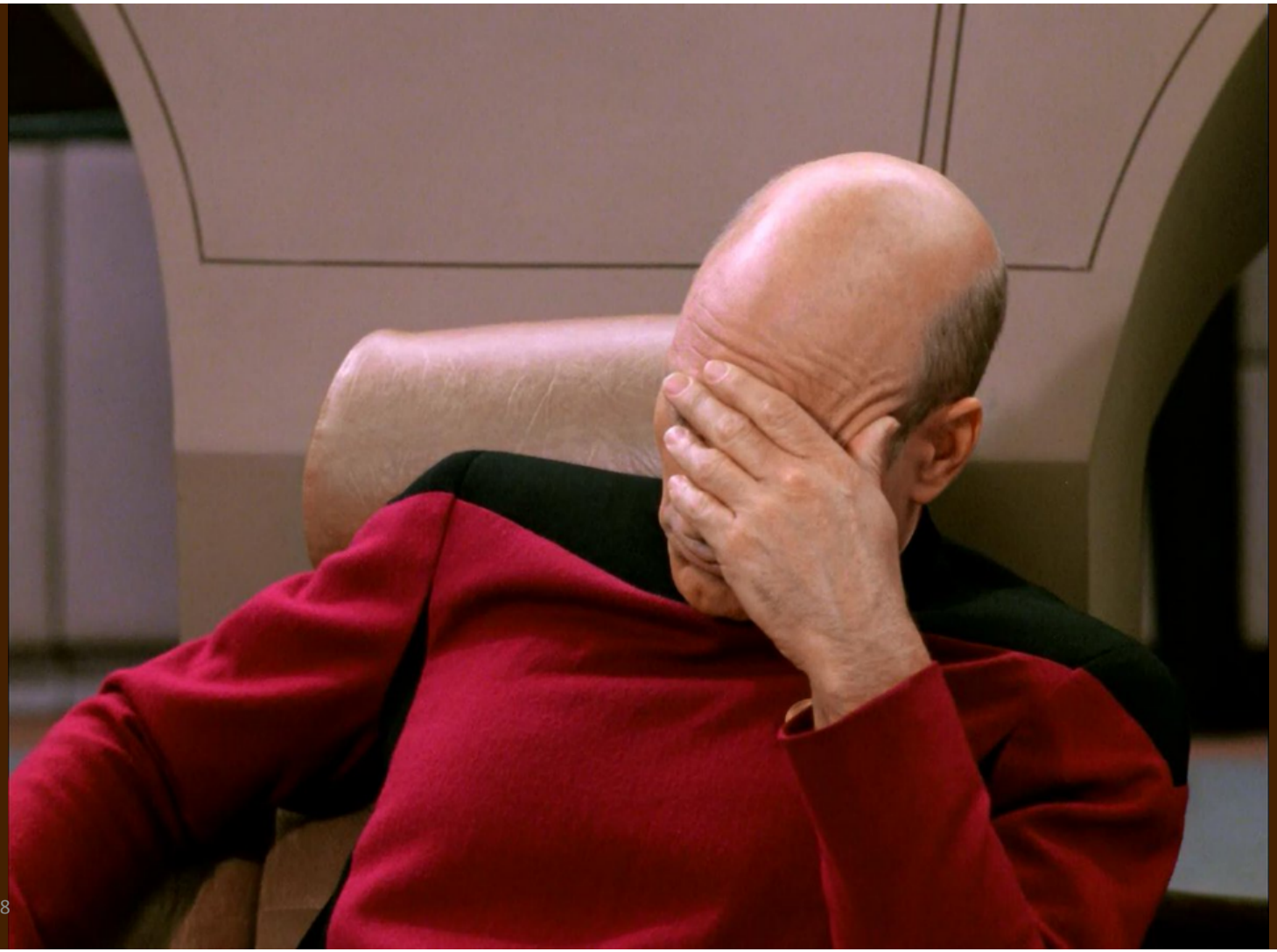
v_{bo} = burnout velocity - i.e. maximum velocity at burnout

v_o = initial rocket and fuel velocity

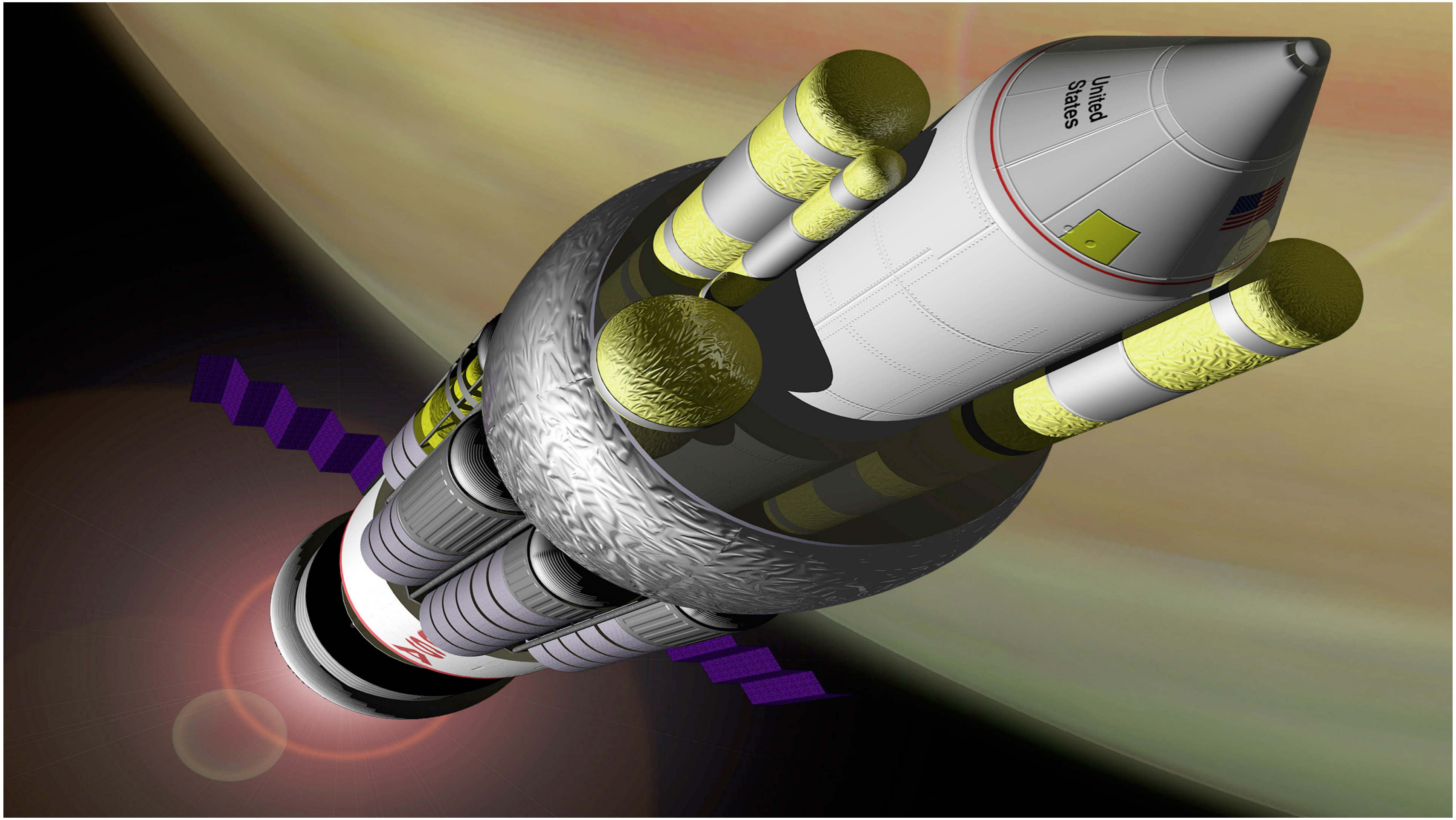
I_{sp} = specific impulse

R = thrust (to weight) ratio

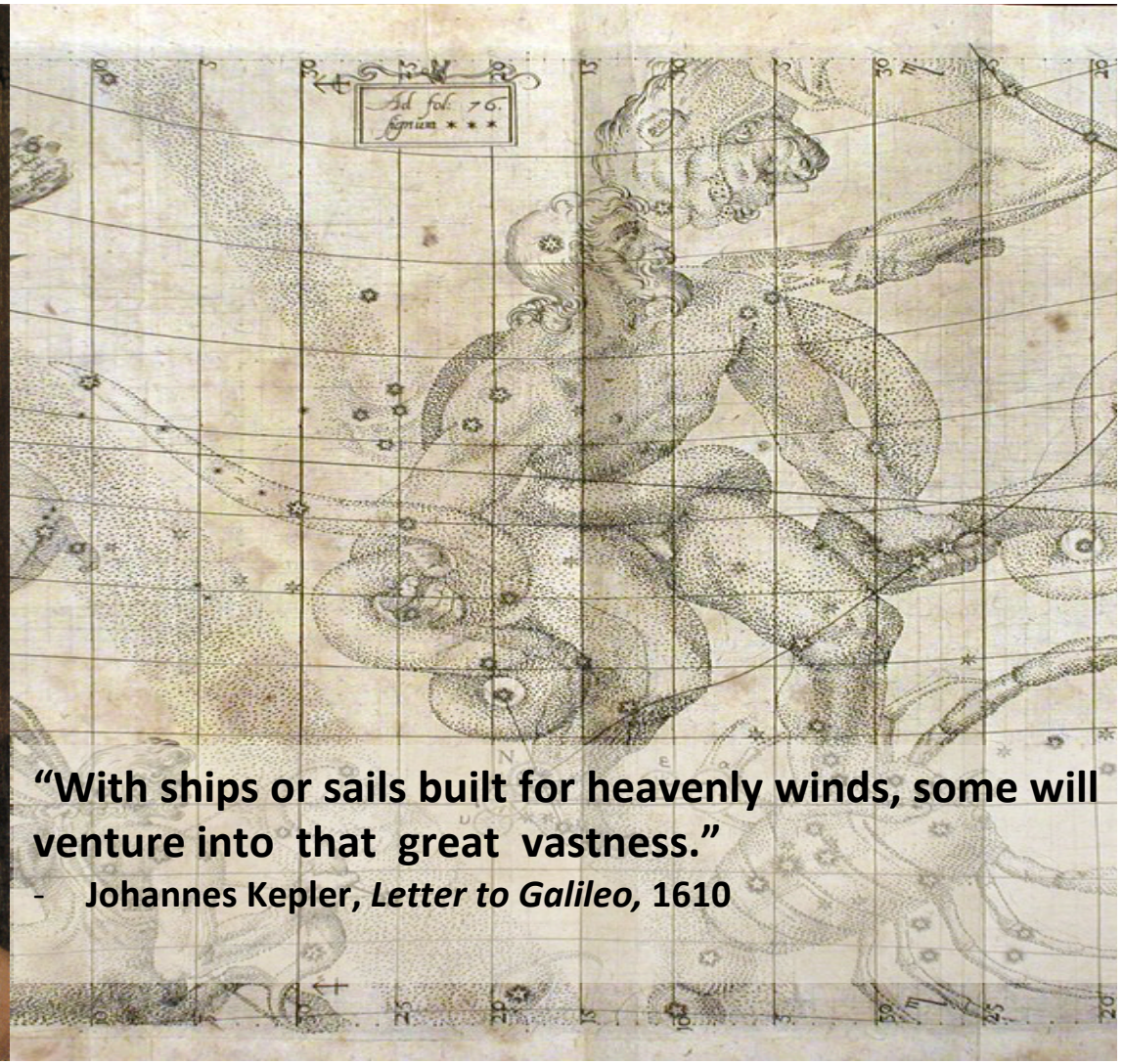
FOR FINAL VELOCITIES ≈ 0.1 − 0.5c - $I_{sp} \approx 10^6$ - The "MAGIC MILLION"




NASA

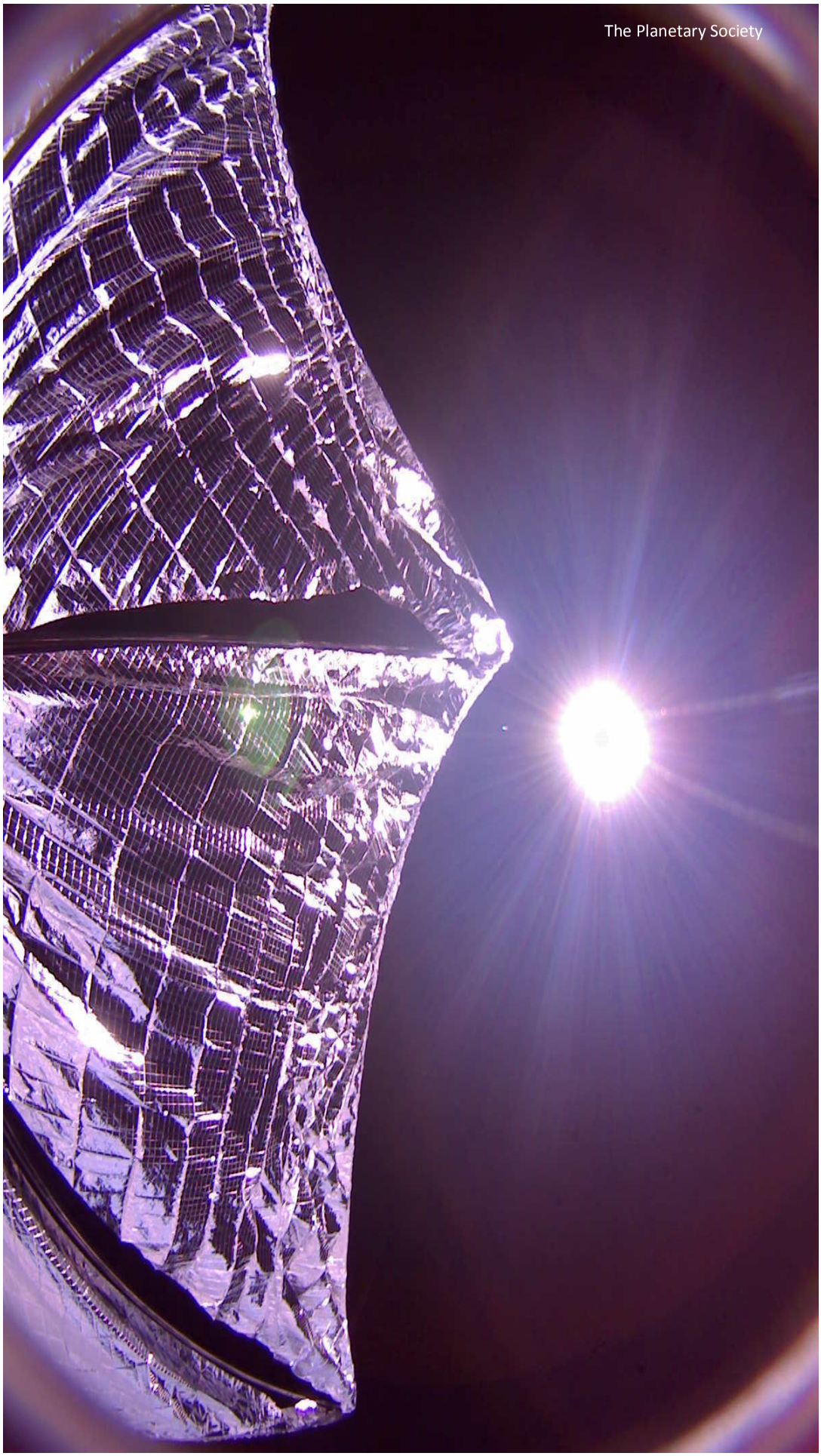

United
States


By firing antiprotons at the skin fission reactions occur and this generates thrust.



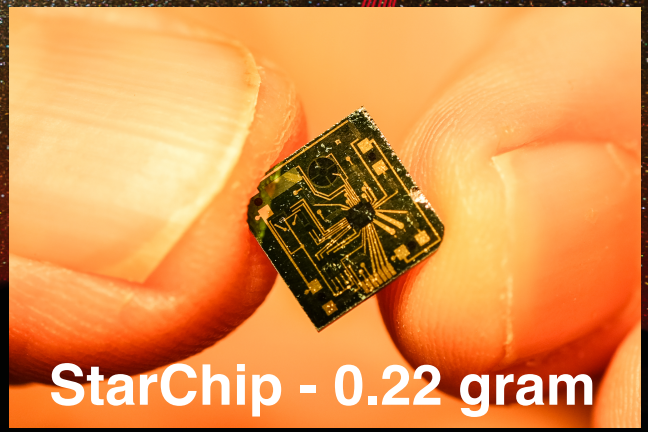
"With ships or sails built for heavenly winds, some will venture into that great vastness."

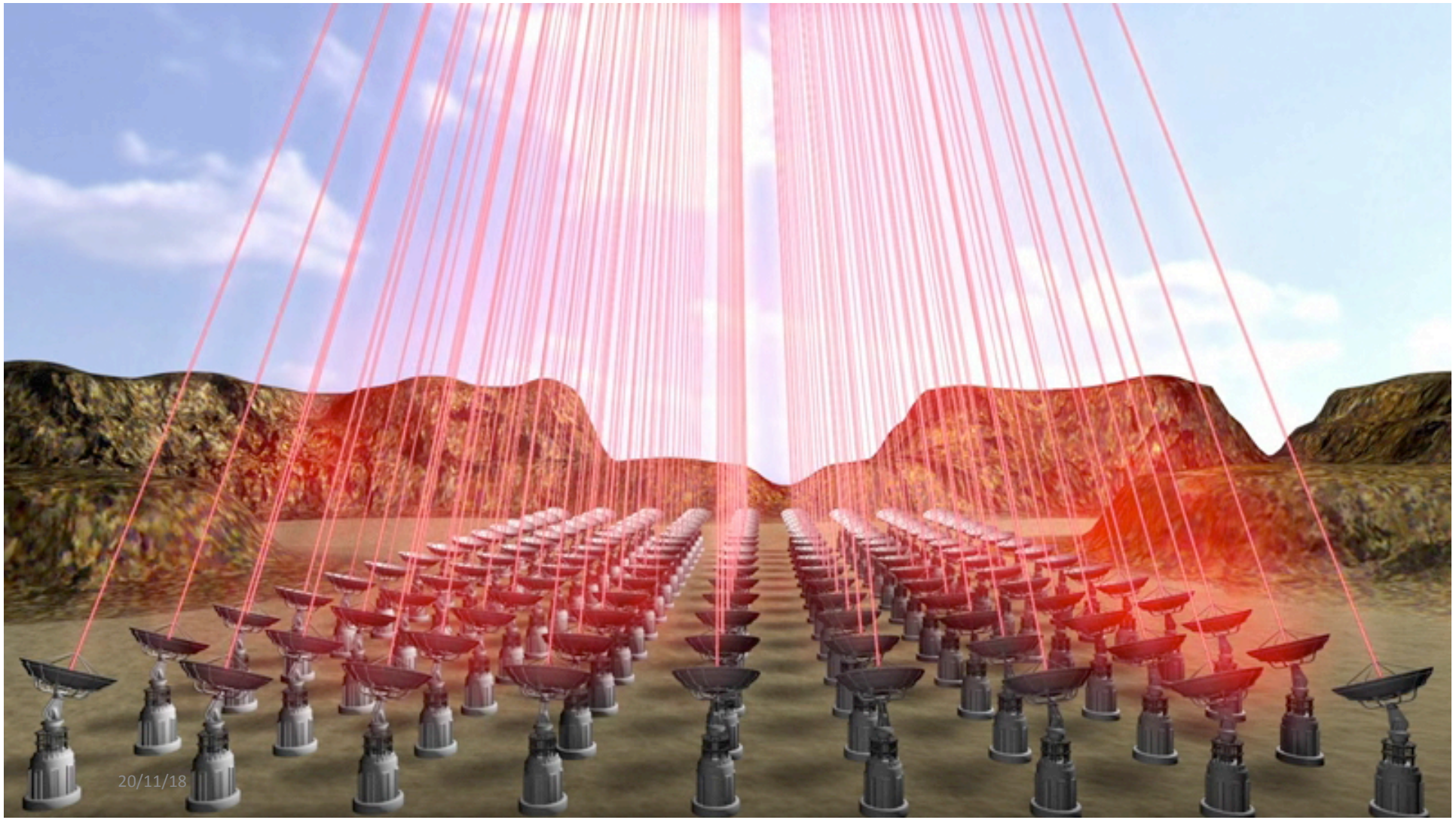
- **Johannes Kepler, *Letter to Galileo,* 1610**


The Planetary Society

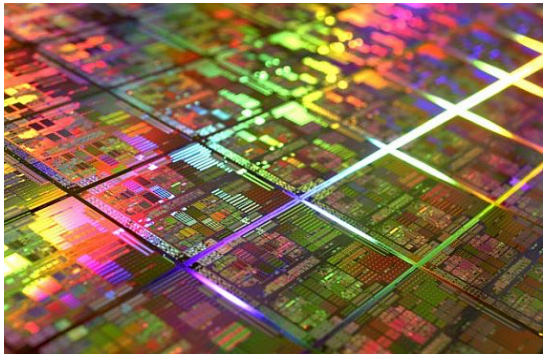
Solution to go fast

1. Lowest possible mass
2. Leave engine/fuel on Earth
3. Attach a chip to a sail
4. Laser beam is the wind

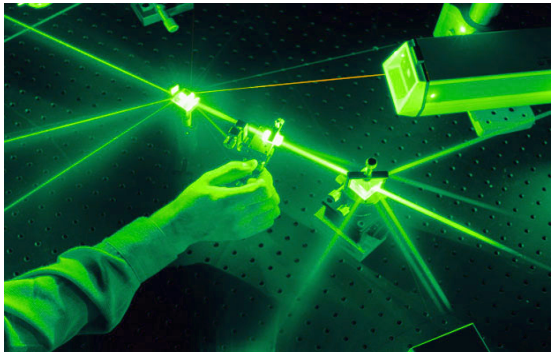




Two transformative trends

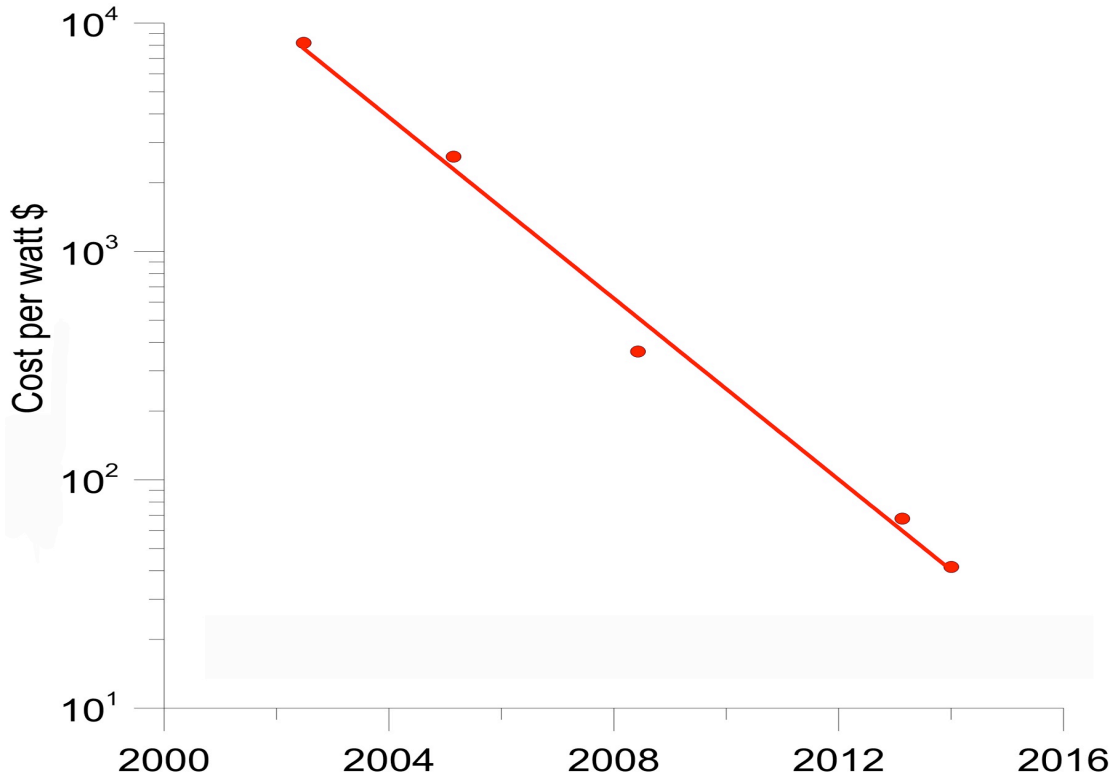


Microelectronics

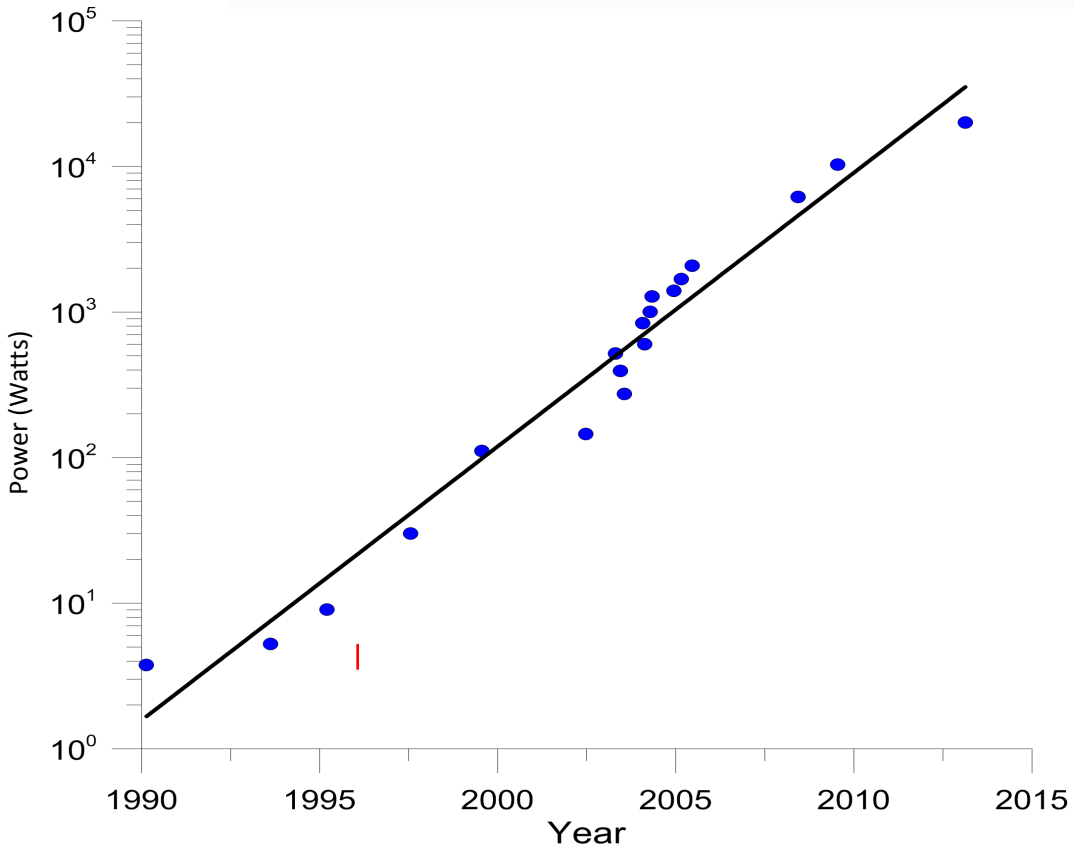


Photonics

Moore's law for lasers: cost

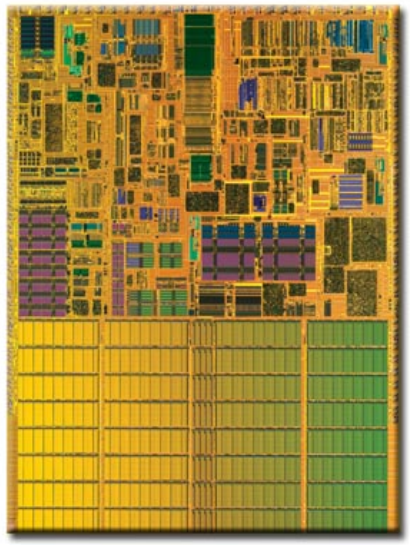


Moore's law for lasers: power



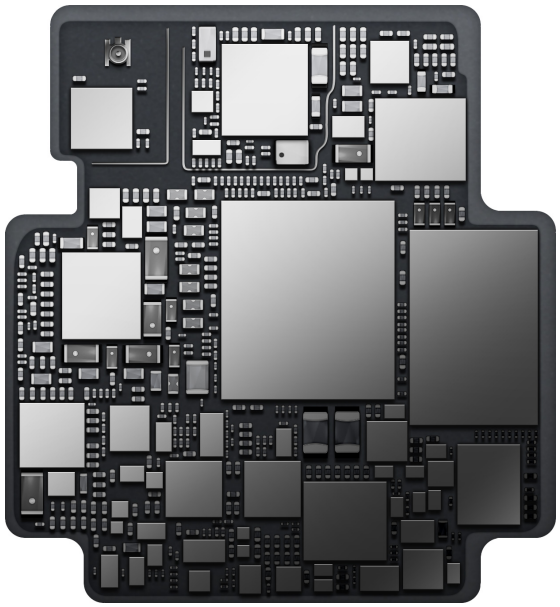

NASA / Kim Shiflett

StarChip size



15mm

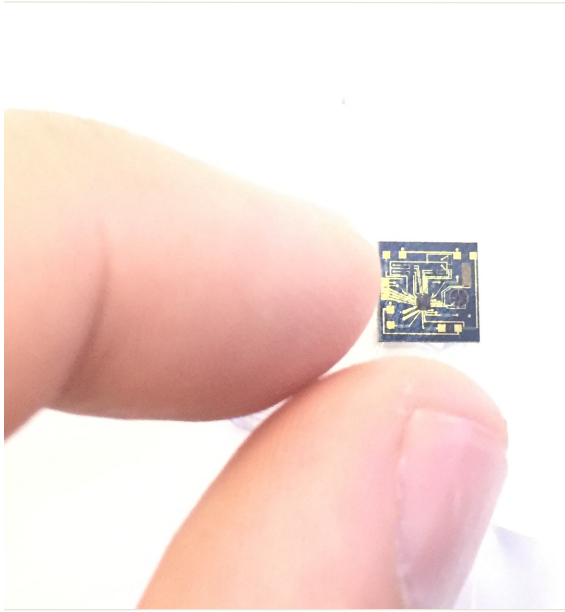
StarChip

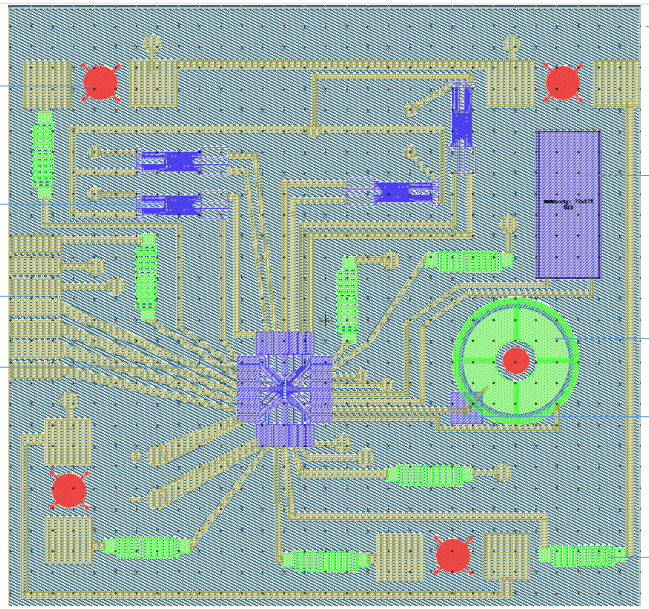


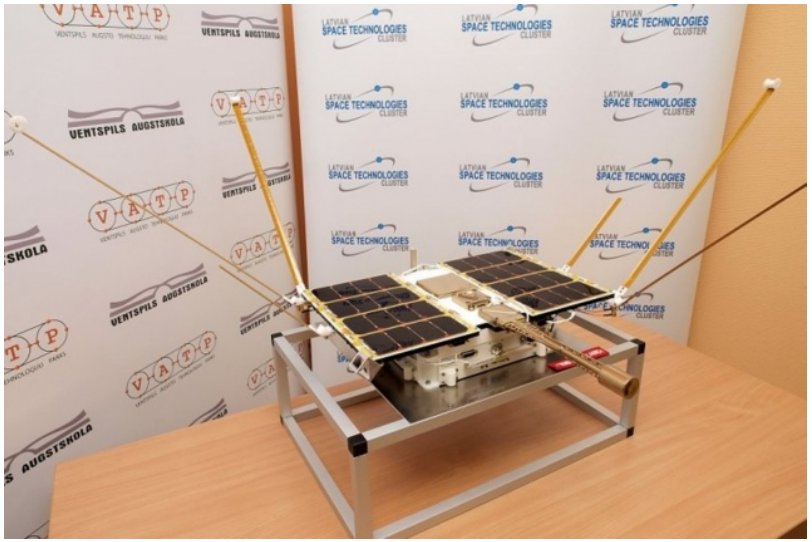
25mm

Apple Watch chip

BREAKTHROUGH STARSHOT



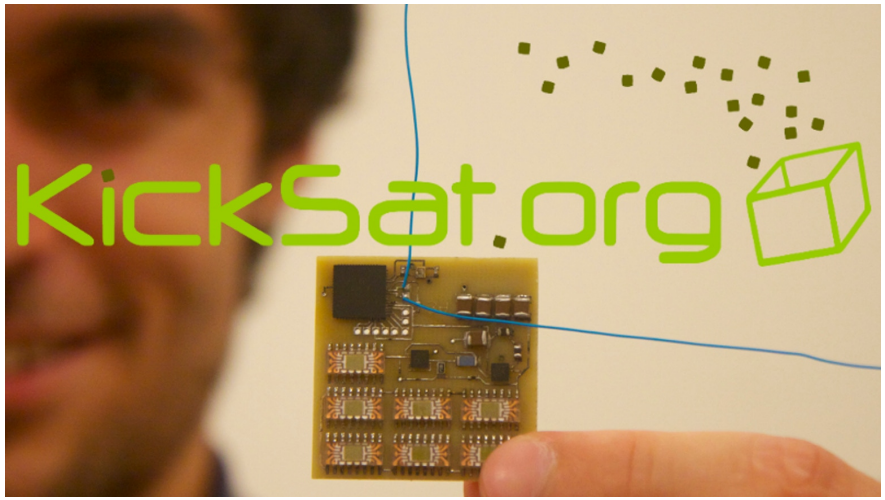


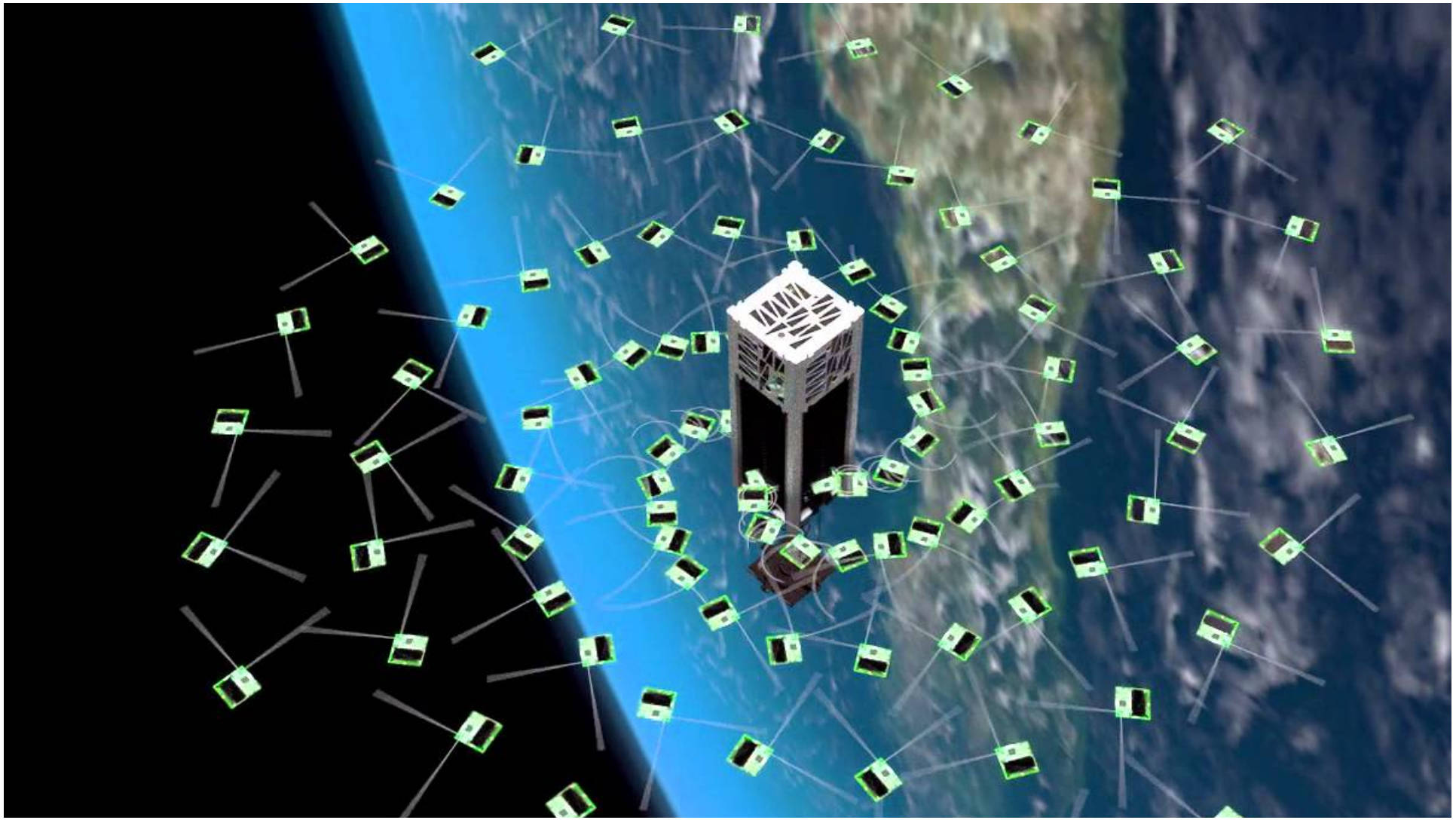


VENTA SATELLITE (LATVIA)

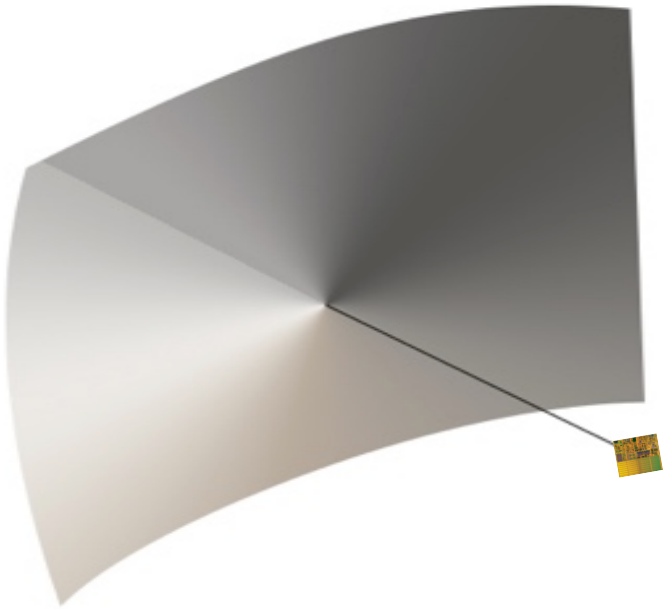
AND SPRITE NANOSAT (CORNELL)

Launched 23 Jun, 2017





StarChip + Lightsail: Nanocraft



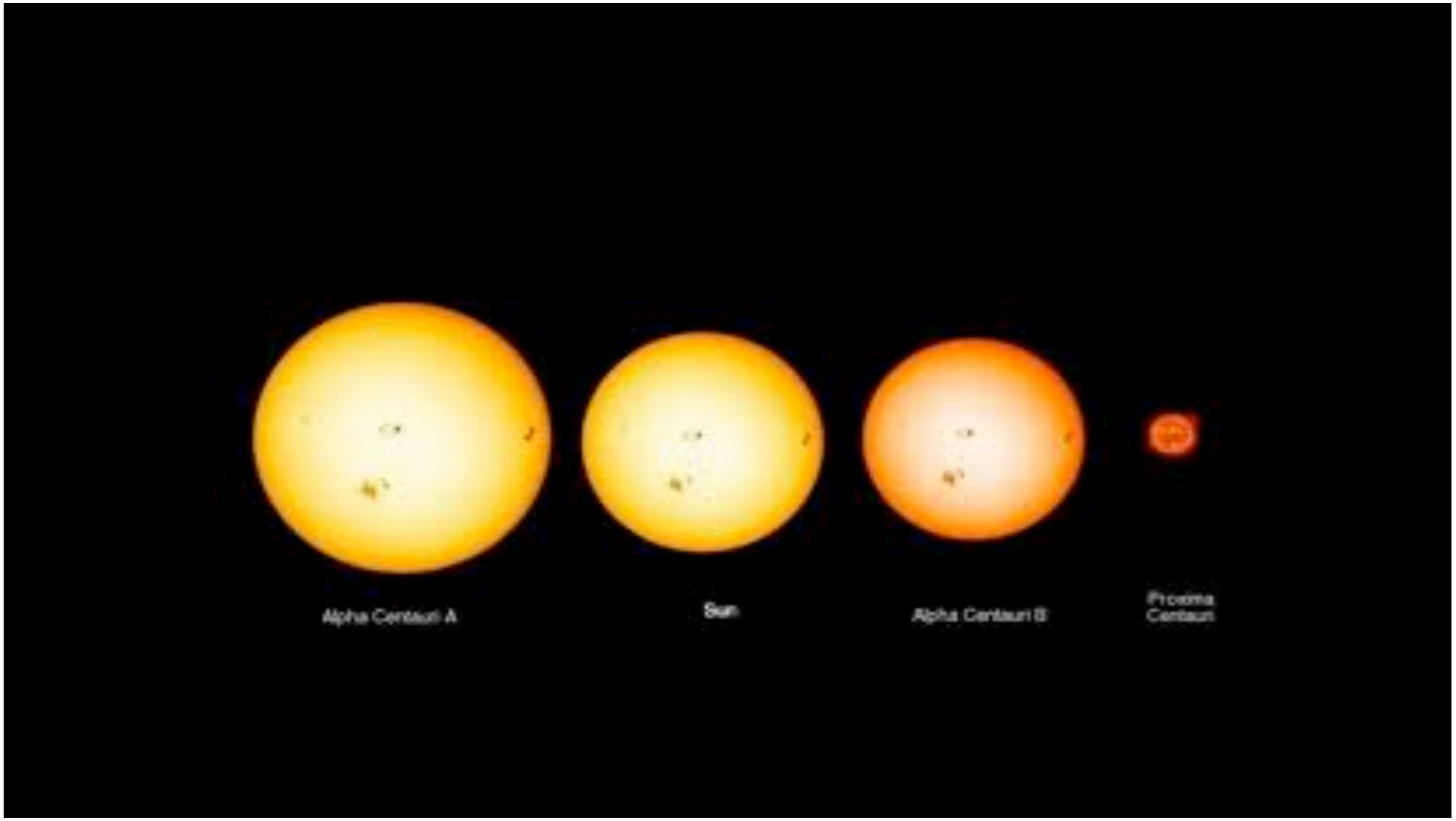
Breakthrough Starshot

- $100 million research and engineering program ≈ 5-7 years
- All results to be published
- Subscale prototype - $500m - $1B – privately funded – 10-15 years
- Laying foundations for launch to Alpha Centauri – public-private partnership – comparable cost to JWST, LHC/CERN

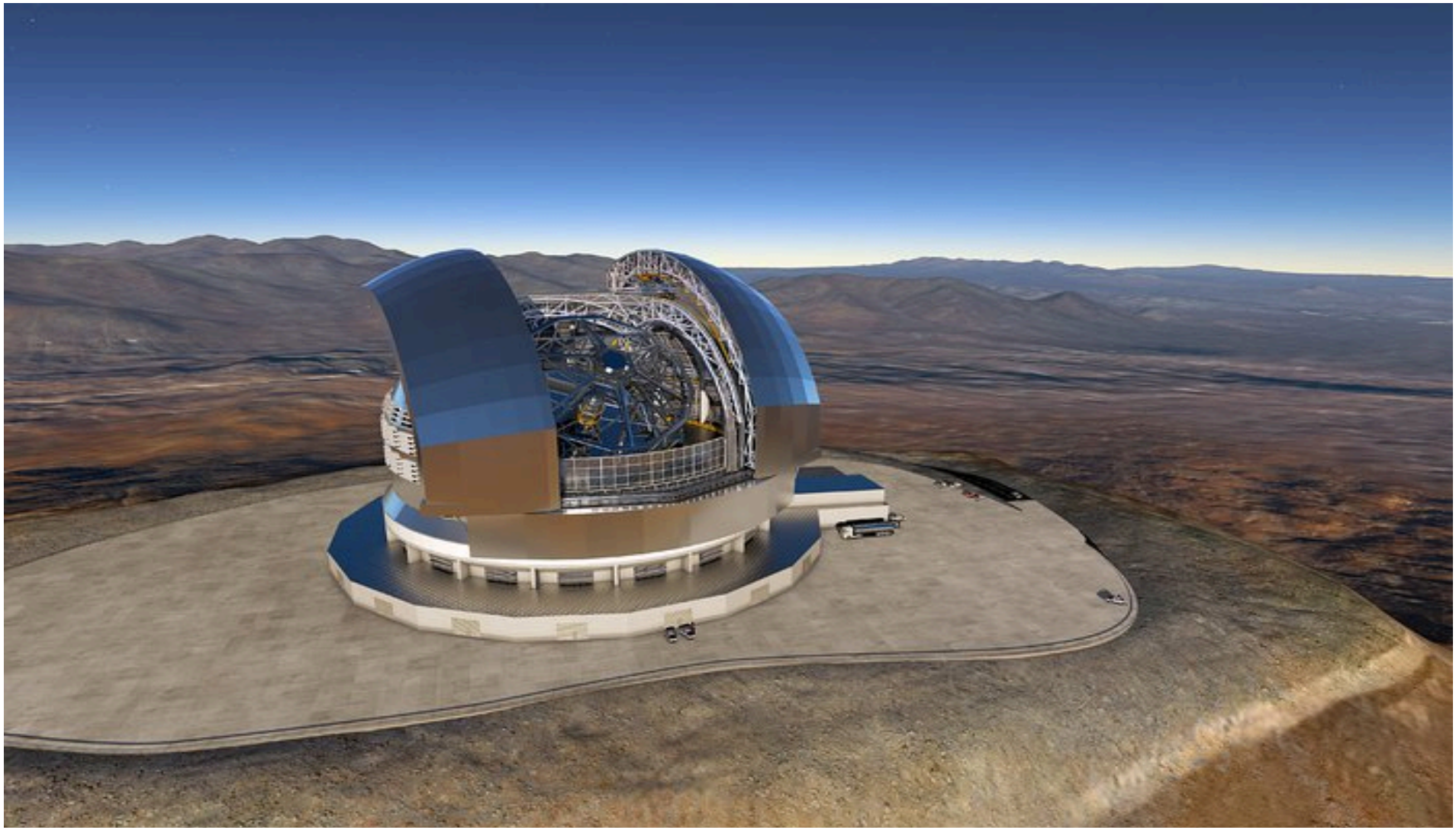
StarShot − Initial Research Goals − 2018

- Laser Device Development − phase large numbers of 1 micron lasers - 12 $150K contracts in p[rocess
- Sail Material Development - High reflectivity − very low absortivity material
- Laser Communications technology


BREAKTHROUGH
WATCH

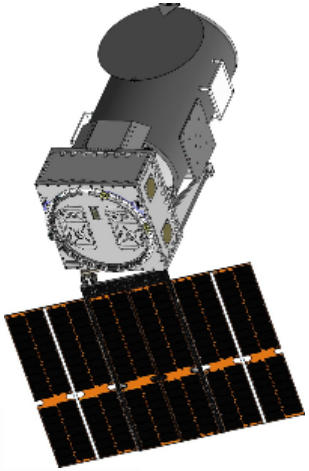

Alpha Centauri A
Sun
Alpha Centauri B
Proxima Centauri

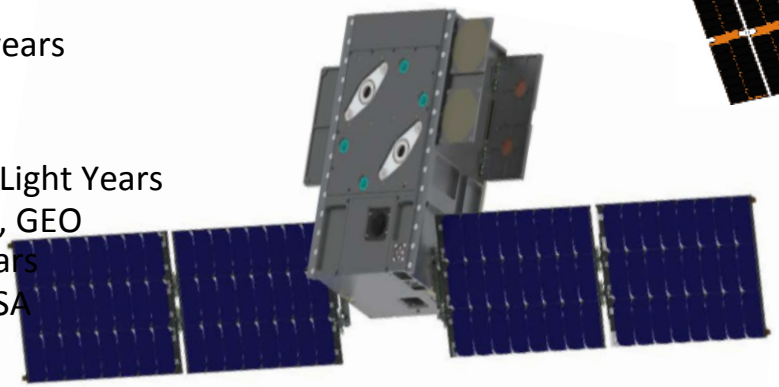

ESO



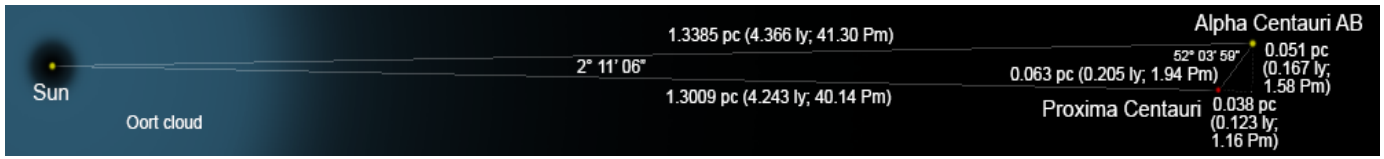
Toliman Proposed Program

- Toliboy ($1,000K-Class)
  - Target Super Earths around Alpha Centuri and 61 Cygni
  - 9 cm F20 telescope, LEO mission
  - Launch 2019, mission length one year
- Toliman ($10,000K-Class)
  - Target Earth size planets, Alpha Centuri, 61 Cygni, 70 Ophiuchi, 36 Ophiuchi, Rho-Eridani, Xi Ursae Majoris
  - 30 cm F20 telescope, GEO mission
  - Launch 2021, mission length: three years
  - Possible Partners ASI, JAXA, NASA
- Toliman Follow On ($100,000K-Class)
  - Target Earths size planets within 15 Light Years
  - 100 cm class Chronograph telescope, GEO
  - Launch 2025, mission length: five years
  - Possible partners ESA, ASI, JAXA, NASA





Target Systems

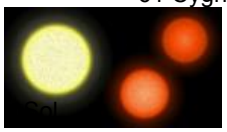


G2V G2V K1V M6Ve

The A and B components of Alpha Centauri have an orbital period of 79.91 years. Their closest approach is 11.2 AU, or the distance between the Sun and Saturn; and their furthest separation is 35.6 AU, the distance between the Sun and Pluto. Apparent visual distance ranges between 2 and 22 arc sec. They are currently at a 4.5 arc sec separation. Apparent visual magnitude 0.3 and 1.3

61 Cygni B
K7V

Sol
G2V



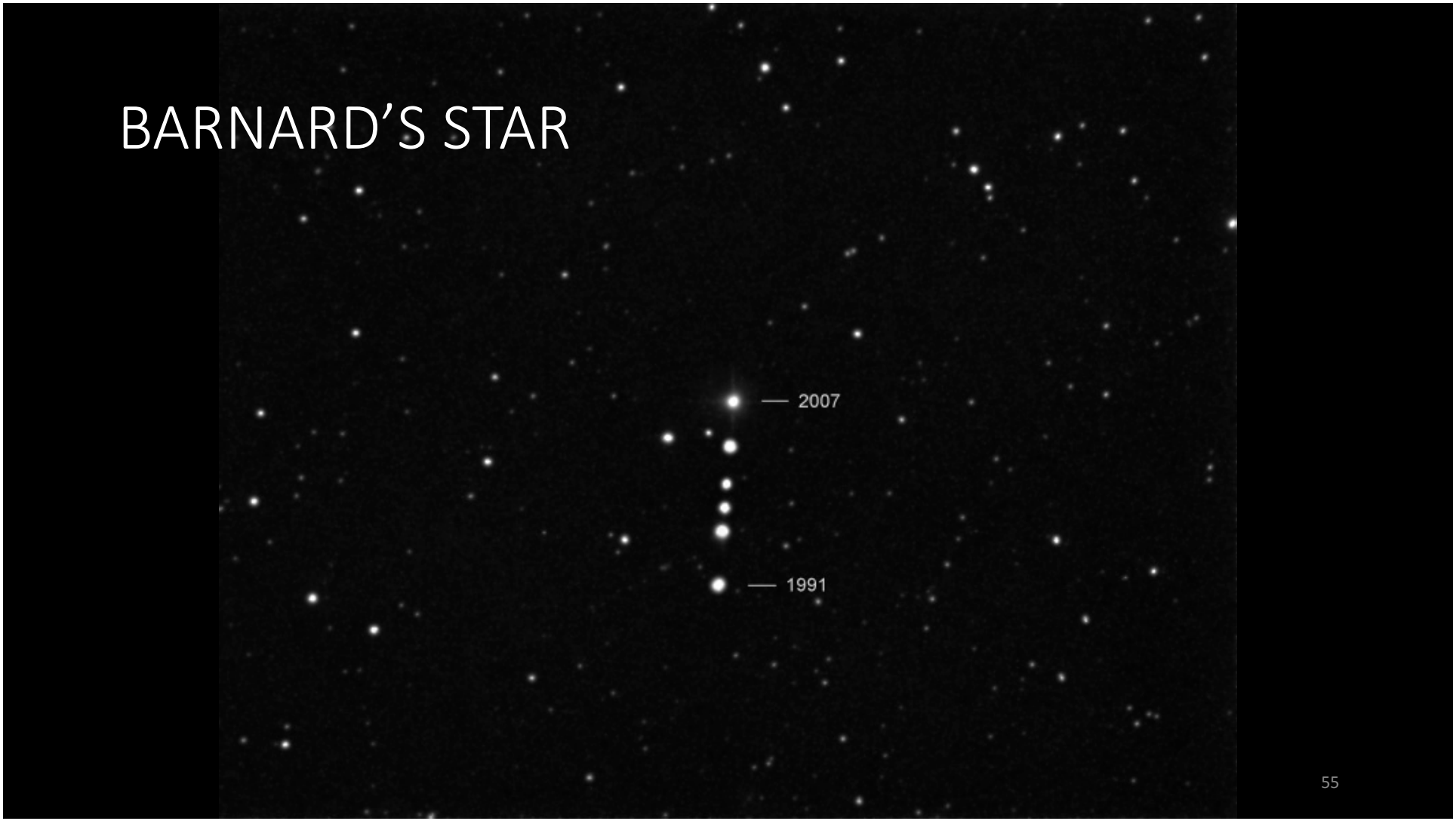
61 Cygni A
K5V

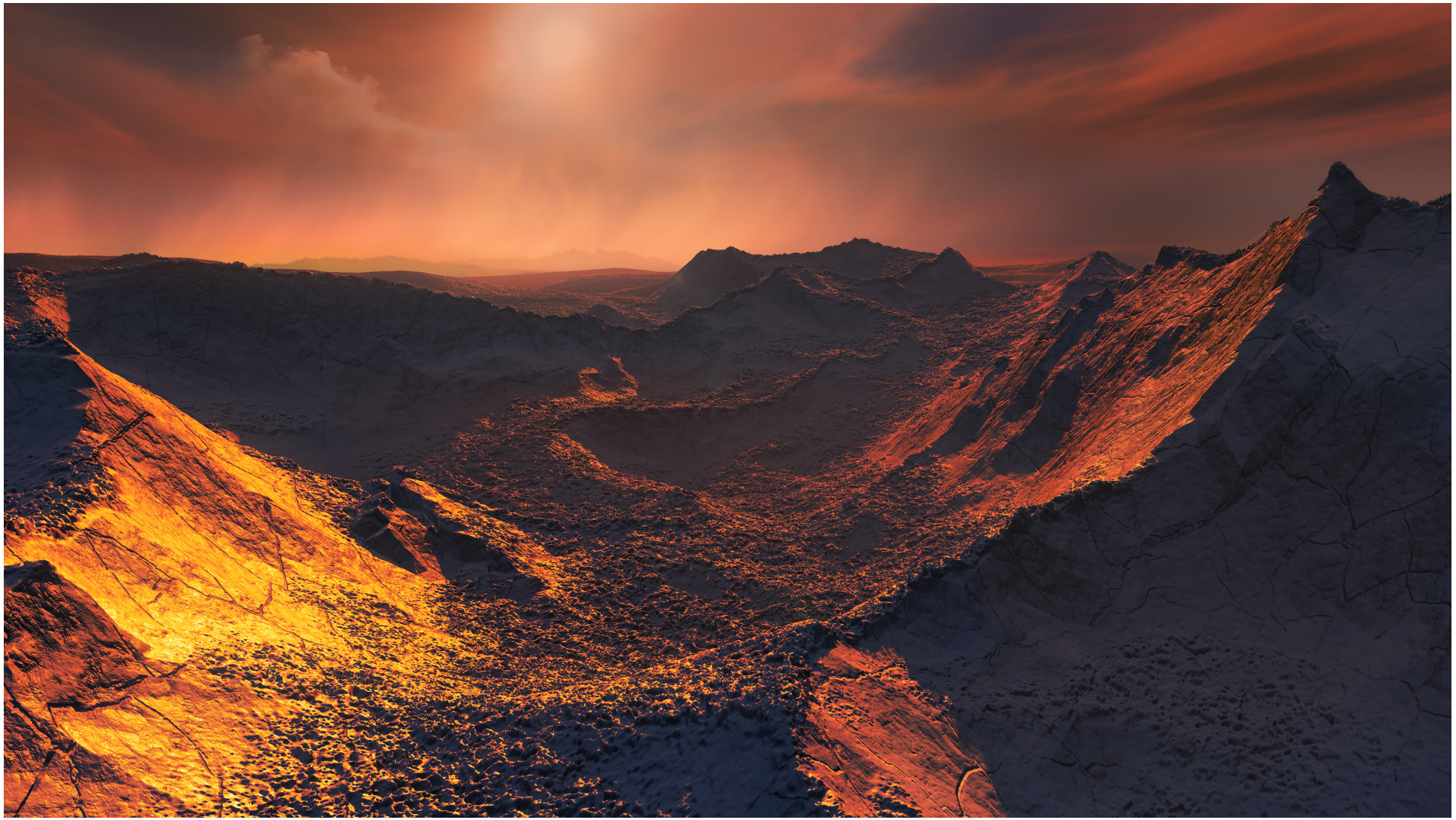
61 Cygni A/B

Alpha Cen A/B

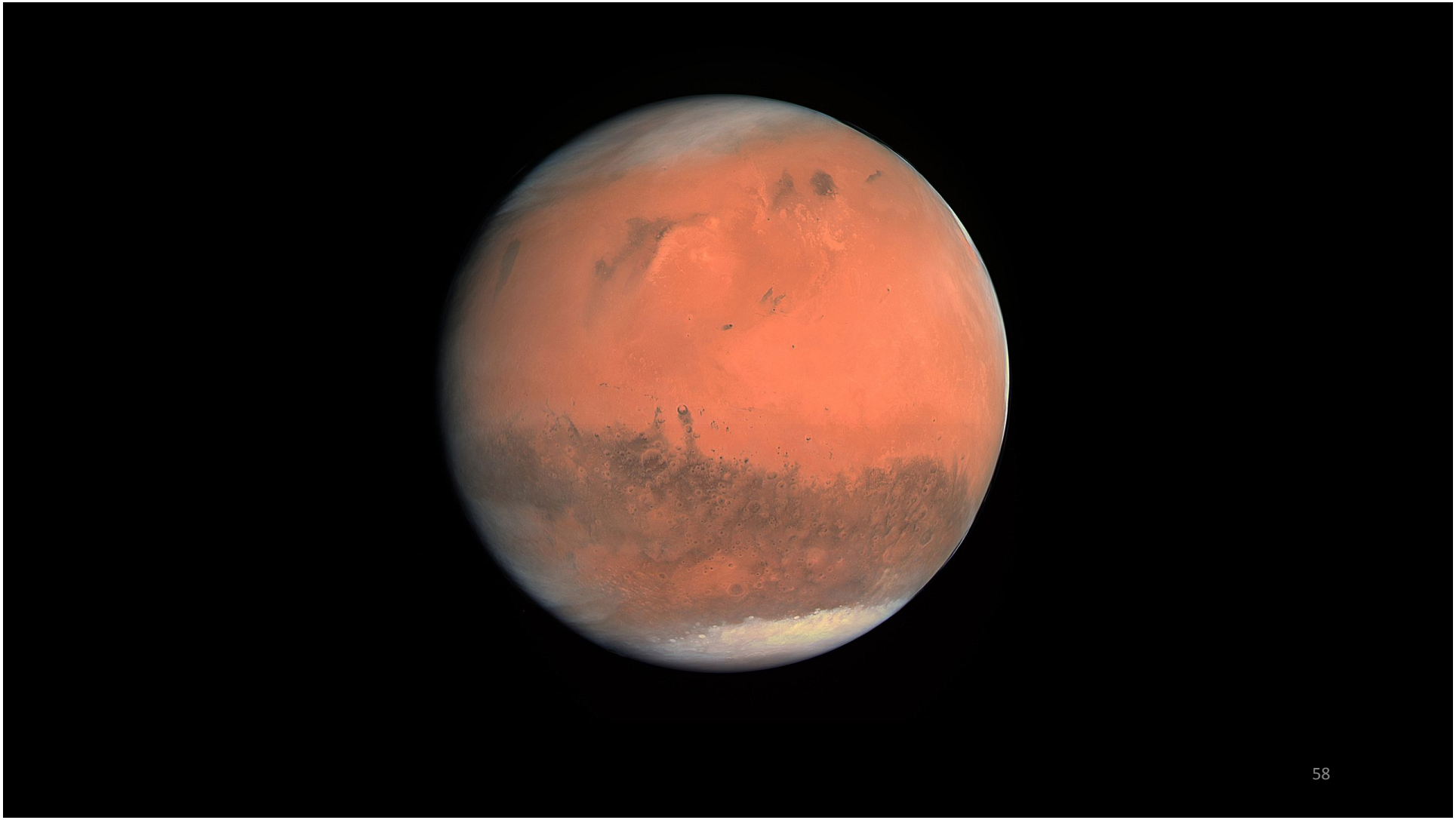
61 Cygni A and B orbit their common barycenter in a period of 659 years, with a mean separation of about 84 AU. Orbital eccentricity of 0.48 means that the two stars are separated by about 44 AU at periapsis and 124 AU at apoapsis. They are currently at a 80 AU or 20 arc sec separation. Apparent visual magnitude 5.2 and 6.0

BARNARD'S STAR

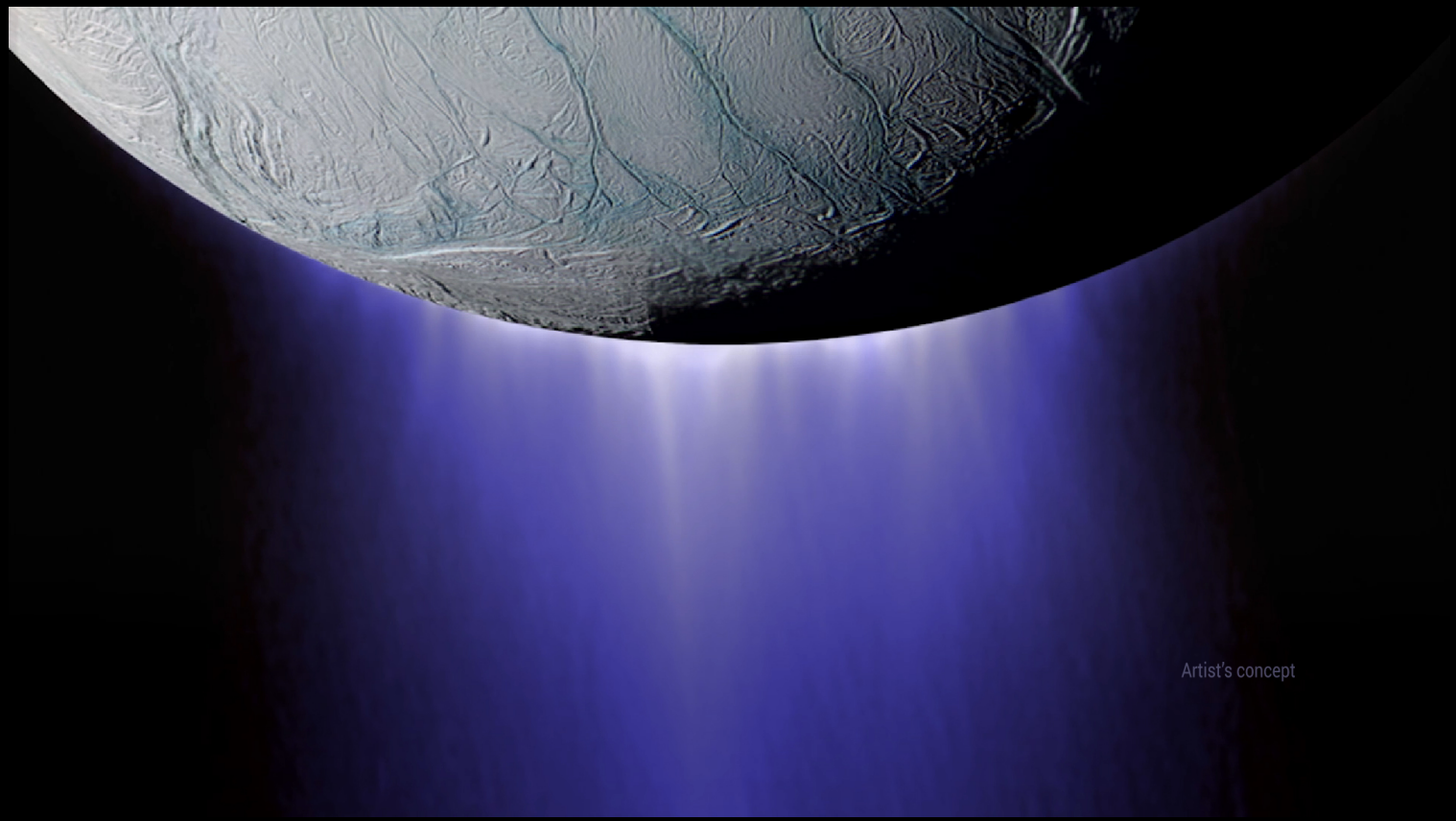




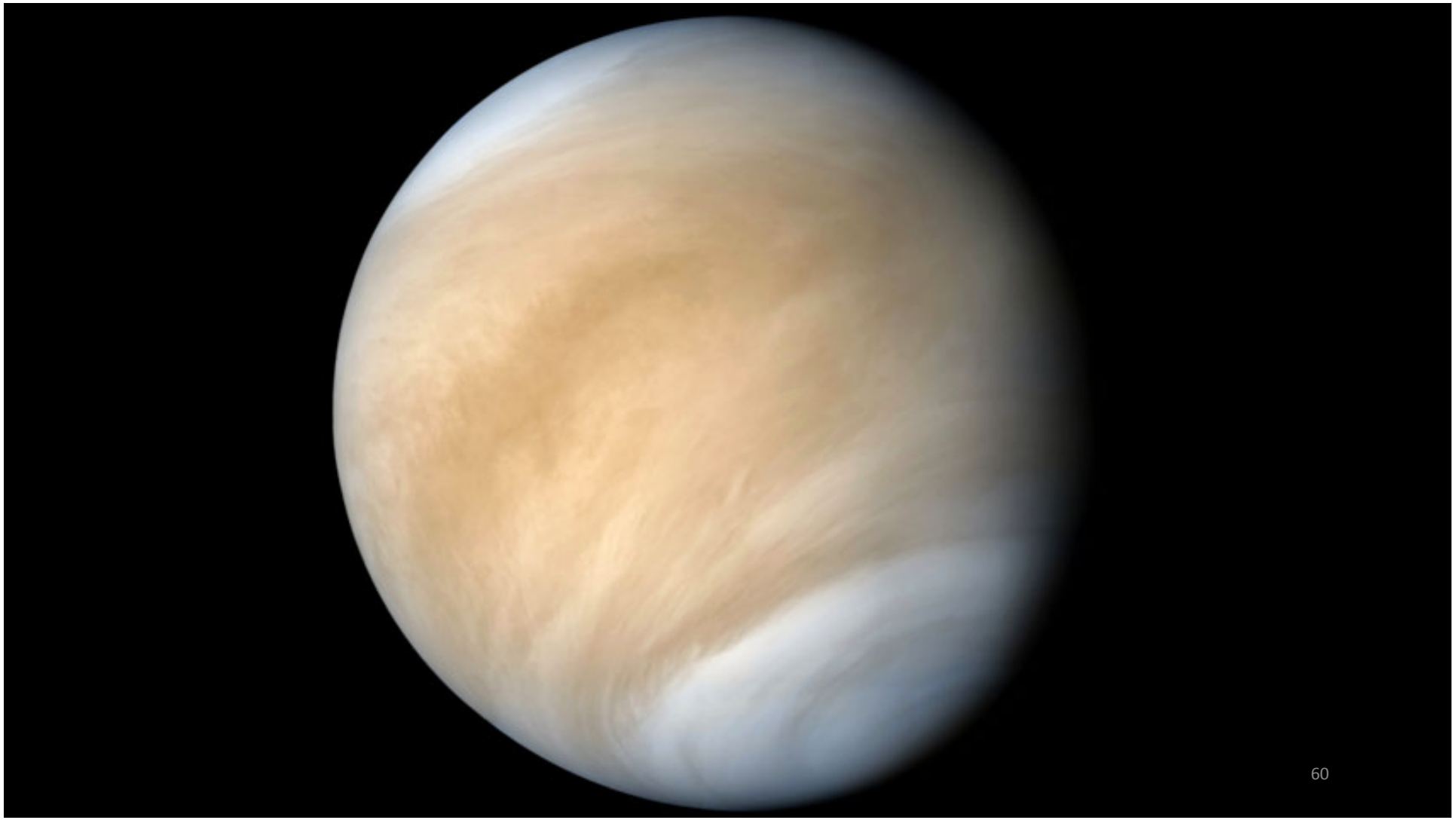

BREAKTHROUGH
SOLAR



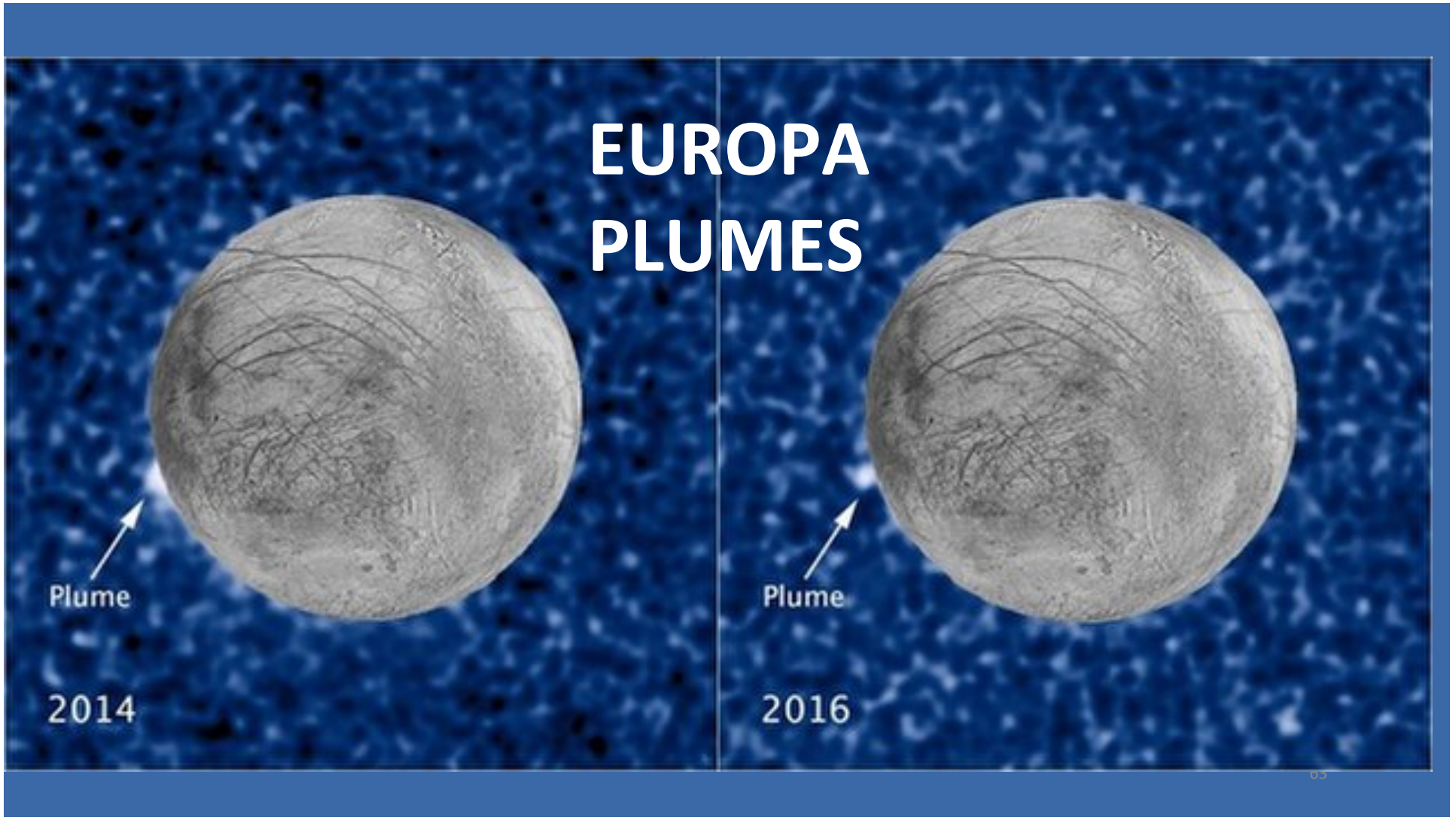
ENCELADUS



Artist's concept




cnes
esa


EUROPA
PLUMES
Plume
2014
Plume
2016


BREAKTHROUGH
Discuss


2018 CONFERENCE,
APRIL 12-13, Stanford University
“Possibilities for Life”
• Exotic and Machine Life
• Advances in Propulsion
• What does Alien Life Look Like

GLOBAL SPACE AGENCY SCIENCE LEADS AT BREAKTHROUGH DISCUSS – 20 APR 2017

CIRCA 2068