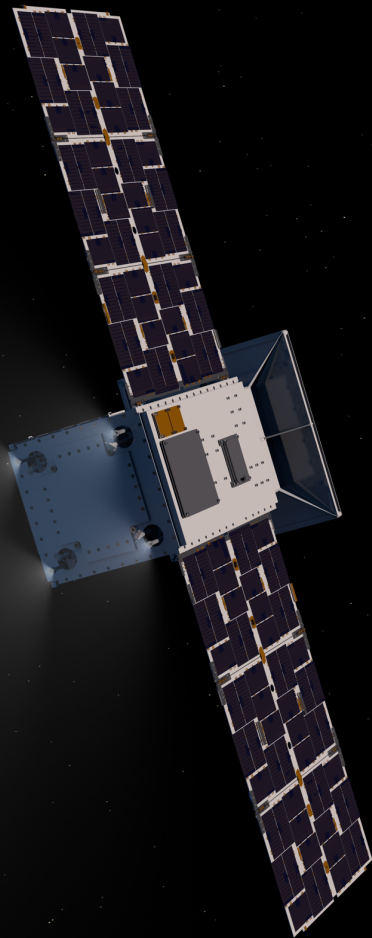




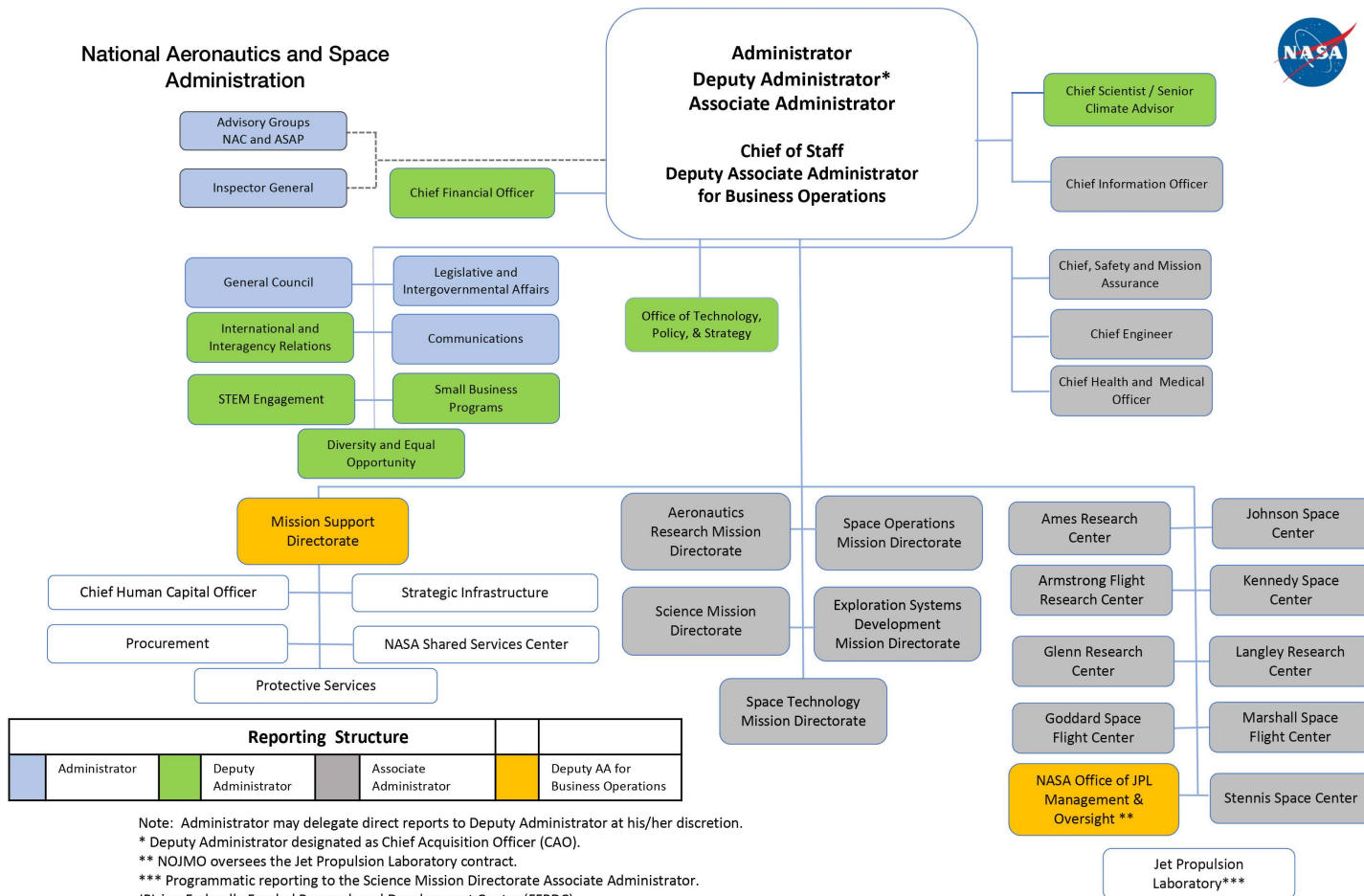
National Aeronautics and
Space Administration



NASA Small Spacecraft Technology Program

Roger C. Hunter
Program Manager

National Aeronautics and Space Administration



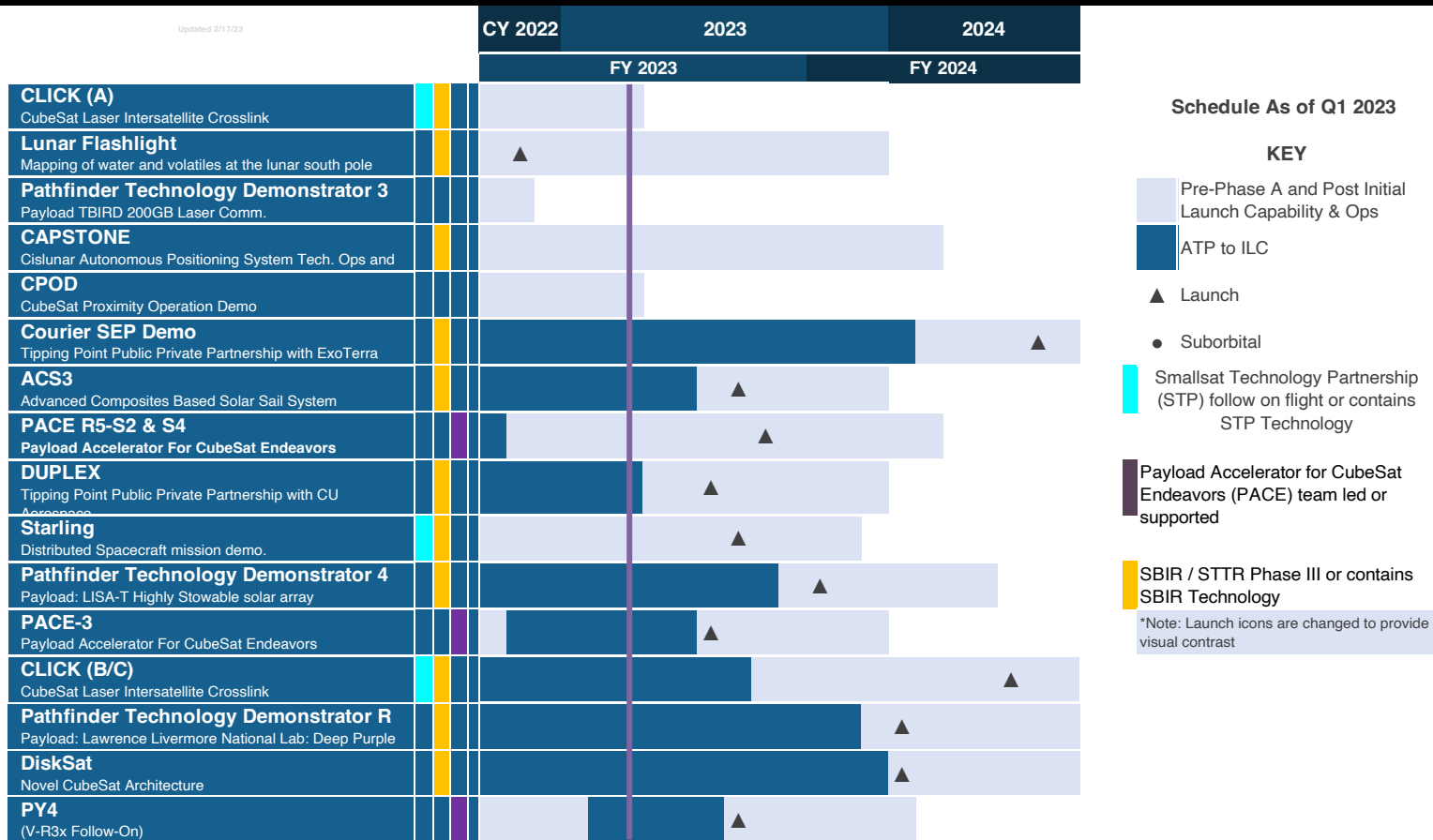
NASA Small Spacecraft Technology Objectives



The Small Spacecraft Technology program **expands U.S. capability to execute unique missions through rapid development and demonstration** of capabilities for small spacecraft applicable to exploration, science and the commercial space sector.

- Enable execution of missions at much **lower cost** than previously possible.
- Substantially **reduce time** required for development of spacecraft.
- Enable and demonstrate **new mission architectures**.
- Expand the capability of small spacecraft to execute missions at **new destinations** and in challenging new environments.
- Enable the **augmentation of existing assets and future missions** with supporting small spacecraft.

Small Spacecraft Technology Demonstration Missions Schedule as of CY Q1'23



U-Class Exploration Mission Status

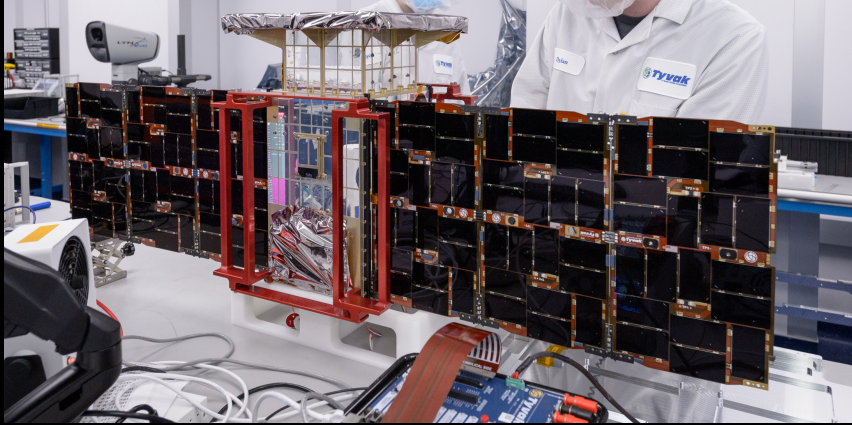


Image Credits: NASA

CAPSTONE

Launched: June 28, 2022

Status: In orbit around the Moon, CAPSTONE to LRO communications continuing

Objective: Demonstrate how to enter and function in a near rectilinear halo orbit around the Moon; demonstrate spacecraft-to-spacecraft navigation

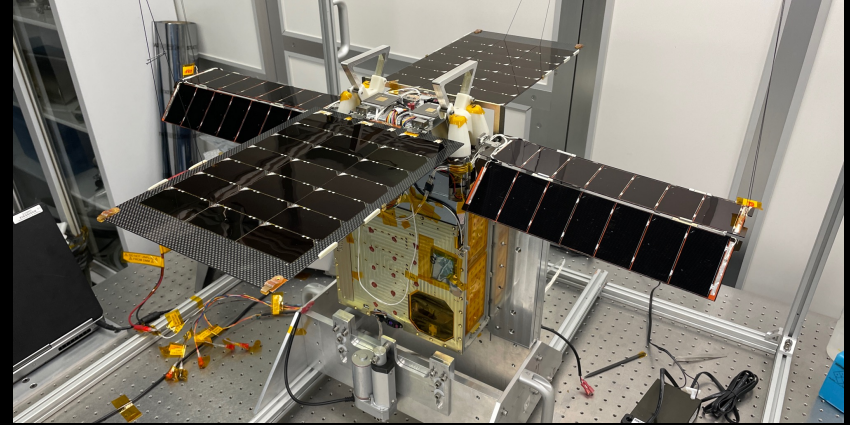


Image Credits:
NASA/JPL-Caltech

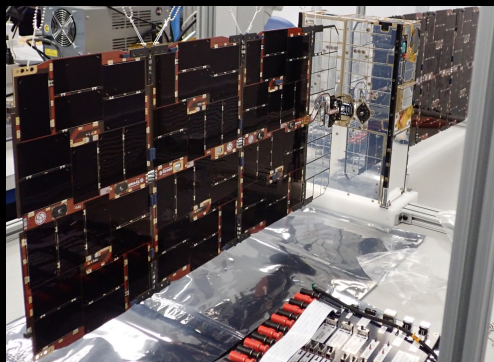
Lunar Flashlight

Launched: December 11, 2022

Status: End of mission

Objective: Characterize lunar *in-situ* resource utilization potential. Measure quantity and distribution of surface ice deposits in lunar South Pole cold traps with a compact laser spectrometer

On-Orbit U-Class Technology Demonstration Missions – 2022



Pathfinder Technology Demonstrator (PTD-3) / TeraByte InfraRed Delivery (TBIRD)
Launched: May 25, 2022

Status: Demonstrated 200 Gbps data downlink rate and 1.4 terabyte data download to an optical ground station during a single 10-minute pass.

Image Credits: Terran Orbital Corporation



CubeSat Proximity Operations Demonstration (CPOD)
Launched: May 25, 2022

Status: Demonstration of rendezvous, proximity operations and docking using two 3U CubeSats is pending

Image Credits: Terran Orbital Corporation

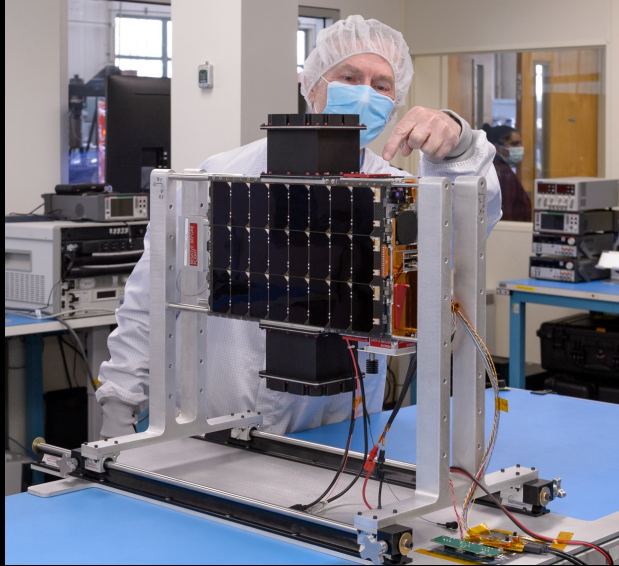


CubeSat Laser Infrared CrossLink (CLICK-A)
Launched: July 14, 2022
Deployed: Sept 6, 2022

Status: Demonstrated precision pointing of the spacecraft's fine steering mirror control system.
Risk reduction mission for CLICK B/C.

Image Credits: NASA

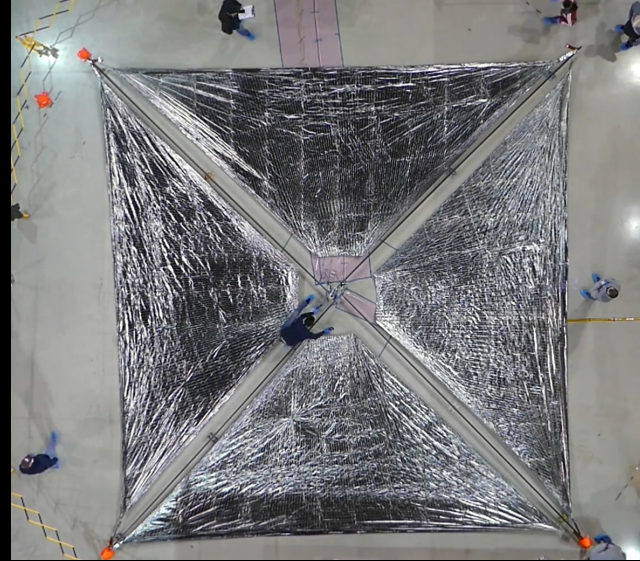
Upcoming U-Class Technology Demonstration Missions – '23/'24



Starling
Launch: NET 15 July 2023

Demonstrate swarm maneuver planning and execution, communications networking, relative navigation, and autonomous coordination between a swarm of four 6U CubeSats

Image Credits: NASA

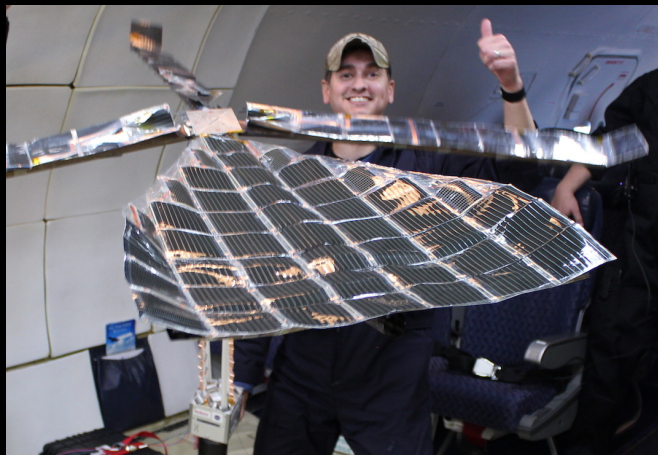


Advanced Composite Solar Sail System (ACS3)
Launch: 1st Half of 2024 (TBR)

Demonstrate deployment of the composite boom solar sail in low-Earth orbit. The unfurled solar sail will measure approximately 84 m²

Image Credits: NASA

Upcoming U-Class Technology Demonstration Missions – 2023 / 2024



Pathfinder Technology Demonstrator (PTD-4)

Launch: 1st Half of 2024

Demonstrate Lightweight Integrated Solar Array and anTenna (LISA-T), a high-power, low-volume deployable solar array with an integrated antenna

Image Credits: NASA



CubeSat Laser Infrared Crosslink (CLICK B/C)

Launch: Mid 2024

Demonstrate optical crosslink and precision ranging between two 3U CubeSats at a data rate of 20 Mbps and range up to 580 km

*Image Credits: NASA (illustration) and
Blue Canyon Technologies (photograph)*

SmallSat Technology Partnerships Overview



Overview:

- U.S.-based university and NASA center, PI-lead cooperative agreements
- Competitive solicitations
- Specific technology topics vary
- Grants for max duration of two years
- Year-2 option after first annual review
- 5 “classes” to-date: 2013, 2015, 2016, 2018, 2020

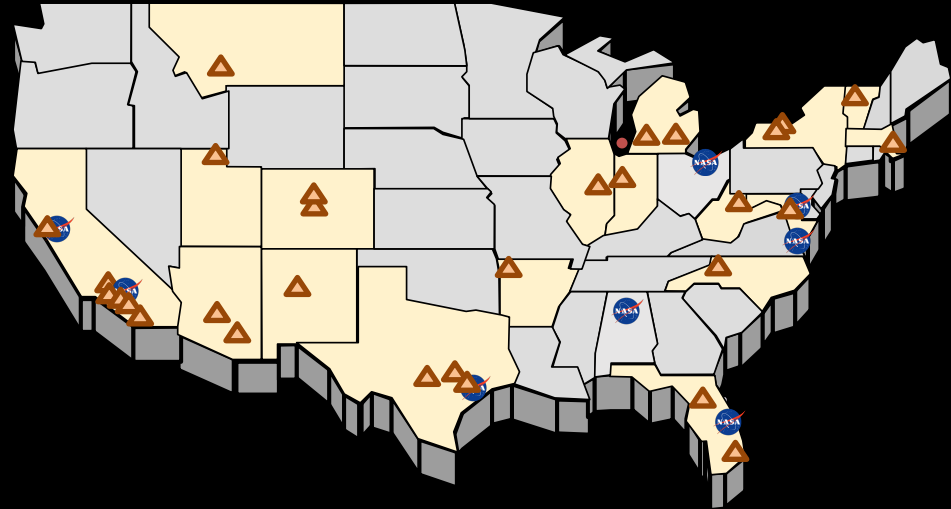
Investments:

- Over \$26,468,000 awarded
- 8 of 10 NASA Centers partnered
- 30 Universities in 18 states
- 46 partnerships in 5 class years

Results:

- 1 Intersatellite Network Planning/ Routing tool software open-sourced
- 4 New Technology Reports / Patents
- 13 flight demonstrations planned
- 27+ Conference presentations
- 46+ Papers published
- 100+ Students involved + Many TRLs raised

 **30 Universities in 18 States**
 **8 NASA Centers (including JPL FFRDC)**



2013	\$6,500,000	17 awards;	13 Y2 option
2015	\$3,590,150	8 awards;	8 Y2 option
2016	\$4,676,693	8 awards;	8 Y2 option
2018	\$5,802,500	8 awards;	8 Y2 option
2020	\$5,900,000	9 awards:	(assumes 2 yrs)

Announcement of Collaboration Opportunity Projects – 2018



Diagram of the concept of operations for the Cislunar Autonomous Positioning System (CAPS). CAPS is an innovative spacecraft-to-spacecraft navigation solution to be demonstrated on the CAPSTONE mission currently in orbit around the Moon. CAPS is anticipated to allow future spacecraft the ability to determine their location relative to the Moon without relying exclusively on tracking from Earth.
Image Credits: Advanced Space, LLC

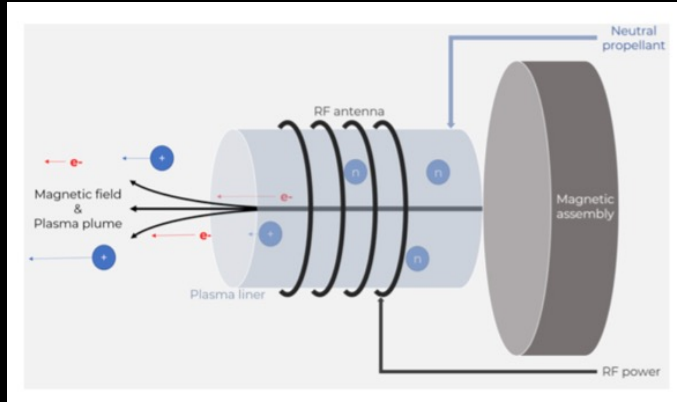
A public-private partnership with NASA's Goddard Space Flight Center



The Vulcan Wireless CubeSat radio, NSR-SDR-S/S. This CubeSat radio is a fully integrated, full-duplex, software-defined radio transponder. The radio transponder is being tested for compatibility with NASA's Space Network.
Image Credits: Vulcan Wireless, Inc.

A public-private partnership with NASA's Goddard Space Flight Center

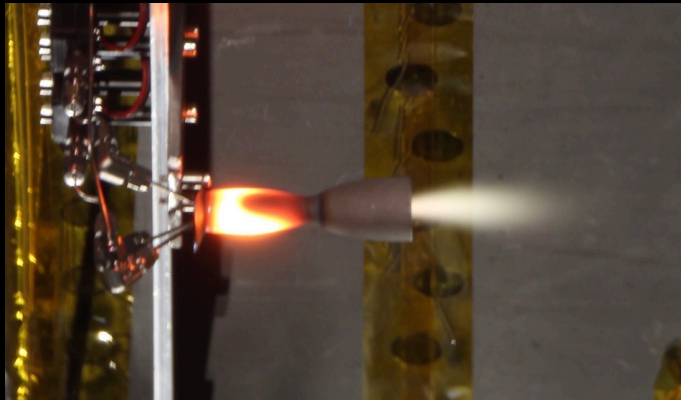
Announcement of Collaboration Opportunity Projects - 2020



The Phase Four RF plasma thruster operates by using RF to heat propellant into ionized plasma that is then ejected away from a spacecraft by a permanent magnet, creating thrust.

Image Credits: Phase Four

A public-private partnership with NASA's Glenn Research Center



A prototype bipropellant thruster is shown in ambient pressure testing. The key technology being tested is the propellant pump - an enabling technology for launch safety approval (no stored gas) and system performance (lightweight tanks). Testing includes a propulsion system composed of monopropellant and bipropellant systems.

Image Credits: Stellar Exploration, Inc.

A public-private partnership with NASA's Ames Research Center

Tipping Point Projects – 2019



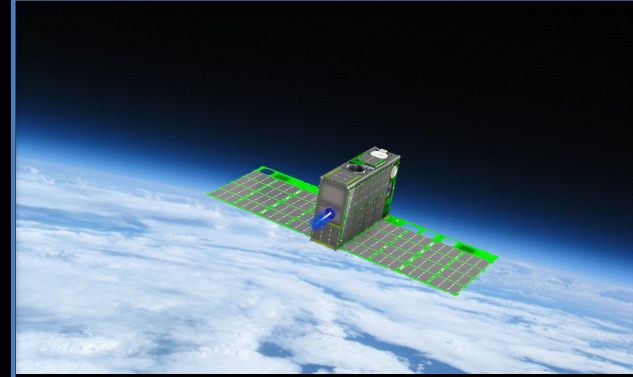
The 12U Courier CubeSat contains a compact, high impulse solar electric propulsion module. The mission will demonstrate a Halo Hall Effect Thruster which operates between 85-175 watts.

Image Credits: ExoTerra Resource, LLC.



Accion's Tiled Ionic Liquid Electro spray 3. The compact, modular electric system uses a non-volatile ionic salt propellant.

Image Credits: Accion Systems, Inc.



A 6U Dual Propulsion Experiment CubeSat. Both propulsion systems, the Fiber-fed Pulsed Plasma Thruster and Monofilament Vaporization Propulsion, were developed with NASA SBIR funding.

Image Credits: CU Aerospace, LLC.

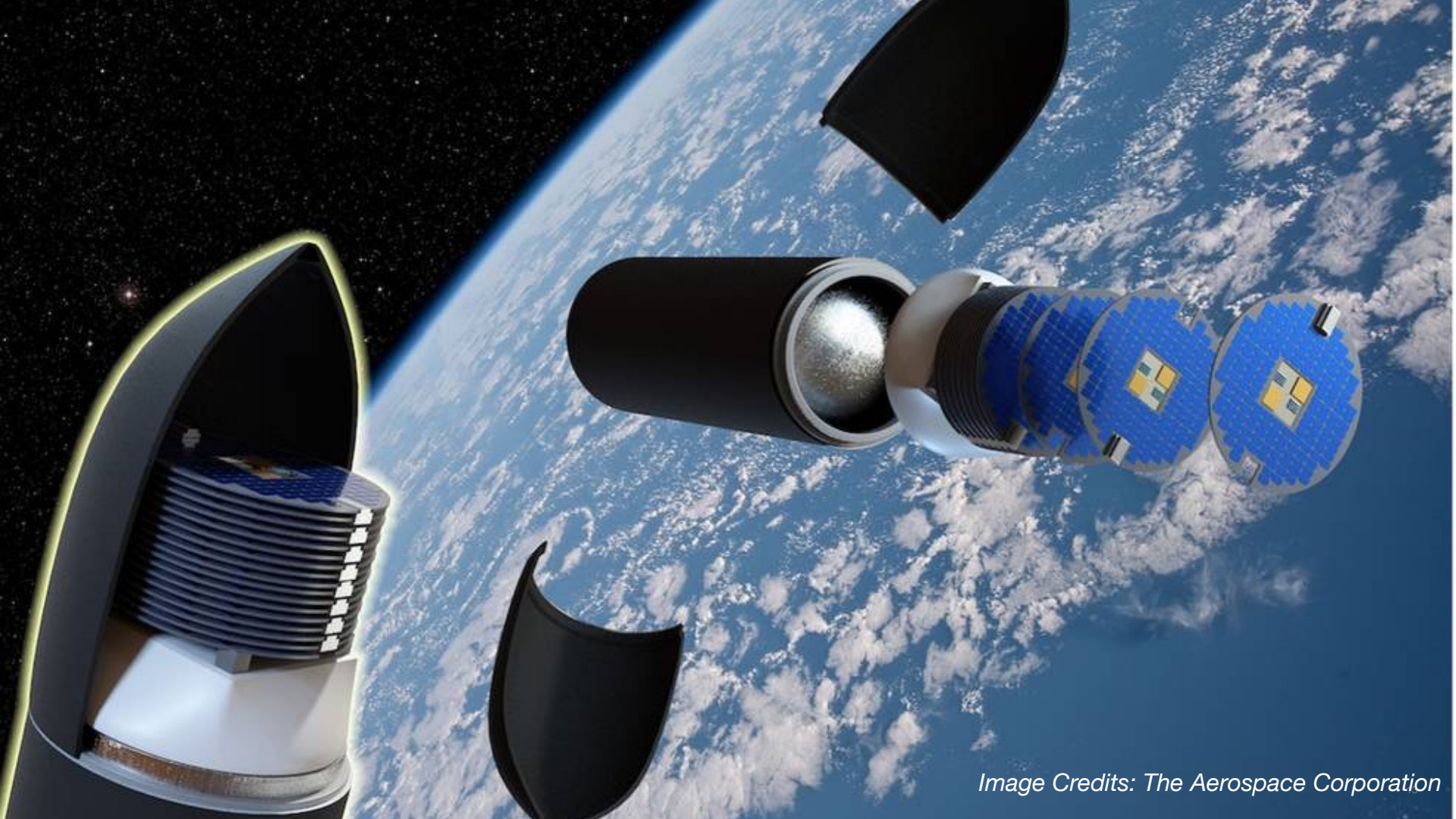
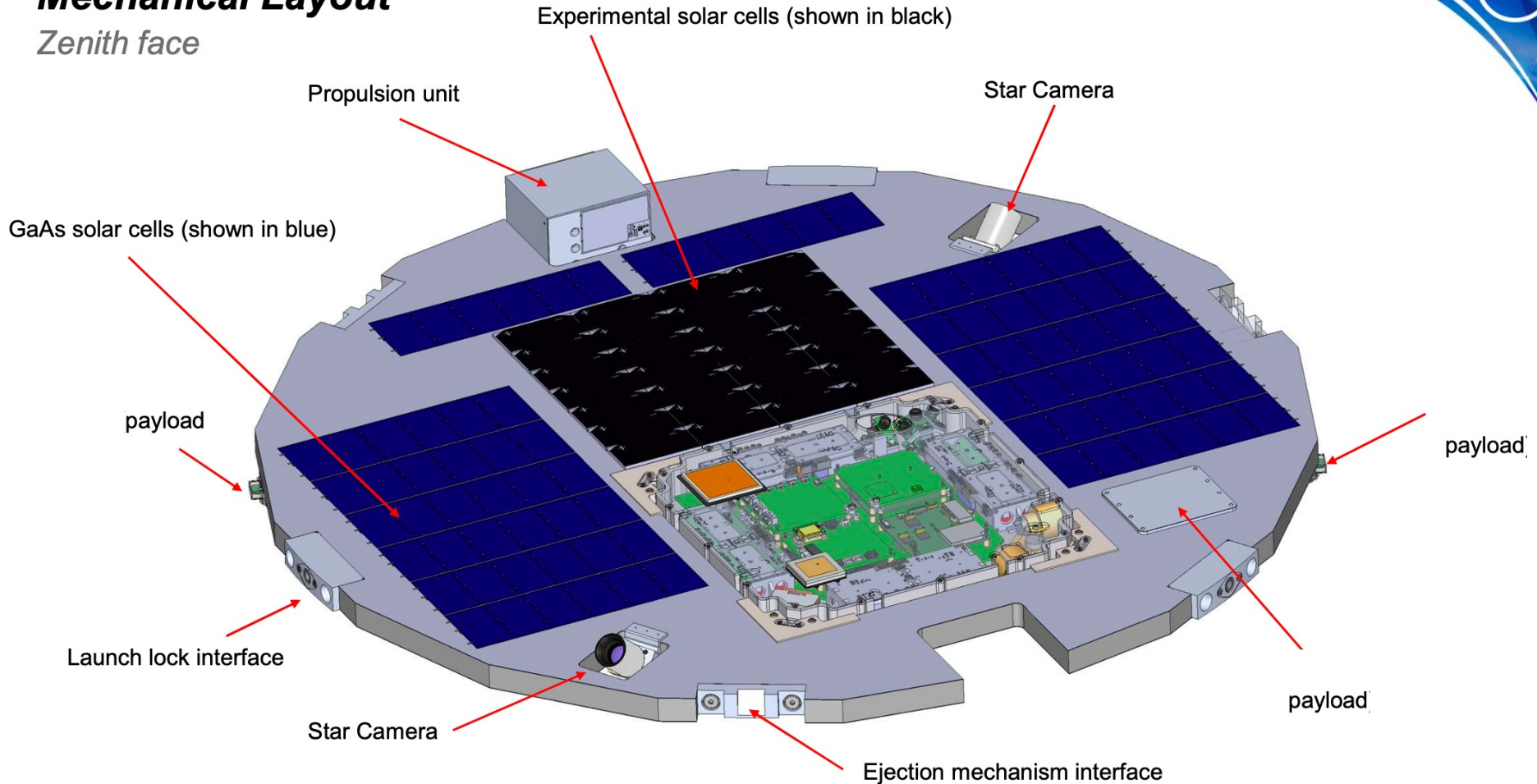


Image Credits: The Aerospace Corporation

Mechanical Layout

Zenith face



Mechanical Layout

Nadir face

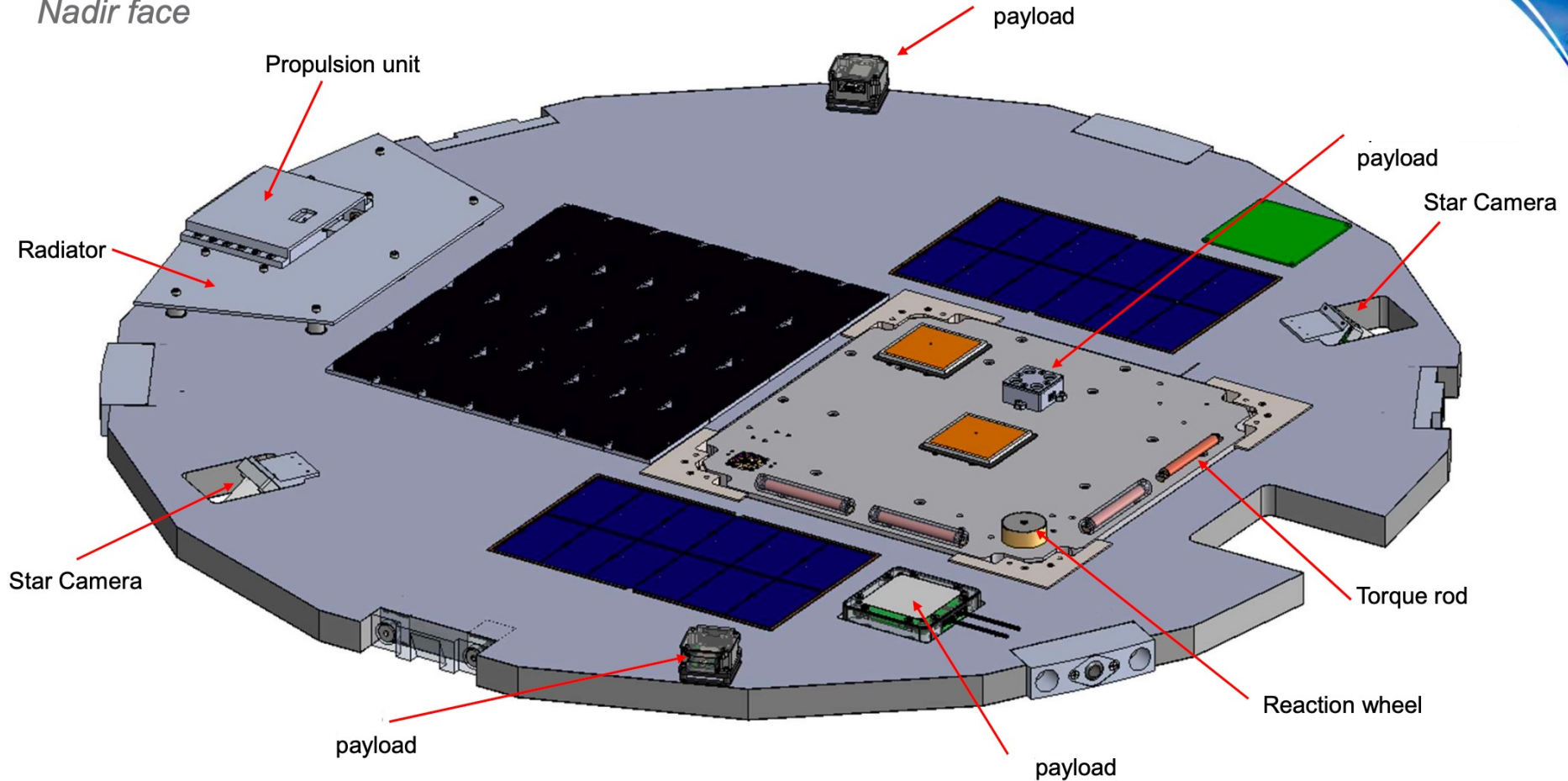
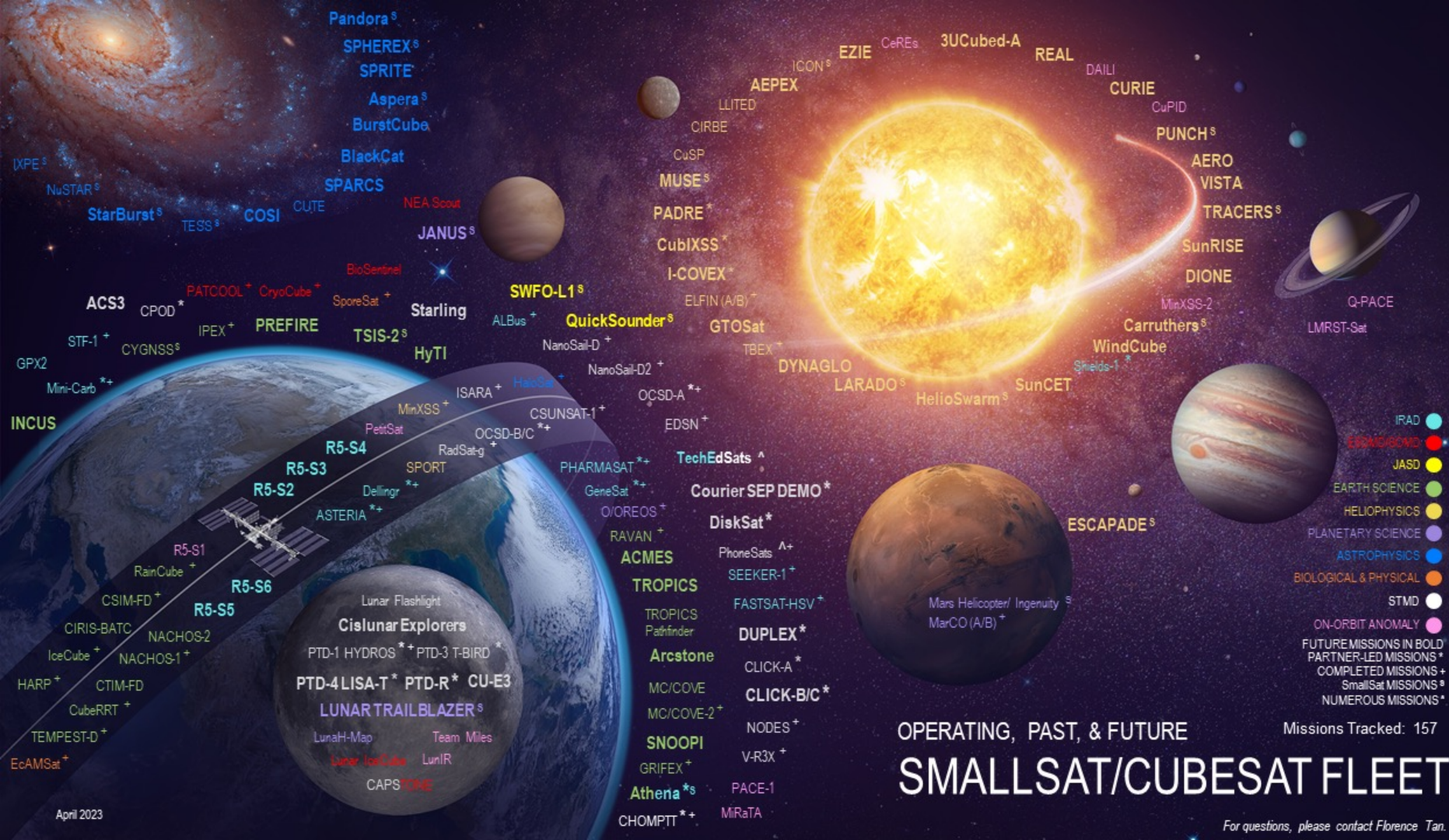


Image Credits: The Aerospace Corporation







Thu Jun 1, 9:12 PM

6 min

33°

10° above WNW

10° above SSE

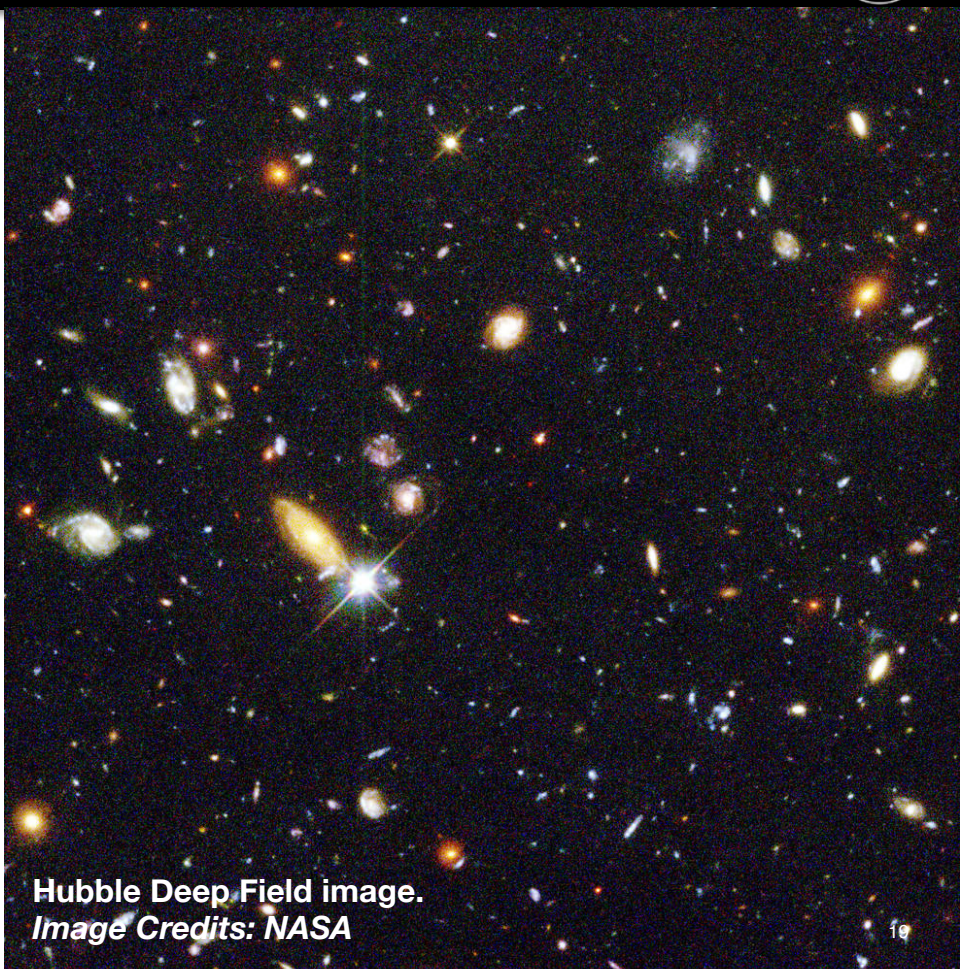
Image Credits: NASA

NASA James Webb Space Telescope



Webb's First Deep Field image.

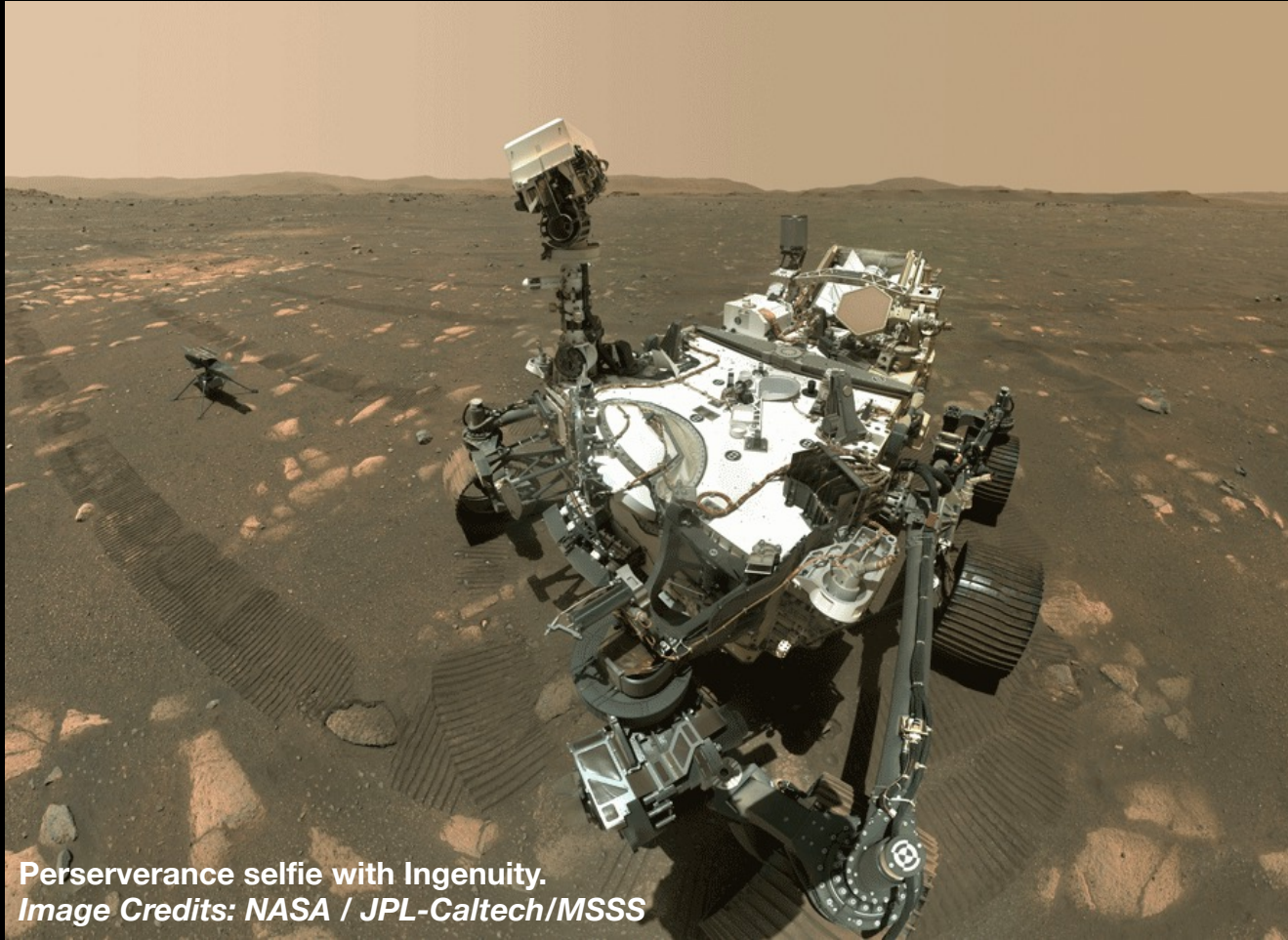
Image Credits: NASA, ESA, CSA, and STScI



Hubble Deep Field image.

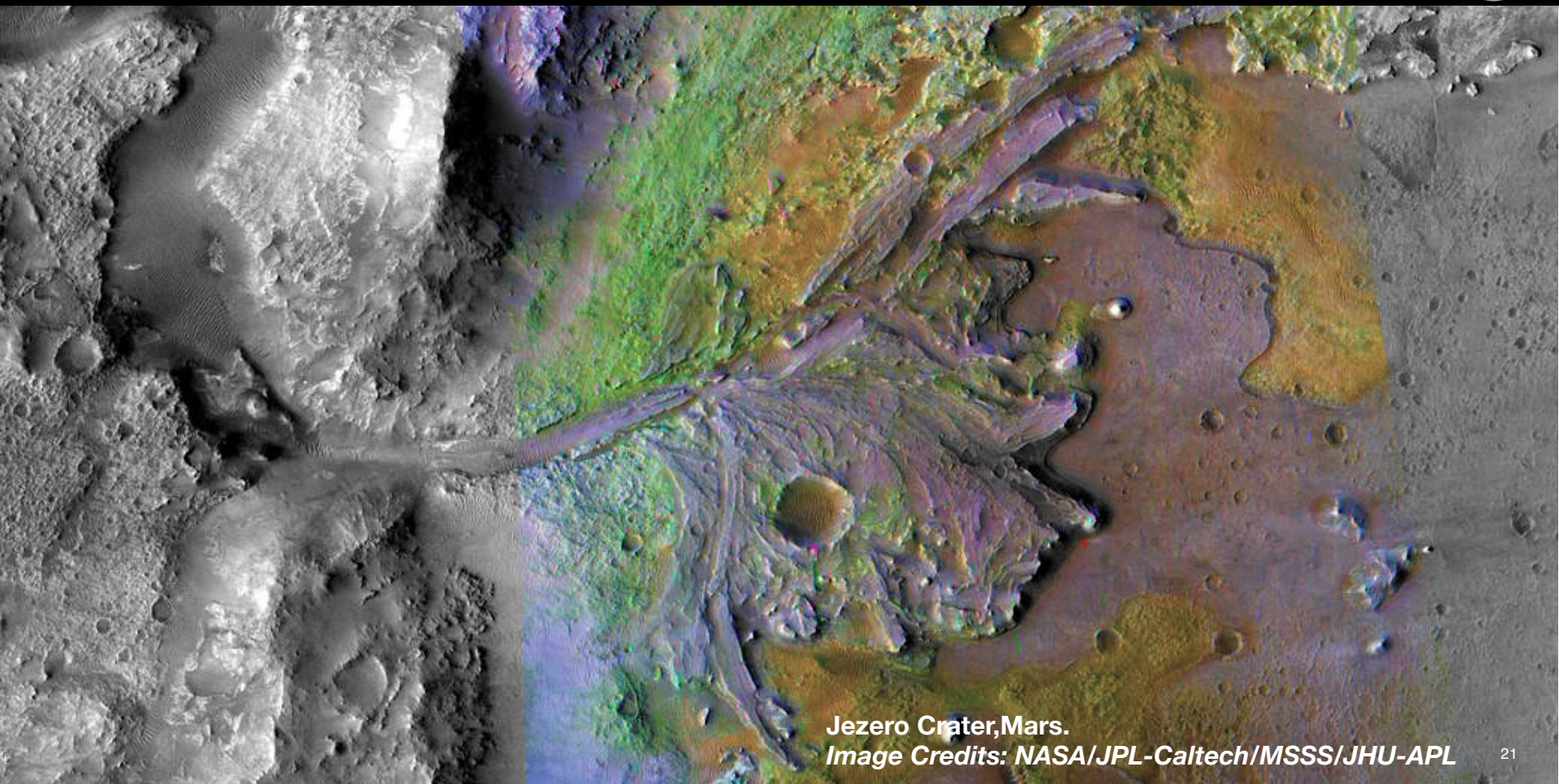
Image Credits: NASA

NASA Mars 2020 – Perseverance Rover with Ingenuity Mars Helicopter



Perseverance selfie with Ingenuity.
Image Credits: NASA / JPL-Caltech/MSSS

NASA Mars 2020 Mission Destination – Jezero Crater, Mars



Jezero Crater, Mars.

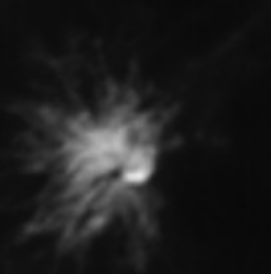
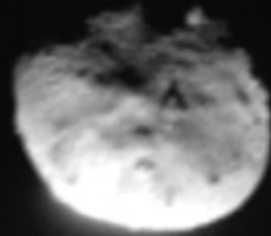
Image Credits: NASA/JPL-Caltech/MSSS/JHU-APL

DART: LAUNCH NOVEMBER '21
IMPACT 26 SEPTEMBER '22 DIDYMOS BINARY ASTEROID



Image Credits: NASA

NASA's Double Asteroid Redirection Test (DART) Light Italian CubeSat for Imaging of Asteroids (LICIACube)



ASI's LICIACube satellite acquired this image just before its closest approach to the Dimorphos asteroid, after the Double Asteroid Redirect Test, or DART mission, purposefully made impact on Sep. 26, 2022. Didymos, Dimorphos, and the plume coming off of Dimorphos after DART impact are clearly visible. Image *credits*: ASI/NASA

NASA's Artemis Program



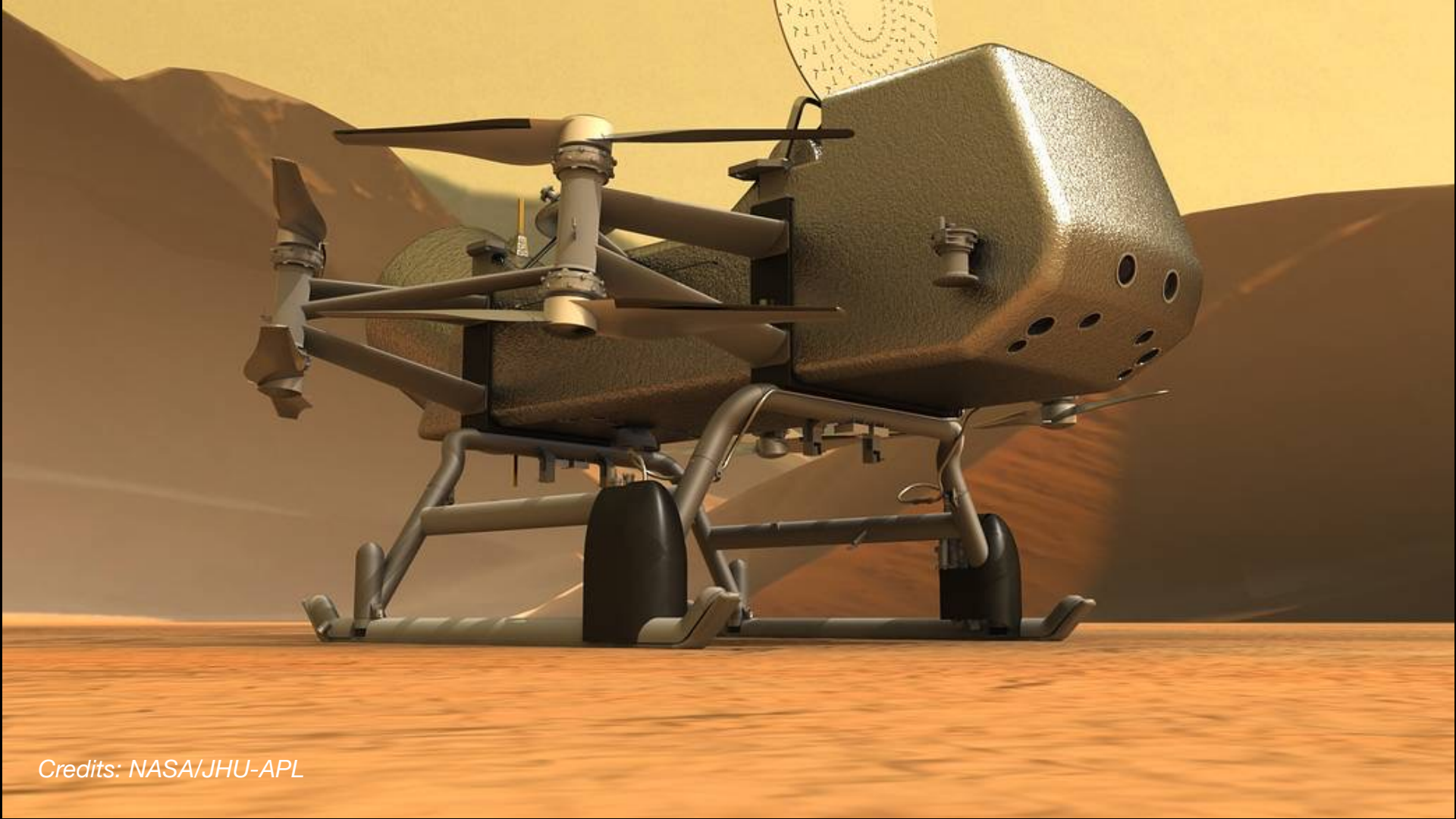
Orion Gazes at Moon Before Return to Earth
Image Credits: NASA



ARTEMIS II

FOR ALL HUMANITY





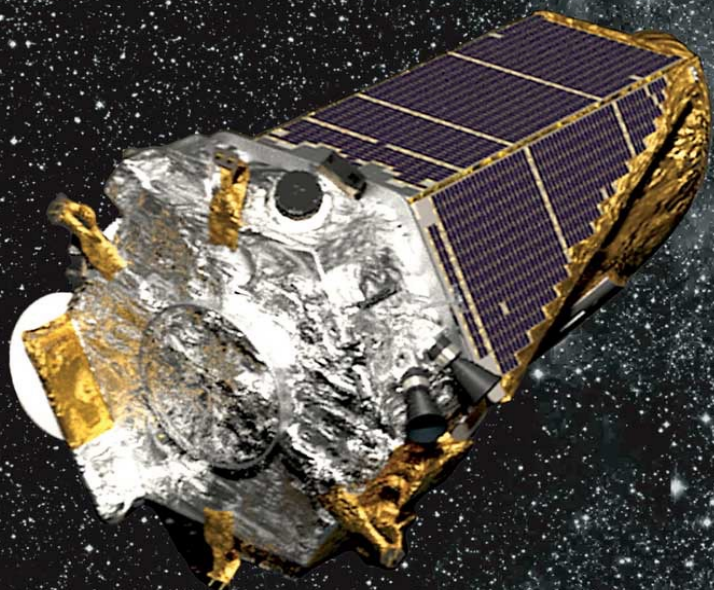
Credits: NASA/JHU-APL



Credits: NASA/JHU-APL



Credits: NASA



Credits: NASA

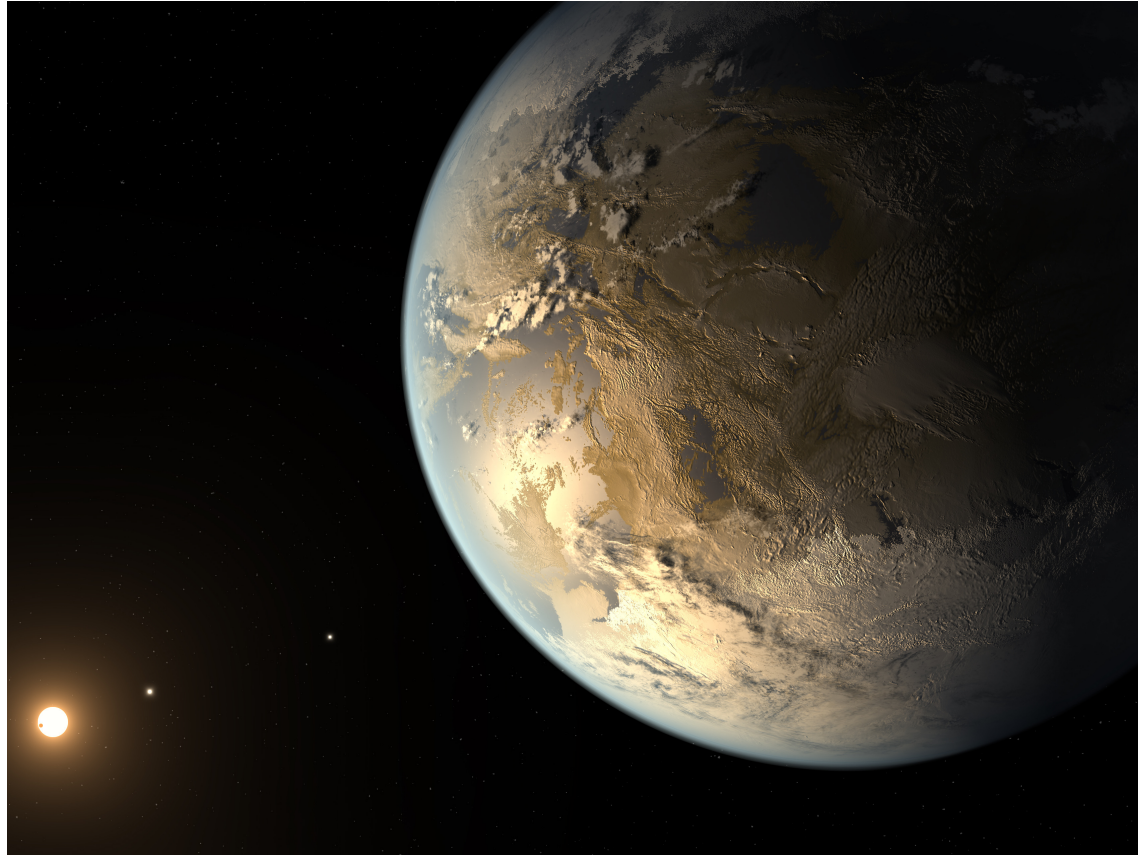
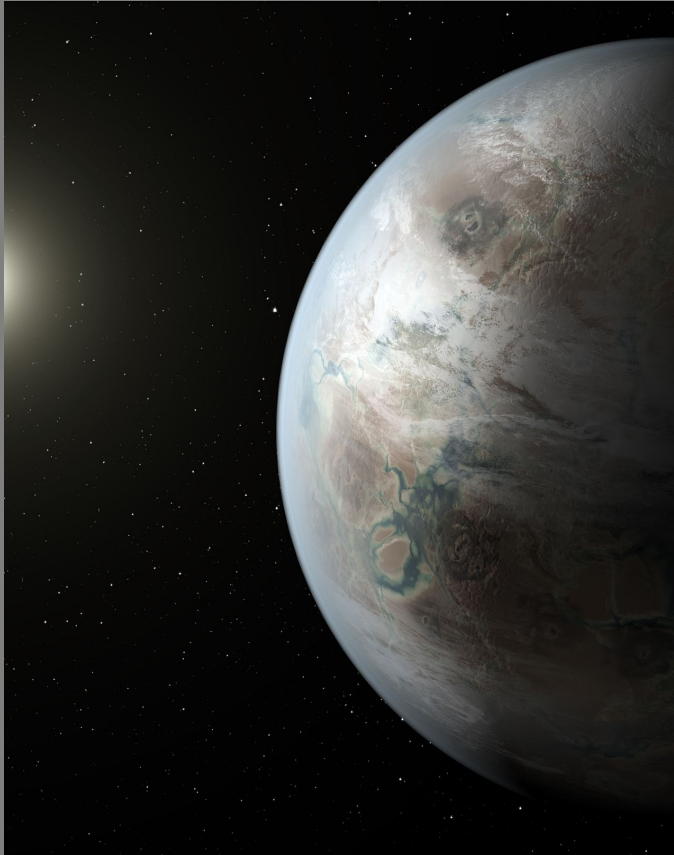


BRIGHTNESS



TIME IN HOURS

Credits: NASA





***The Occurrence of Rocky Habitable-zone Planets around Solar-like Stars from Kepler Data
Steve Bryson¹, Michelle Kunimoto², Ravi K. Kopparapu³, Jeffrey L. Coughlin^{1,4}, William J.
Borucki¹, David Koch^{1,46}, Victor Silva Aguirre⁵, Christopher Allen⁶, Geert Barentsen⁷, Natalie
M. Batalha⁸. Published 2020 December 22 • © 2020. The Author(s). Published by the
American Astronomical Society.
The Astronomical Journal, Volume 161, Number 1***

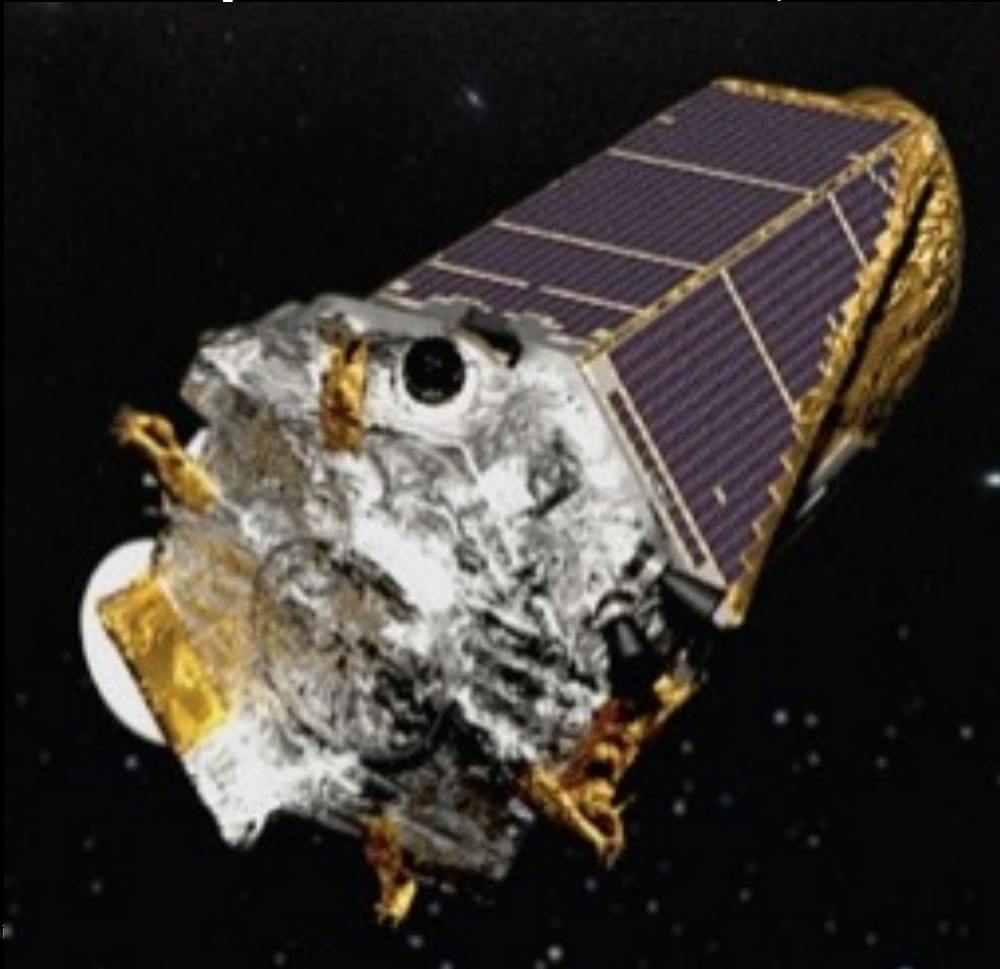
Table 5
Number of Habitable Zone Planets per Star for Various Ranges of Planet Radii and Host Star Effective Temperatures, Computed Using the Population Model Based on the hab2 Stellar Population with the Poisson Likelihood Method and Incorporating Uncertainties in Planet Radius, Instellation Flux, and Host Star Effective Temperature

Planet Radius	4800–6300 K		3900–6300 K		3900–5300 K (K Dwarfs)		5300–6000 K (G Dwarfs)	
	Low Bound–High Bound		Low Bound–High Bound		Low Bound–High Bound		Low Bound–High Bound	
	Conservative HZ							
Model 1								
0.5–1.5 $R_{\oplus}$	0.37^{+0.48}_{-0.21} – 0.60^{+0.90}_{-0.36}		0.35 ^{+0.43} _{-0.19} – 0.50 ^{+0.73} _{-0.29}		0.32 ^{+0.35} _{-0.17} – 0.42 ^{+0.50} _{-0.23}		0.38 ^{+0.50} _{-0.22} – 0.63 ^{+0.94} _{-0.38}	
1.5–2.5 $R_{\oplus}$	0.16 ^{+0.07} _{-0.05} – 0.24 ^{+0.14} _{-0.08}		0.15 ^{+0.06} _{-0.05} – 0.20 ^{+0.12} _{-0.07}		0.14 ^{+0.05} _{-0.04} – 0.17 ^{+0.07} _{-0.06}		0.17 ^{+0.06} _{-0.05} – 0.26 ^{+0.13} _{-0.09}	
0.5–2.5 $R_{\oplus}$	0.54 ^{+0.52} _{-0.24} – 0.85 ^{+0.99} _{-0.42}		0.51 ^{+0.46} _{-0.22} – 0.71 ^{+0.80} _{-0.34}		0.46 ^{+0.37} _{-0.19} – 0.60 ^{+0.52} _{-0.26}		0.56 ^{+0.53} _{-0.25} – 0.90 ^{+1.01} _{-0.45}	
Model 2								
0.5–1.5 $R_{\oplus}$	0.39^{+0.51}_{-0.23} – 0.56^{+0.83}_{-0.33}		0.36 ^{+0.44} _{-0.20} – 0.47 ^{+0.67} _{-0.27}		0.33 ^{+0.36} _{-0.18} – 0.40 ^{+0.47} _{-0.22}		0.40 ^{+0.53} _{-0.23} – 0.59 ^{+0.86} _{-0.35}	
1.5–2.5 $R_{\oplus}$	0.16 ^{+0.06} _{-0.05} – 0.24 ^{+0.13} _{-0.08}		0.15 ^{+0.06} _{-0.05} – 0.20 ^{+0.11} _{-0.07}		0.14 ^{+0.05} _{-0.04} – 0.17 ^{+0.07} _{-0.06}		0.17 ^{+0.06} _{-0.05} – 0.25 ^{+0.12} _{-0.08}	
0.5–2.5 $R_{\oplus}$	0.56 ^{+0.54} _{-0.26} – 0.81 ^{+0.91} _{-0.39}		0.51 ^{+0.47} _{-0.23} – 0.68 ^{+0.75} _{-0.32}		0.47 ^{+0.38} _{-0.20} – 0.58 ^{+0.50} _{-0.25}		0.57 ^{+0.56} _{-0.27} – 0.85 ^{+0.94} _{-0.42}	
Model 3								
0.5–1.5 $R_{\oplus}$	0.59^{+0.74}_{-0.34} – 0.79^{+0.95}_{-0.44}		0.43 ^{+0.63} _{-0.26} – 0.59 ^{+0.82} _{-0.35}		0.31 ^{+0.37} _{-0.17} – 0.43 ^{+0.51} _{-0.24}		0.64 ^{+0.72} _{-0.35} – 0.85 ^{+0.93} _{-0.46}	
1.5–2.5 $R_{\oplus}$	0.20 ^{+0.11} _{-0.07} – 0.29 ^{+0.15} _{-0.10}		0.15 ^{+0.13} _{-0.06} – 0.22 ^{+0.17} _{-0.09}		0.11 ^{+0.05} _{-0.04} – 0.16 ^{+0.07} _{-0.05}		0.22 ^{+0.07} _{-0.06} – 0.32 ^{+0.11} _{-0.09}	
0.5–2.5 $R_{\oplus}$	0.81 ^{+0.79} _{-0.39} – 1.11 ^{+1.02} _{-0.52}		0.60 ^{+0.71} _{-0.32} – 0.84 ^{+0.92} _{-0.44}		0.42 ^{+0.39} _{-0.20} – 0.60 ^{+0.54} _{-0.28}		0.87 ^{+0.75} _{-0.38} – 1.18 ^{+0.97} _{-0.51}	
Optimistic HZ								
Model 1								
0.5–1.5 $R_{\oplus}$	0.58^{+0.73}_{-0.33} – 0.88^{+1.28}_{-0.51}		0.54 ^{+0.64} _{-0.29} – 0.73 ^{+1.02} _{-0.41}		0.49 ^{+0.51} _{-0.26} – 0.60 ^{+0.69} _{-0.33}		0.60 ^{+0.75} _{-0.34} – 0.93 ^{+1.32} _{-0.55}	
1.5–2.5 $R_{\oplus}$	0.25 ^{+0.09} _{-0.06} – 0.35 ^{+0.19} _{-0.11}		0.23 ^{+0.09} _{-0.06} – 0.29 ^{+0.17} _{-0.10}		0.21 ^{+0.07} _{-0.06} – 0.25 ^{+0.09} _{-0.08}		0.26 ^{+0.09} _{-0.07} – 0.37 ^{+0.17} _{-0.11}	
0.5–2.5 $R_{\oplus}$	0.84 ^{+0.78} _{-0.37} – 1.25 ^{+1.39} _{-0.59}		0.78 ^{+0.68} _{-0.33} – 1.04 ^{+1.13} _{-0.47}		0.71 ^{+0.53} _{-0.28} – 0.86 ^{+0.72} _{-0.36}		0.87 ^{+0.79} _{-0.38} – 1.33 ^{+1.42} _{-0.63}	
Model 2								
0.5–1.5 $R_{\oplus}$	0.61^{+0.77}_{-0.35} – 0.83^{+1.17}_{-0.48}		0.55 ^{+0.66} _{-0.31} – 0.68 ^{+0.95} _{-0.39}		0.50 ^{+0.54} _{-0.27} – 0.57 ^{+0.66} _{-0.31}		0.63 ^{+0.79} _{-0.36} – 0.87 ^{+1.22} _{-0.51}	
1.5–2.5 $R_{\oplus}$	0.25 ^{+0.09} _{-0.06} – 0.34 ^{+0.17} _{-0.10}		0.23 ^{+0.09} _{-0.07} – 0.29 ^{+0.16} _{-0.10}		0.21 ^{+0.07} _{-0.06} – 0.25 ^{+0.09} _{-0.08}		0.26 ^{+0.08} _{-0.07} – 0.37 ^{+0.16} _{-0.11}	
0.5–2.5 $R_{\oplus}$	0.87 ^{+0.81} _{-0.39} – 1.19 ^{+1.28} _{-0.56}		0.79 ^{+0.70} _{-0.34} – 0.99 ^{+1.05} _{-0.45}		0.72 ^{+0.55} _{-0.29} – 0.84 ^{+0.69} _{-0.35}		0.90 ^{+0.83} _{-0.40} – 1.25 ^{+1.32} _{-0.59}	
Model 3								
0.5–1.5 $R_{\oplus}$	0.92^{+1.12}_{-0.52} – 1.14^{+1.35}_{-0.63}		0.67 ^{+0.96} _{-0.40} – 0.85 ^{+1.17} _{-0.50}		0.46 ^{+0.55} _{-0.26} – 0.61 ^{+0.70} _{-0.33}		1.00 ^{+1.08} _{-0.54} – 1.23 ^{+1.32} _{-0.65}	
1.5–2.5 $R_{\oplus}$	0.31 ^{+0.16} _{-0.11} – 0.42 ^{+0.21} _{-0.15}		0.22 ^{+0.20} _{-0.10} – 0.31 ^{+0.25} _{-0.13}		0.16 ^{+0.07} _{-0.05} – 0.23 ^{+0.10} _{-0.07}		0.34 ^{+0.10} _{-0.08} – 0.46 ^{+0.14} _{-0.12}	
0.5–2.5 $R_{\oplus}$	1.26 ^{+1.19} _{-0.59} – 1.60 ^{+1.43} _{-0.73}		0.92 ^{+1.07} _{-0.49} – 1.20 ^{+1.30} _{-0.62}		0.63 ^{+0.58} _{-0.29} – 0.85 ^{+0.75} _{-0.38}		1.35 ^{+1.11} _{-0.57} – 1.71 ^{+1.36} _{-0.71}	

National Aeronautics and Space Administration. **Notes.** The $\eta_{\oplus}$ values for model 1 are shown in boldface. The low and high bounds correspond to the constant- and zero-completeness extrapolation of Section 3.3.2.

As explained in Section 5.2 we recommend model 1 as the baseline model. Results from the other models are included for comparison.

September 25, 2060



Credits: NASA



Courtesy: Marco Grob for TIME

