

LUNAR PHOTON

ROCKET LAB'S MISSION TO THE MOON

Rocket Lab USA, Inc.
rocketlabusa.com



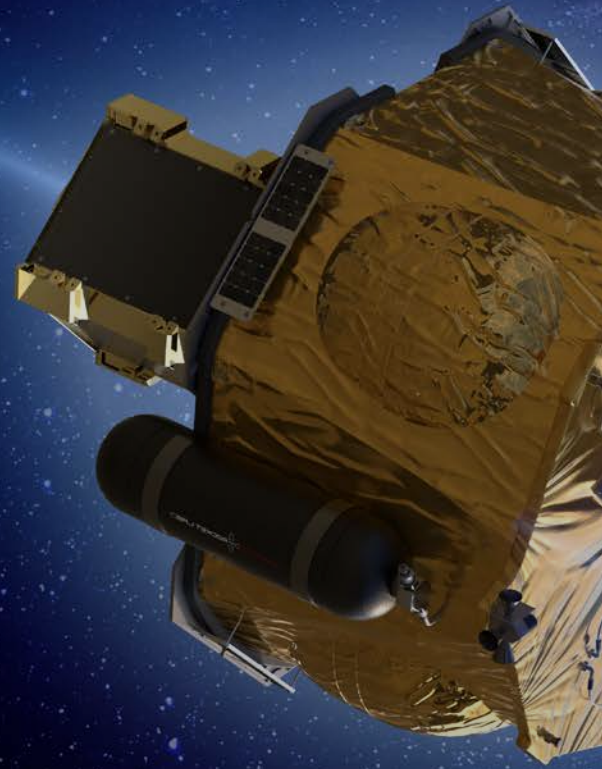
CAPSTONE MOON MISSION

In February 2020, Rocket Lab was selected as the launch service provider for NASA's CAPSTONE mission. The mission was executed using the Electron launch vehicle and a high-energy variant of Rocket Lab's Photon spacecraft called Lunar Photon.

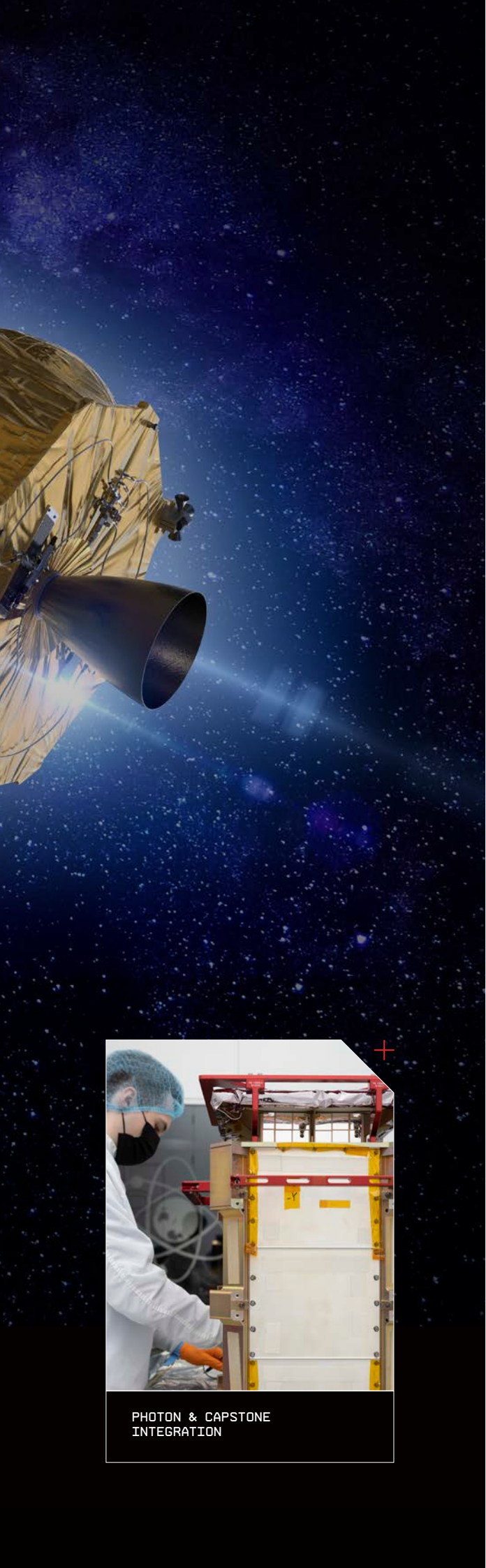
The CAPSTONE satellite is a microwave oven-sized CubeSat that is serving as the first spacecraft to test a unique, elliptical lunar orbit as part of the Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE).

As a pathfinder for Gateway, a Moon-orbiting outpost that is part of NASA's Artemis program, CAPSTONE is helping to reduce risk for future spacecraft by validating innovative navigation technologies and verifying the dynamics of this halo-shaped orbit.

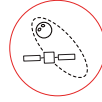
The orbit, formally known as a Near Rectilinear Halo Orbit (NRHO), is significantly elongated. Its location at a precise balance point in the gravities of Earth and the Moon, offers stability for long-term missions like Gateway and requires minimal energy to maintain. CAPSTONE's orbit also establishes a location that is an ideal staging area for missions to the Moon and beyond. The orbit will bring CAPSTONE within 1,000 miles of one lunar pole on its near pass and 43,500 miles from the other pole at its peak every seven days, requiring less propulsion capability for spacecraft flying to and from the Moon's surface than other circular orbits.



LUNAR PHOTON SPACECRAFT
WITH CAPSTONE SATELLITE



NASA'S MISSION OBJECTIVES



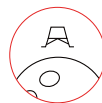
- › Verify the characteristics of a cis-lunar near rectilinear halo orbit for future spacecraft



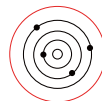
- › Demonstrate entering and maintaining this unique orbit that provides a highly-efficient path to the Moon's surface and back



- › Demonstrate spacecraft-to-spacecraft navigation services that allow future spacecraft to determine their location relative to the Moon without relying exclusively on tracking from Earth



- › Lay a foundation for commercial support of future lunar operations



- › Gain experience with small dedicated launches of CubeSats beyond low-Earth orbit, to the Moon, and beyond



PHOTON & CAPSTONE
INTEGRATION

ROCKET LAB'S ROLE IN CAPSTONE

Rocket Lab's
role in the
mission took
place over
two phases.

PHASE

01

LAUNCH

CAPSTONE was launched to low Earth orbit by Rocket Lab's Electron launch vehicle on June 28th, 2022. Around nine minutes after lift-off, the Lunar Photon spacecraft (carrying CAPSTONE) separated from the Electron launch vehicle's second stage at an altitude of 165 km, as planned. From this point, Rocket Lab's Lunar Photon spacecraft provided in-space transportation and thermal management to CAPSTONE.



CAPSTONE MISSION ELECTRON LAUNCH
LAUNCH COMPLEX 1, MAHIA NEW ZEALAND



CAPSTONE MISSION OPERATIONS & PAYLOAD DEPLOYMENT
MISSION CONTROL CENTER, AUCKLAND NEW ZEALAND

PHASE

02

ORBIT RAISING & BALLISTIC LUNAR TRANSFER

From this initial low Earth parking orbit, Photon's HyperCurie engine performed a series of seven orbit raising maneuvers over five days. With these precisely planned maneuvers using the Hyper Curie engine, Lunar Photon increased its velocity and the orbit apogee into a prominent ellipse around Earth. Six days after launch, HyperCurie ignited a final time, accelerating Lunar Photon to 24,500 mph (39,500 km/h) and setting it on ballistic lunar transfer. Within 20 minutes of this final burn on July 4th, 2022, Photon released CAPSTONE into deep space for the first leg of the CubeSat's solo flight.

CAPSTONE's journey to NRHO is expected to take around four months from Lunar Photon separation. Assisted by the Sun's gravity, CAPSTONE will reach a distance of 963,000 miles from Earth – more than three times the distance between Earth and the Moon – before being pulled back towards the Earth-Moon system.

Unlike the Apollo lunar missions of the 1960s and 70s, which took a free return trajectory to the Moon, this fuel efficient ballistic lunar transfer made it possible to send CAPSTONE to such a distant orbit using a small launch vehicle.

ABOUT PHOTON

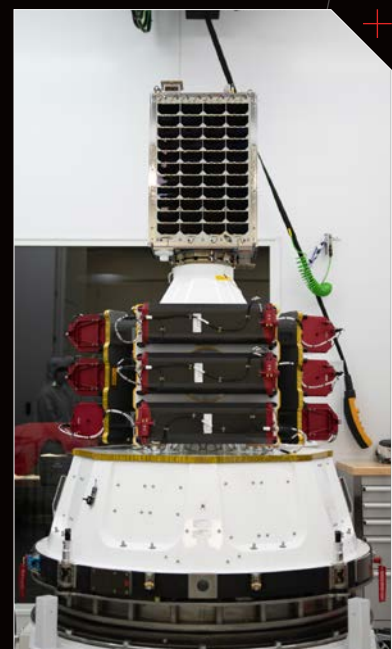
Photon is Rocket Lab's configurable family of satellites to meet mission requirements in LEO, MEO, GEO, lunar, and planetary destinations. The spacecraft that deployed CAPSTONE to a lunar trajectory is the high-energy variant, tailored for deep space missions.

The high-energy, deep space variant of Photon is a self-sufficient spacecraft capable of long-duration interplanetary cruise. Its power system is conventional, using photovoltaic solar arrays and lithium-polymer secondary batteries.

The attitude control system includes star trackers, sun sensors, an inertial measurement unit, three reaction wheels, and a cold-gas RCS. S-band or X-band RF ranging transponders can support communications with the Deep Space Network (DSN) or commercial networks and traditional deep space radiometric navigation methods. A Global Position System (GPS) receiver is used for navigation near Earth.

ΔV greater than 3 km/sec is provided by a storable, re-startable bi-propellant propulsion system called HyperCurie, evolved from the heritage Curie engine, using electric pumps to supply pressurized propellant to a thrust vector-controlled engine. The propellant tanks achieve high propellant mass fraction and can be scaled to meet mission-specific needs.

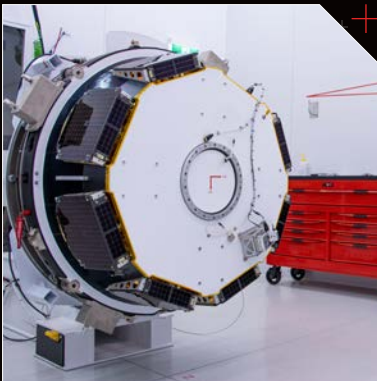
The high energy Photon variant is also being matured for the NASA Escape and Plasma Acceleration and Dynamics Explorers (ESCAPADE) mission, launching to Mars in 2024.



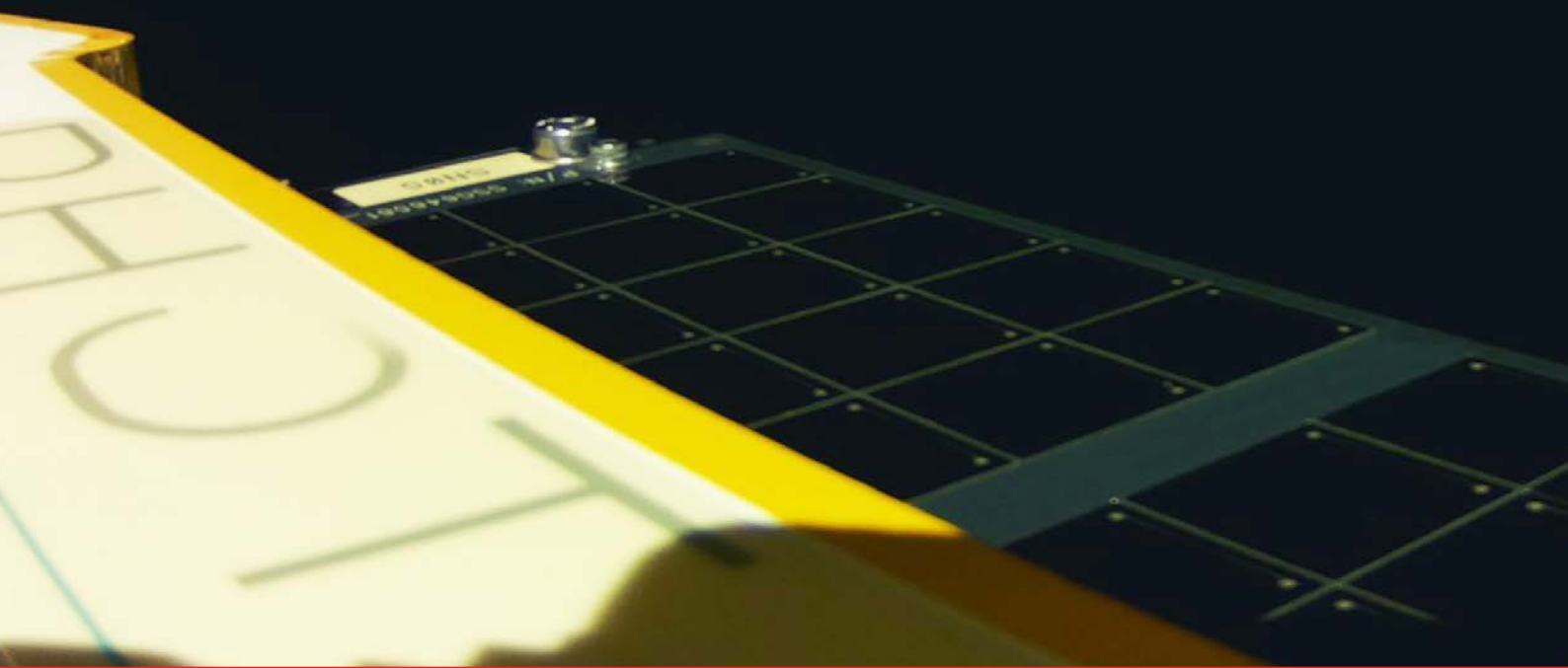
ELECTRON LAUNCH VEHICLE
KICK STAGE WITH CUBESATS
AND MICROSATELLITE
INTEGRATED FOR LAUNCH

**Vertically integrated
with in-house
satellite components
and discriminating
capabilities including:**

- + Precision attitude determination and control
- + High radiation tolerance avionics and power systems
- + High power (3 kW+) systems
- + Deep space capable communications and navigation
- + High delta-V, in-space chemical propulsion



PHOTON IN CLEANROOM 1,
LAUNCH COMPLEX 1
F14, JULY 2020



PHOTON HERITAGE

Lunar Photon joins a growing list of flight proven Photon spacecraft in orbit. First Light, Rocket Lab's first Photon spacecraft, was launched on the company's 14th Electron flight in August 2020. This mission demonstrated Photon's baseline power management system, coarse attitude control, and upgraded avionics.



Pathstone, Rocket Lab's second Photon spacecraft, launched on the company's 19th Electron flight in March 2021. The mission was a risk reduction pathfinder for the NASA CAPSTONE mission. First Light and Pathstone demonstrated a unique capability in operating as a Kick Stage for the launch phase of flight, before switching to satellite mode and continuing with a secondary mission.

For both missions, more than 100 kg of customer satellites were integrated onto the Photon spacecraft for launch. Around 60 minutes after lift-off, Photon's Curie engine performed an orbit raising burn to circularize its orbit and deploy the customer satellites. Shortly after deployment, a command was sent to Photon, transitioning it from Kick Stage to spacecraft mode. First Light and Pathstone are both still operated on orbit by Rocket Lab.

LUNAR PHOTON SPECIFICATIONS

DRY MASS:

55 kg /
121 lbs

ORBIT OPTIONS:

LEO, MEO,
GEO, Moon,
Mars, Venus

VOLUME/DIMENSION:

1.4 m x 1.1 m
x 1.0 m

AVIONICS:

Single string,
radiation
tolerant

PROPELLANT:

Hypergolic
bi-propellant,
storable and
re-startable

ENGINE:

HyperCurie with
480N of thrust and
a vacuum specific
impulse of 310s

SOLAR ARRAY POWER:

150 W (BOL),
body fixed solar
panels

COMMUNICATIONS:

Frontier-S radio
2.5 kbps to 1 Mbps
downlink, 2 kbps
uplink, ranging
and doppler for
navigation

LAUNCH VEHICLE COMPATIBILITY:

Electron Launch
Vehicle and ESPA
Grande Rideshare
Compatible

AVAILABLE PAYLOAD VOLUME:

Electron fairing

RECEIVE FREQUENCY RANGE:

2067-2110 MHz

TRANSMIT FREQUENCY RANGE:

2245-2290 MHz

DELTA-V:

**>3.2
km/sec**

MISSION ASSURANCE:

**NASA Class D
equivalent**

POINTING ACCURACY:

**0.3
deg**

**ONBOARD
DATA STORAGE:**

1-9GB

**LINK
PERFORMANCE:**

**G/TSys -30.6 dB/K,
EIRP -2 dBW
(On Boresight)**

**ENERGY
STORAGE:**

**Two 8s1p (33.6V
4200mAh) strings
connected in
parallel to SPOC**

ATTITUDE CONTROL:

**Star trackers,
reaction wheels,
cold gas reaction,
and fine sun
sensors**

PAYLOAD INTERFACES:

**Ethernet, USB
and Serial**

RHCP:

Up and down

SUPPORTED MISSION PROFILES



**Imaging and
remote sensing**



**In-space
transportation**



Communications



**Technology
Demonstration**

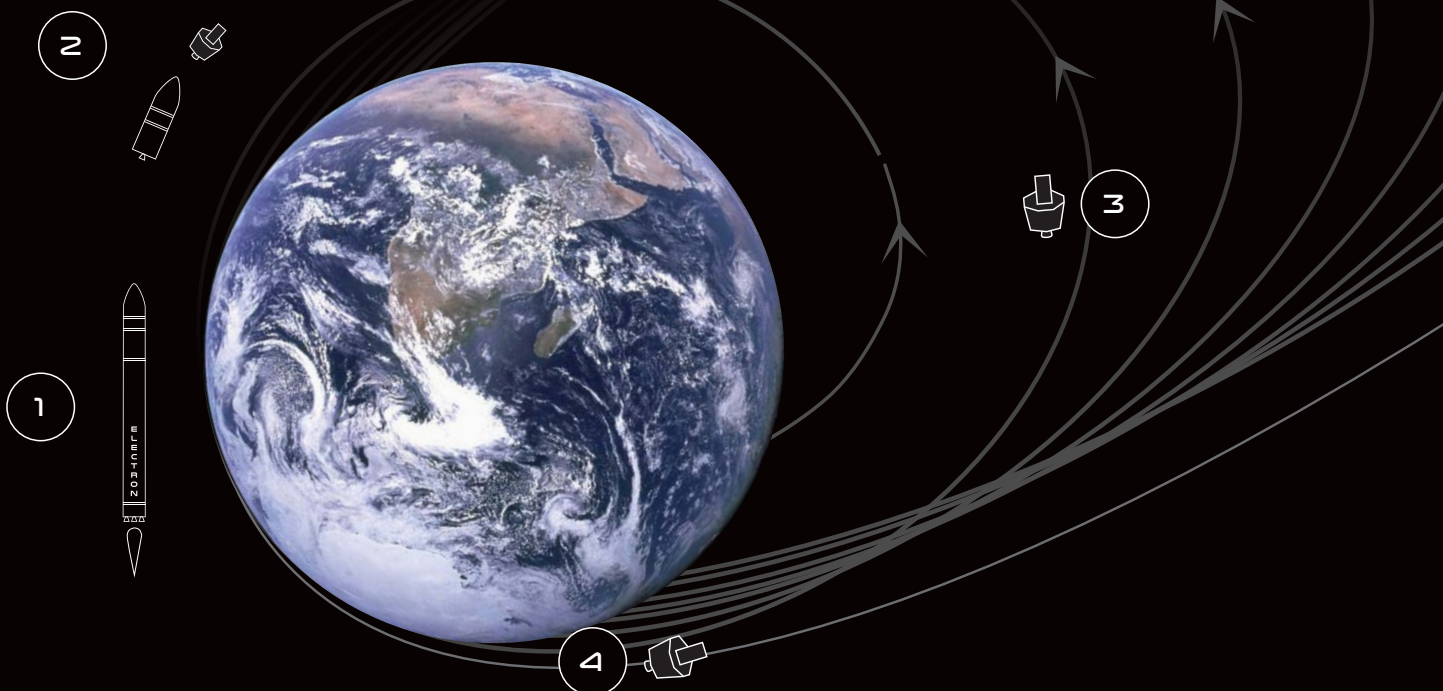
CAPSTONE MISSION TRAJECTORY

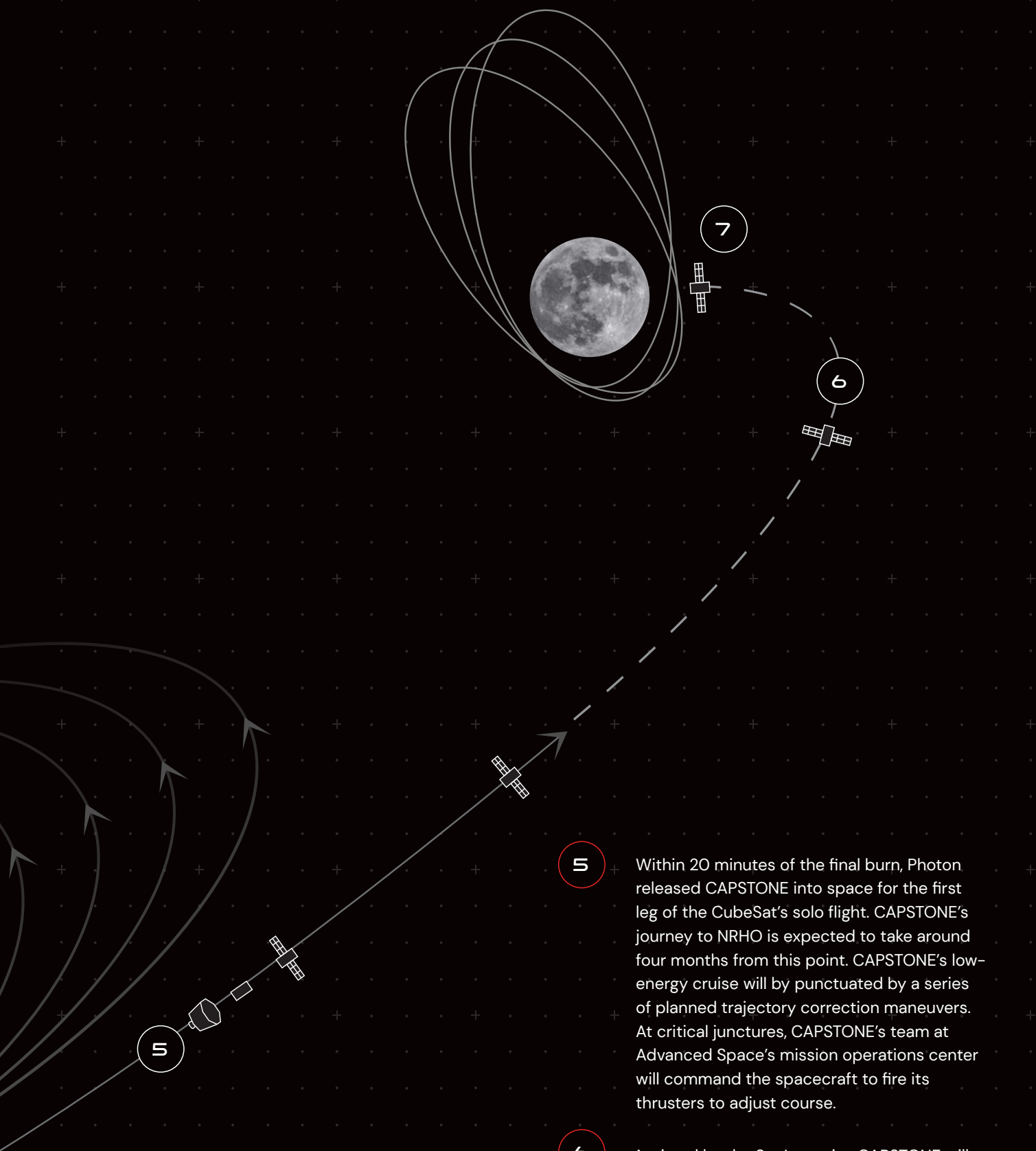
1 Electron lifted off from Launch Complex 1 with CAPSTONE integrated onto the Photon spacecraft bus inside the fairing.

2 Around nine minutes after lift-off, Electron's second stage separated from Photon, placing the spacecraft bus and its CAPSTONE payload into an initial low Earth orbit at an altitude of 165km.

3 From this initial parking orbit, Photon's HyperCurie engine performed a series of orbit raising maneuvers over five days. The HyperCurie engine ignited periodically to increase Photon's velocity, stretching its orbit into a prominent ellipse around Earth.

4 Six days after launch, HyperCurie ignited one final time, accelerating Photon to 24,500 mph (39,500 km/h) enabling it to escape low-Earth orbit and set CAPSTONE on a course for the Moon.

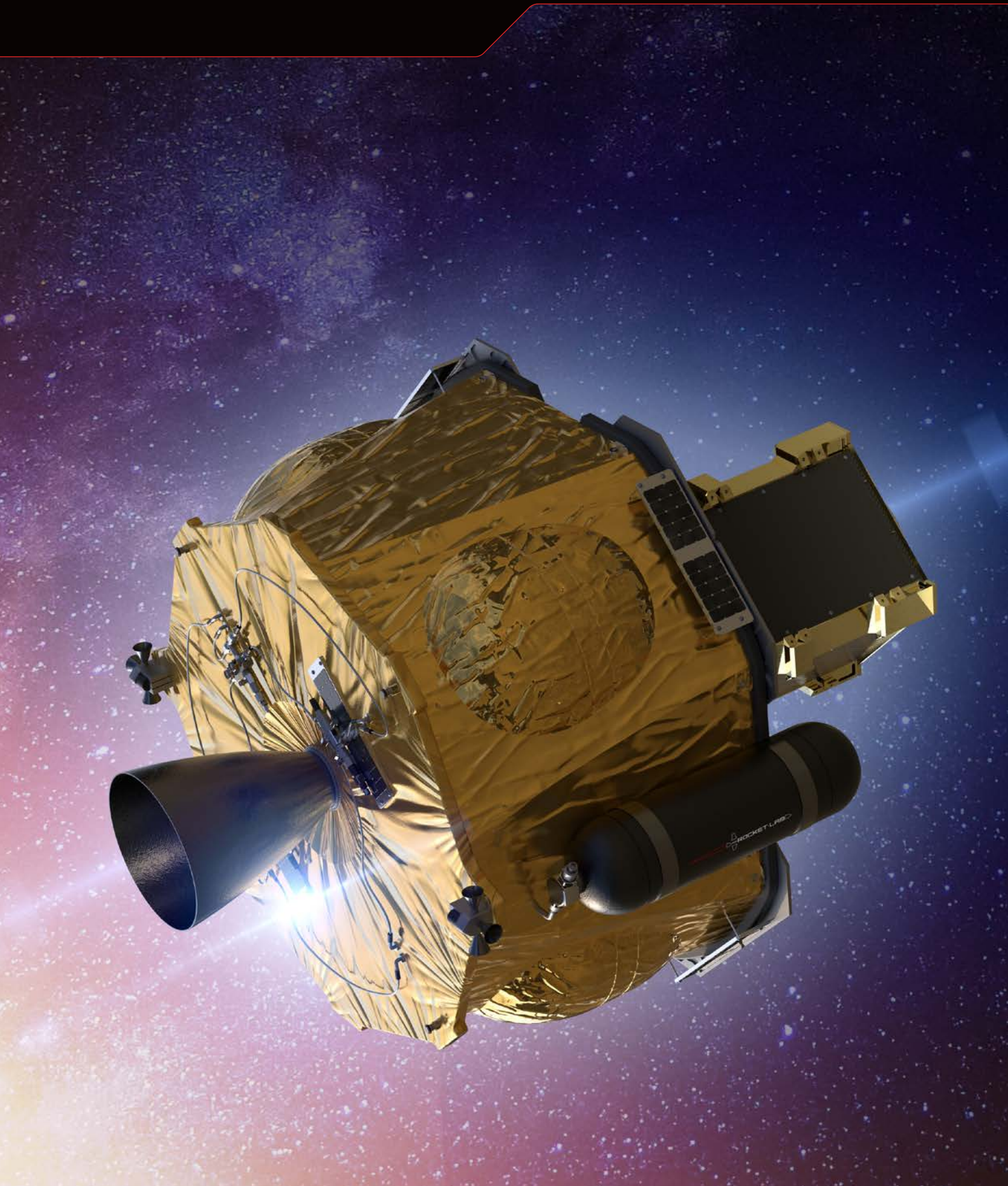


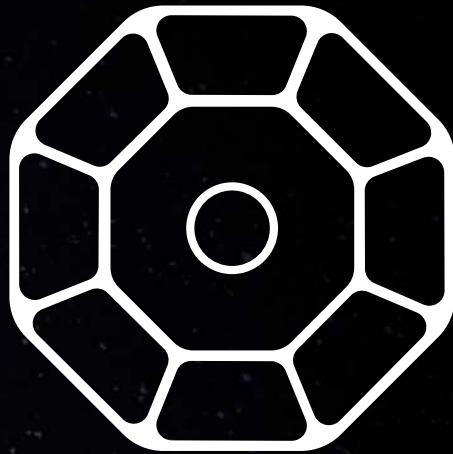


5 Within 20 minutes of the final burn, Photon released CAPSTONE into space for the first leg of the CubeSat's solo flight. CAPSTONE's journey to NRHO is expected to take around four months from this point. CAPSTONE's low-energy cruise will be punctuated by a series of planned trajectory correction maneuvers. At critical junctures, CAPSTONE's team at Advanced Space's mission operations center will command the spacecraft to fire its thrusters to adjust course.

6 Assisted by the Sun's gravity, CAPSTONE will reach an altitude of 963,000 miles (1.5 million km) from Earth – more than three times the distance between the Earth and the Moon – before being pulled back towards the Earth-Moon system.

7 Once successfully inserted into the orbit, CAPSTONE is expected to remain there for at least six months, allowing NASA to study the orbit dynamics.





PHOTON

CONFIGURABLE INTERPLANETARY SPACECRAFT

BOOK YOUR PHOTON TODAY



rocketlabusa.com
media@rocketlabusa.com
[@rocketlab](https://twitter.com/rocketlab)
[@ RocketLabUSA](https://www.instagram.com/RocketLabUSA)