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Bringing Deep Space Missions within Reach for Small Spacecraft

Richard French, Ehson Mosleh, Christophe Mandy, Richard Hunter, Jonathan Currie, Doug Sinclair, Peter Beck

Rocket Lab
3881 McGowen Street, Long Beach, CA 90808; (714) 465 5737 x 164
r.french@rocketlabusa.com

ABSTRACT

There is growing interest in using small spacecraft for science and exploration beyond low Earth orbit, but these missions have been constrained to fly as secondary payloads on rideshare missions that launch infrequently and on less-than-ideal trajectories.

Regular, dedicated, low-cost science missions to planetary destinations can be enabled by Rocket Lab's high-ΔV small spacecraft, the high-energy Photon, supporting expanding opportunities for scientists and increasing the rate of science return. High-energy Photon can launch on Rocket Lab's Electron launch vehicle to precisely target escape asymptotes for planetary small spacecraft missions with payload masses up to ~40 kg without the need for a medium or heavy lift launch vehicle. High-energy Photon can also fly as a secondary payload on an EELV Secondary Payload Adapter (ESPA) Grande port or on other launch vehicles, like Neutron. This paper describes planetary small spacecraft currently in development that leverage Rocket Lab's deep space capabilities, including missions to the Moon, Venus, and Mars.

The high-energy Photon will be demonstrated on the NASA Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) mission, launching in 2021. CAPSTONE is expected to be the first spacecraft to operate in a Near Rectilinear Halo Orbit (NRHO) around the Moon, with high-energy Photon delivering NASA's 12U technology demonstration CubeSat on a Ballistic Lunar Transfer using a phasing orbit approach. The CAPSTONE high-energy Photon will launch on Electron. While NASA performs the primary mission, Rocket Lab plans to execute a secondary mission to demonstrate the high-energy Photon deep space operations capabilities with a lunar flyby.

Rocket Lab has also made the engineering and financial commitment to fly a private mission to Venus in 2023 to help answer the question, "Are we alone in the universe?" The mission will deploy a small probe into the atmosphere in search of biomarkers. The mission is planned for launch in May 2023 on Electron from Rocket Lab's Launch Complex-1. The mission will follow a hyperbolic trajectory with the high-energy Photon performing as the cruise stage and then as a communications relay after deploying a small probe for the science phase of the mission.

In early 2021, Rocket Lab was awarded a contract for the preliminary design of two Photon spacecraft for the Escape and Plasma Acceleration and Dynamics Explorers (ESCAPADE) mission. ESCAPADE is a twin-spacecraft science mission that will orbit a pair of spacecraft around Mars to understand the structure, composition, variability, and dynamics of Mars' unique hybrid magnetosphere. After launch as secondary payloads on a commercial launch vehicle provided by NASA, the two spacecraft will each execute a series of burns with the Hyper Curie engine to prepare for and execute the Trans-Mars Injection (TMI), perform an 11-month interplanetary cruise with several trajectory correction maneuvers (TCMs), and then perform the Mars Orbit Insertion (MOI) burns to insert into elliptical orbits around Mars. ESCAPADE is undergoing a NASA preliminary design review and a confirmation review in the summer of 2021 to evaluate whether the mission proceeds to implementation and flight.

OVERVIEW

Regular, low-cost Decadal-class science missions to planetary destinations enabled by small high-ΔV spacecraft, like the high-energy Photon, and dedicated small launch vehicles, like Electron, support expanding opportunities for scientists and increasing the rate of science return (Refence 1). The high-energy Photon can launch on Electron to precisely target escape asymptotes for planetary small spacecraft missions with payload masses up to ~40 kg without the need for a medium or heavy lift launch vehicle. The high-energy Photon can also launch as a secondary payload or on other launch vehicles, like Neutron, with even greater payload masses to deep-space science targets.

This paper describes planetary small spacecraft missions that leverage Rocket Lab's deep space capabilities, including to the Moon, Venus, and Mars.

PHOTON

Rocket Lab's Photon small spacecraft (Table 1) is based on the Electron Kick Stage, leveraging numerous components that have significant flight heritage, like the Curie engine, an in-house designed and developed in-space propulsion system. Photon evolves the Kick Stage by incorporating high-power generation, high-accuracy attitude determination and control, enhanced propulsion subsystems, and radiation-tolerant avionics to provide a bundled launch-plus-satellite offering. Photon's flight computer acts as the flight computer for Electron during the launch phase and the reaction control system (RCS) used in orbit is also used for Stage 2 roll-control. Photon is not standardized but rather is configurable for a range of missions. A high-energy Photon variant, described below, is in qualification by Rocket Lab for deep space missions to the Moon, Venus, and Mars.

First Light, Rocket Lab's first satellite (Figure 1), was launched on Flight 14 and is demonstrating Photon's baseline power management system, coarse attitude control, and upgraded avionics. Pathstone, Rocket Lab's second Photon satellite, launched on Flight 19 and is performing risk reduction for the National Aeronautics and Space Administration (NASA) Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) mission, also described below.

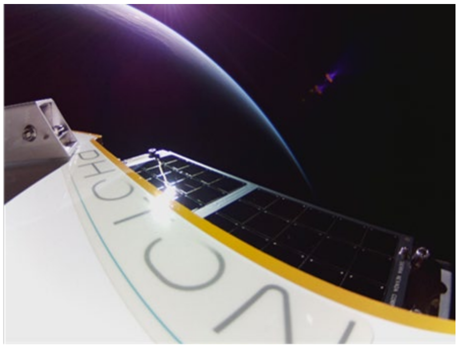

Figure 1: First Light successfully demonstrated Photon subsystems on Flight 14

Table 1: Photon Specifications

Specification	Photon	High-Energy Photon
Payload mass (maximum)	~225 kg (40-degree inclination) ~150 kg (98-degree inclination)	~40 kg (Electron) ~80 kg (GTO rideshare)
Payload volume	Electron standard fairing; extended and expanded fairing options available	
Payload power (orbit average)	Scalable Up to 600 W	Scalable up to 150 W
Payload power (peak)	Scalable from 1.5 kW	Scalable up to 300 W
Bus voltage (nominal)	28 V unregulated, regulated (optional)	
Payload thermal	Isolated or coupled interface, operational/survival heaters, temp sensors	
Propulsion	Pressure-fed, storable bi-propellant or pump-fed, storable bi-propellant	
Delta-V	Scalable from 50 m/sec to >4 km/sec	
Pointing accuracy	<10 arcsec (fine pointing)	
Pointing stability	<2 arcsec/sec (fine pointing)	
Pointing knowledge	<5 arcsec (fine pointing)	
Slew rate (maximum)	>3 deg/sec	
Orbit accuracy	<5 m, <1 cm/sec (on GPS)	<100 m, <2 cm/sec (lunar typical, post-OD)
Data storage	Scalable from 32 GB to >1 TB	
Telemetry, command, and payload data	L-, S-bands: up to 1 Mbps X-band: >50 Mbps Compatible with AFSCN, NEN, K-SAT$^{\text{LITE}}$, SSC	Mission-specific rates, DSN-compatible, SSC, other commercial
Encryption	AES-256 (software) or NSA Type 1 (hardware)	
Payload data interfaces	CAN, RS-422, RS-485, Space Wire, LVDS, USB, GigE, SATA, PCIe, Camera Link	
Time distribution	High precision (< 100 nsec) pulse per second	
Design life	3 years, minimum	
Radiation tolerance	Operate through SEU, Recover from SEL; 30 krad (Si), 37 MeV-cm2/mg, RDM = 1	
Reliability	Single string with selective redundancy; full redundancy options available	

HIGH-ENERGY PHOTON

The high-energy Photon (Figure 2) is a self-sufficient small 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 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 4 km/sec is provided by a storable, re-startable bi-propellant propulsion system called Hyper Curie, 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.

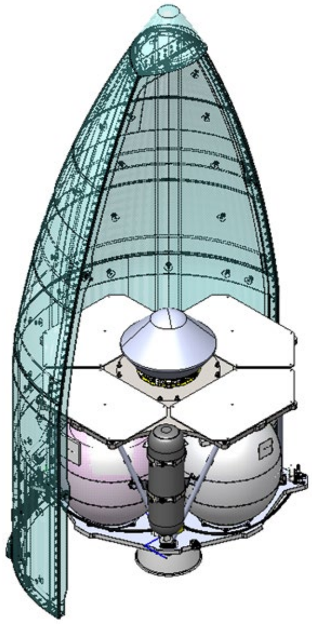

Figure 2: High-energy Photon and small Venus entry probe shown in an Electron fairing cutaway

ELECTRON

The high-energy Photon is designed for launch on Electron (Figure 3), Rocket Lab's dedicated small launch vehicle. Electron can lift up to 200 kg to a 500 km sun-synchronous orbit from either of two active, state-of-the-art launch sites: Launch Complex-1 (LC-1) on the Mahia Peninsula in New Zealand and Launch Complex-2 on Wallops Island, Virginia. As of May 2021, Electron has delivered 104 satellites to orbit, building a strong flight heritage with missions for both commercial and government customers including NASA, the Defense Advanced Research Projects Agency, the United States Air Force, and the National Reconnaissance Office.

Electron is a two-stage, all carbon composite launch vehicle with a Kick Stage, standing at 18-meter tall with a diameter of 1.2-meter and a lift-off mass of ~13,000 kg. Electron's engine, the 25 kN Rutherford, is fueled by liquid oxygen and kerosene fed by electric pumps. Rutherford is based on an entirely new propulsion cycle that makes use of brushless direct current electric motors and high-performance lithium polymer batteries to drive impeller pumps. Electron's Stage 1 uses nine Rutherford engines while Stage 2 requires just a single Rutherford vacuum engine. Rutherford is the first oxygen/hydrocarbon engine to use additive manufacturing for all primary components, including the regeneratively cooled thrust chamber, injector pumps, and main propellant valves. All Rutherford engines on Electron are identical, except for a larger expansion ratio nozzle on Stage 2 optimized for performance in near-vacuum conditions.

Figure 3: Electron small launch vehicle

Electron's Kick Stage circularizes the orbit after launch and is capable of engine restarts to deliver multiple payloads to a range of orbits, meet precise insertion requirements, and deorbit itself. The Kick Stage was first demonstrated in January 2018 and has flown successfully on every orbital mission since. The Kick Stage is powered by the 120 N Curie bi-propellent engine, is equipped with a cold gas (N_2) RCS for precision pointing, and houses the avionics, power, and communications subsystems that control Electron.

The high-energy Photon replaces Electron's standard Kick Stage for deep space missions. Photon's flight computer acts as the flight computer for Electron and the RCS used in cruise is also used for Stage 2 roll-control. By removing duplicate subsystems, Electron and the high-energy Photon increase mass to orbit that can be dedicated to more fuel or payload.

DEDICATED LAUNCH ON ELECTRON

Rocket Lab's dedicated small launch-enabled deep space missions use the high-energy Photon to target escape asymptotes with progressive phasing orbits to ensure robust, efficient, and accurate departure. Electron first delivers Photon to a circular parking orbit. After separating from Stage 2, Photon performs preprogrammed burns to establish a preliminary elliptical commissioning orbit. Photon then performs a series of burns through increasingly elliptical orbits, each time raising the apogee altitude while maintaining a nearly constant perigee. Breaking the departure across multiple maneuvers is an efficient approach to Earth escape. By holding burns close to perigee and limiting their duration, propulsive energy is efficiently spent raising apogee while avoiding the burn losses associated with long duration maneuvers.

Each phasing maneuver is followed by a planned number of phasing orbits at the new apogee altitude. Phasing orbits provide time for on-orbit navigation, maneuver planning, and conjunction screening. Each planned maneuver includes contingency options to mitigate conjunction events or missed maneuvers. After the nominal apogee raising maneuvers are performed, a final injection burn is executed to place Photon on an escape trajectory. Photon can fly integrated with science instruments or with another spacecraft that can be separated to improve staging performance.

All burns are terminated based on velocity using an onboard guidance algorithm that typically achieves better than ~1 m/sec execution accuracy. During ground station passes, GPS data is downlinked to support orbit determination and maneuver reconstruction. The maneuver reconstruction outputs a high accuracy estimate of the Hyper Curie engine performance – a key input into subsequent phasing maneuvers and, most importantly, the escape burn. By precisely determining the orbit and calibrating Hyper Curie over multiple phasing orbits, Rocket Lab's deep space mission approach ensures that Photon delivers an accurate and precise C3 at escape, a feature normally reserved for expensive, high-performance upper stages.

The phasing orbit approach also achieves a precise alignment to the required right ascension of the ascending node (RAAN) and Argument of Perigee (AOP) at escape. Photon experiences drift in RAAN while in the phasing orbits due to the Earth's gravitational harmonics. The nominal orbit raising profile, therefore, contains a series of RAAN drift-rate steps associated with each orbit raising segment. The launch time is biased to offset the launch RAAN from the required RAAN by the sum of the RAAN drifts that occur during the phasing orbits. This RAAN-rate profile is planned prior to launch but is adjusted in-flight to compensate for any error in the phasing orbit RAAN drift rates, for missed maneuvers, or other contingencies. Adjustment is achieved by varying the apogee altitude of the intermediate phasing orbits and the number of phasing orbits at each step. The phasing maneuvers can also be offset from perigee to actively adjust for any errors in the planned drift in target AOP.

SECONDARY GTO LAUNCH

The high-energy Photon can also be carried to orbit as a secondary payload on an EELV Secondary Payload Adapter (ESPA) Grande port (4-meter fairing compatible). While many mission designs are possible, by injecting directly into Geosynchronous Transfer Orbit (GTO), the high-energy Photon can access higher-energy trajectories to science targets with increased payload mass and is used as a reference design for many new mission formulations.

DEDICATED LAUNCH ON NEUTRON

Rocket Lab recently announced the Neutron medium lift launch vehicle (Figure 4). Neutron is designed for national security launch requirements and constellation deployments, among other missions, and will enable a new class of small spacecraft planetary missions, including to the outer planets. With an ~8-ton (metric) mass to low Earth orbit, a reusable first stage, and launching out of Wallops Island, VA in 2024, Neutron will provide greater than 1,200 kg of wet mass on a Venus direct transfer.

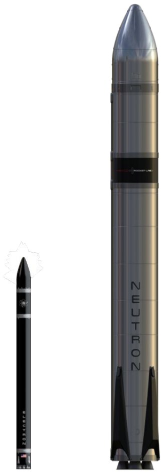

Figure 4: Neutron medium lift launch vehicle compared to Electron

HIGH-ENERGY PHOTON PERFORMANCE

Photon payload mass as a function of circular orbit altitude and orbit inclination is shown in Figure 5 for reference. Payload mass as a function of C3 is shown in Figure 6 for dedicated Electron launch of a 320 kg wet mass high-energy Photon and launch as a secondary payload to GTO. For the GTO trajectories, Photon is placed on a 250 x 35,786 km transfer orbit, performs a 200 m/sec maneuver to raise apogee to 110,000 km altitude, and then performs the injection burn. Spacecraft wet mass as a function of departure C3 for dedicated launch on Neutron, assuming a representative upper stage, is shown in Figure 7.

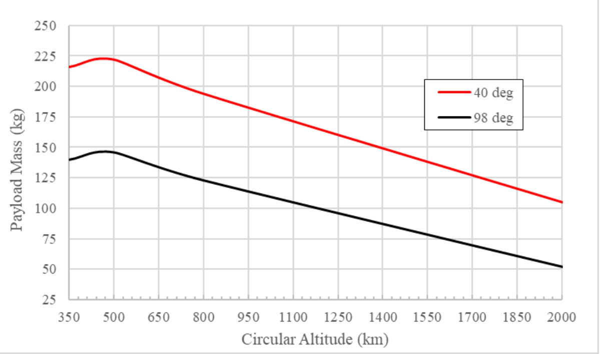

Figure 5: Photon payload mass for a representative configuration launched on Electron to circular orbit

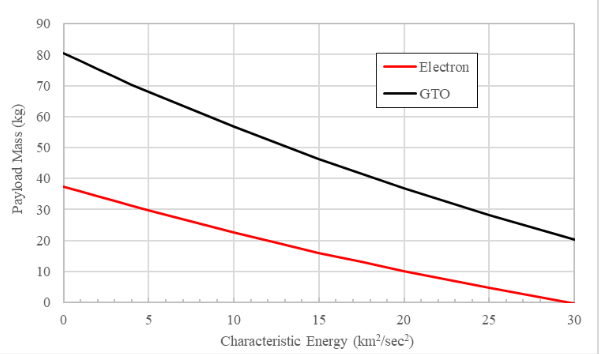

Figure 6: High-energy Photon performance when launched on a dedicated Electron deep space mission

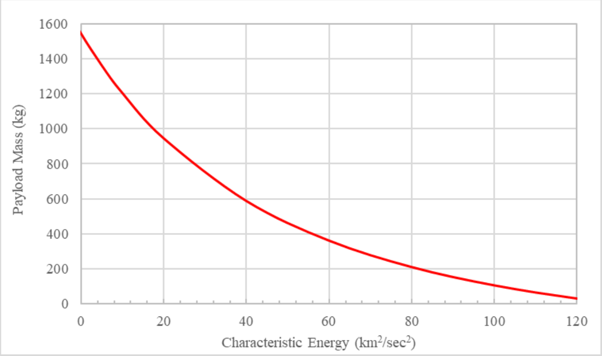

Figure 7: Neutron will enable a new class of planetary small spacecraft missions, including to the Outer planets

NASA CAPSTONE MISSION

In February 2020, Rocket Lab was selected as the launch service provider for the NASA Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) mission. CAPSTONE is a precursor mission for the Lunar Gateway, part of NASA's Artemis program. CAPSTONE will also be the first launch in the Artemis program. CAPSTONE is a technology demonstration mission led by Advanced Space of Boulder, CO that will verify the dynamics of the Near Rectilinear Halo Orbit (NRHO) around the Moon, demonstrate autonomous navigation relative to the Lunar Reconnaissance Orbiter, and demonstrate a ballistic lunar transfer (BLT) to achieve the NRHO.

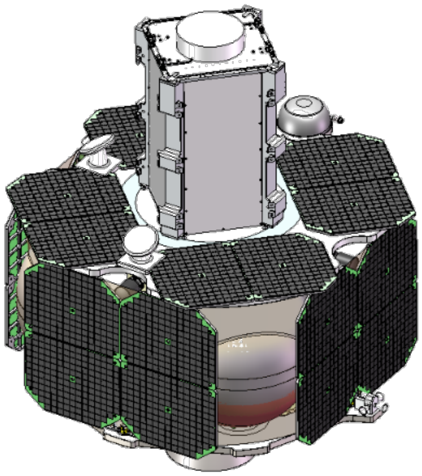

Figure 8: CAPSTONE mission high-energy Photon

CAPSTONE, launching in 2021, is expected to be the first spacecraft to operate in a NRHO around the Moon. A High-energy Photon (Figure 8) will deliver NASA's 37 kg, 12U technology demonstration CubeSat on the BLT using the phasing orbit approach described above

(Figure 9). The CAPSTONE spacecraft will separate shortly after the escape burn and then demonstrate communications and navigation technology after achieving the NRHO.

While NASA performs the primary mission, Rocket Lab plans to execute a secondary mission to demonstrate high-energy Photon deep space operations capabilities with a lunar flyby.

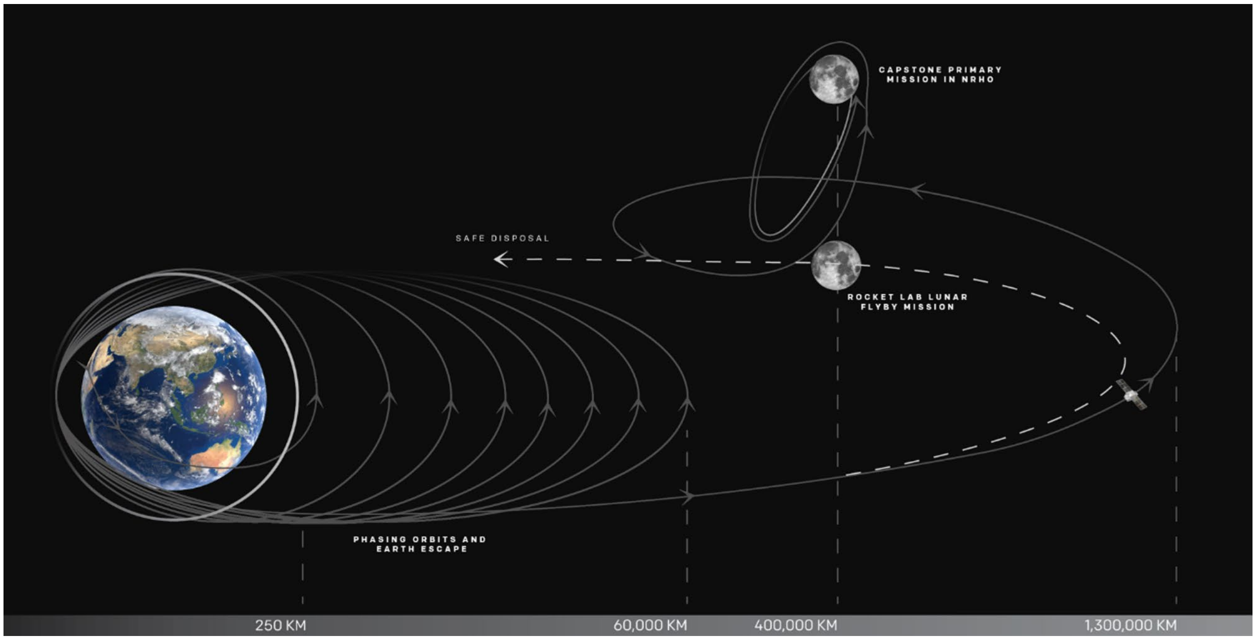

Figure 9: Rocket Lab will demonstrate deep space operations with a lunar flyby in 2021 during an extended mission after deploying the CAPSTONE spacecraft onto a ballistic lunar transfer

VENUS 2023 MISSION

Rocket Lab has made the engineering and financial commitment to fly a private mission to Venus (Figure 10) in 2023 to help answer the question, “Are we alone in the universe?”

The specific goals of Rocket Lab’s mission are:

1. To look for life!
2. Demonstrate a high-impact small planetary probe capability
3. Enable game changing, more regular Decadal-class planetary science using dedicated small launch vehicles and small spacecraft
4. Take the first step in a campaign of small missions to better understand Venus

The mission is planned for launch in May 2023 on Electron from Rocket Lab’s LC-1. The specific launch opportunity will be selected after a more thorough study of the transfer window sensitivities in the detailed design phase. The mission will follow a hyperbolic trajectory with the high-energy Photon performing as the cruise stage and then as a communications relay after deploying a small probe for the science phase of the mission.

Electron first delivers high-energy Photon to a circular parking orbit (Figure 11) around Earth and follows the same phasing orbit mission plan as described above to achieve Earth escape. Trajectory correction maneuvers (TCMs) using the Hyper Curie engine or integrated RCS are used to make fine adjustments to the trajectory and target the appropriate entry interface.

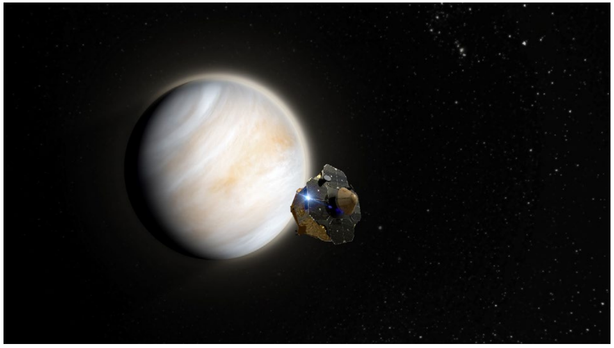

Figure 10: Rocket Lab’s Electron-launched private mission to Venus will deploy a small probe from a high-energy Photon in 2023 in a search for bio-markers in the atmosphere

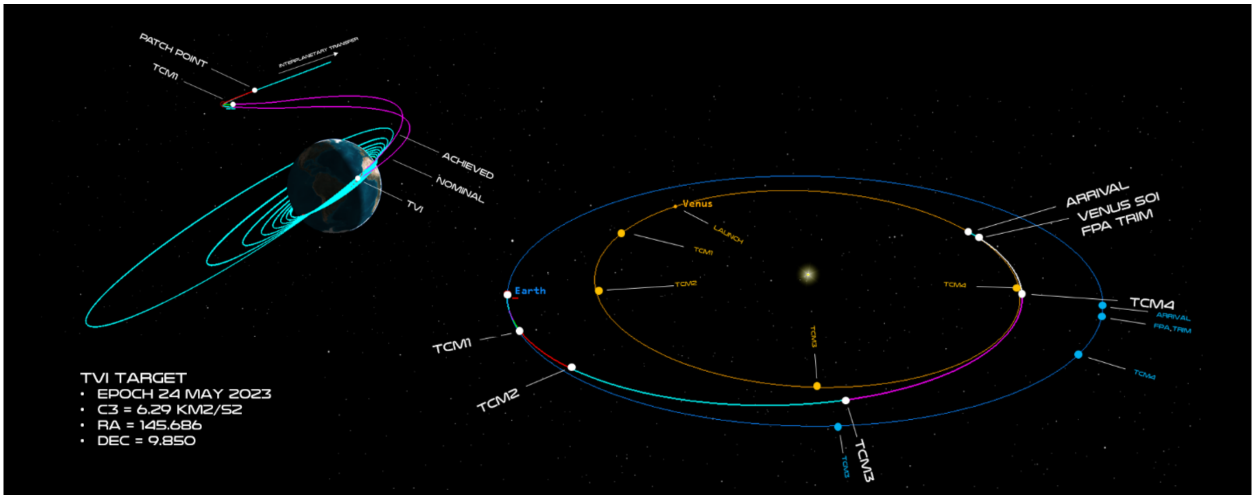

Figure 11: Phasing orbits approach to escape trajectory and typical trajectory correction maneuvers are used to target entry interface at Venus

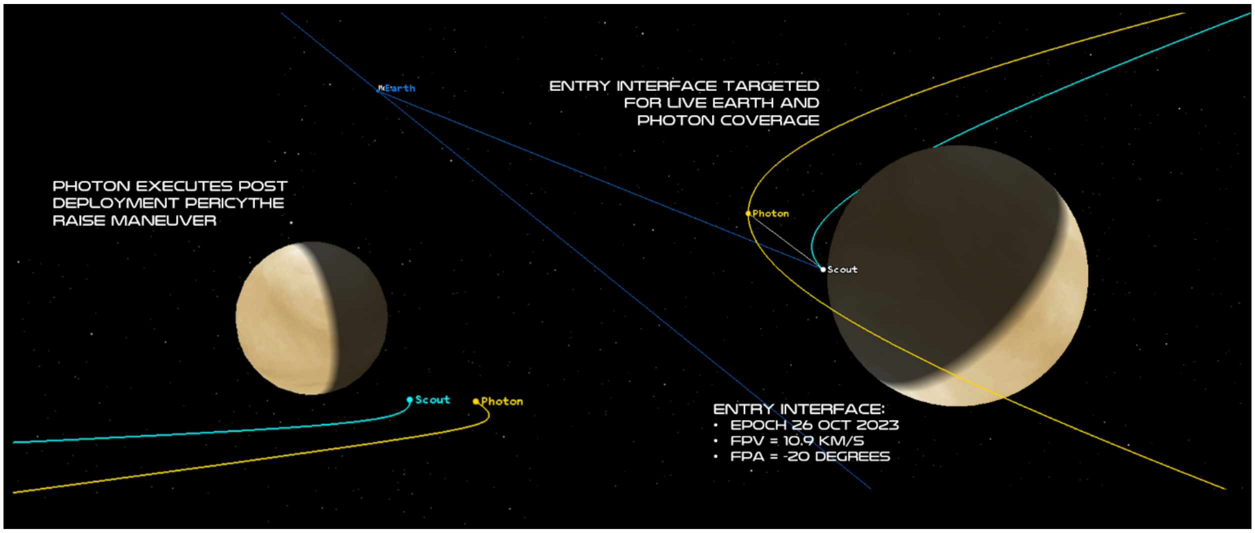

Figure 12: High-energy Photon releases the entry probe after targeting the entry interface before raising pericythe to improve communications relay geometry for the science phase

In October 2023, after the cruise phase, the high-energy Photon will target an entry interface to deploy a small (15-20 kg) probe directly into the atmosphere with an entry flight path angle (EFPA) between -10 and -30 degrees (Figure 12). The probe communicates with the high-energy Photon through an S-band communications link with a hemispherical antenna, while the high-energy Photon communicates to Earth through an X-band communications link with a high gain antenna. A back-up direct-to-Earth communications link for the small probe will be traded during the detailed design phase. The entry interface will be selected to satisfy science objectives (day/night, latitude targeting), Earth communication geometry, and other factors. The EFPA will be selected based on an analysis of the entry and descent timeline, the integrated heat load and required thermal protection system (TPS) thickness, probe acceleration (g-loading) limits, navigation precision, and other factors. After separating the probe, the high-energy Photon will perform a pericythe raise maneuver to improve the communications geometry to the probe and back to Earth.

The small probe (Figure 13) will contain ~3 kg of science payload to explore the habitability of the atmosphere, achieving ~270 sec in the cloud layer between ~45-60 km altitude to perform science operations. The science instrument is currently being traded.

The small probe is notionally a ~40 cm diameter, 45-degree half-angle sphere-cone blunt body with a hemi-spherical aft body for static stability in the hypersonic flow regime. The probe shape will be traded during the detailed design phase based on the stability characteristics in various flow regimes (hypersonics, transonic, subsonic, etc.) and center of gravity location constraints, among other considerations, with the goal of eliminating the need to "spin up" the probe to add gyroscopic stiffness. The probe diameter will be set based on instrument accommodation and mass growth allowance margins.

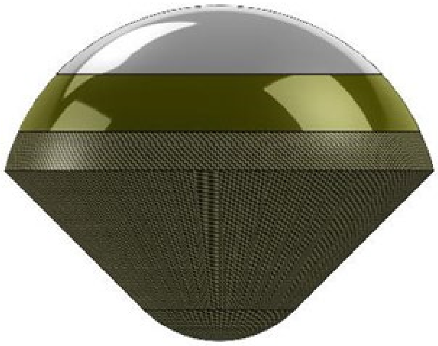

Figure 13: The small Venus probe is a 45-degree half-angle sphere cone ~40 cm in diameter (Credit: NASA ARC)

Two key trades, heat shield separation and the need for a pressure vessel, are still open and will be closed based on instrument selection and mission requirements in the detailed design phase. The probe forebody TPS material is notionally Heat-shield for Extreme Entry Environment Technology (HEEET) with the aft body materials a combination of Phenolic Impregnated Carbon Ablator (PICA) and a radio frequency (RF) transparent TPS like PTFE (e.g., Teflon) or Silicone Impregnated Reusable Ceramic Ablator (SIRCA).

The probe will follow the following preliminary Science Phase (Figure 14) sequence of events, with absolute timing dependent upon the selected EFPA:

- Probe release (potential spin up) after final entry interface targeting
- Photon communications burn/pericythe raise
- Coast phase (hours to days, low energy state)
- Pre-entry (initialization of key systems)
- Relay communications begins and continues throughout science phase
- Entry interface reached
- Heating pulse, RF blackout, peak G's (20 – 80 sec after entry interface)
- Heatshield separation, if required (30-90 sec after entry interface)
- Reconfiguration of probe for science data collection (if required)
- Enter clouds (100 – 200 sec after entry interface)
- Primary science data collection (275-300 sec data collection)
- Leave clouds (375 – 500 sec after entry interface)
- Continued data transmission/re-transmission of science data
- Potential lower cloud layer measurements
- Surface contact (~3500-4000 sec after entry interface)
- Attempt to image surface
- Attempt to transmit surface image
- Communication ends/vehicle passivated

Once the probe is through the cloud layer, the science data will be re-transmitted as required to the high-energy Photon for transmission back to Earth. Finally, a camera is being traded based on the available data budget, mass budget, and overall complexity. The camera could be used to provide context, such as below the cloud layer or to provide additional science value in other ways. However, objectives below the cloud layer, like the potential to continue science observations with the primary instrument or to return an image of the surface will be performed on a best effort basis only.

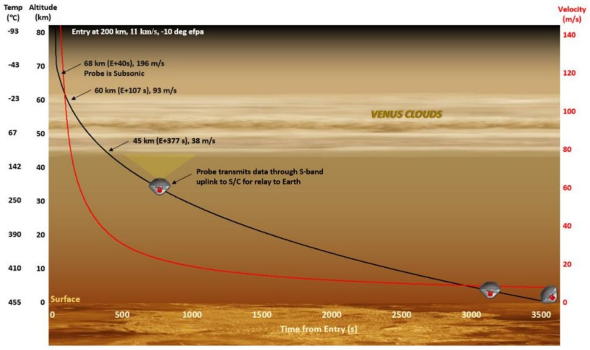

Figure 14: The science phase targets the Venus cloud layer between 45 and 60 km altitude, enabling ~270 sec of science observations (Credit: NASA ARC)

NASA ESCAPADE MISSION

In early 2021, Rocket Lab was awarded a contract to deliver two Photon spacecraft for a scientific mission to Mars.

The Escape and Plasma Acceleration and Dynamics Explorers (ESCAPADE) mission (Figure 15), led by Rob Lillis at the University of California, Berkeley Space Sciences Laboratory, is a twin-spacecraft science mission that will orbit two spacecraft around Mars to understand the structure, composition, variability, and dynamics of Mars' unique hybrid magnetosphere. This mission will explore how solar wind strips the atmosphere away from the planet to better understand how Mars' climate has changed over time.

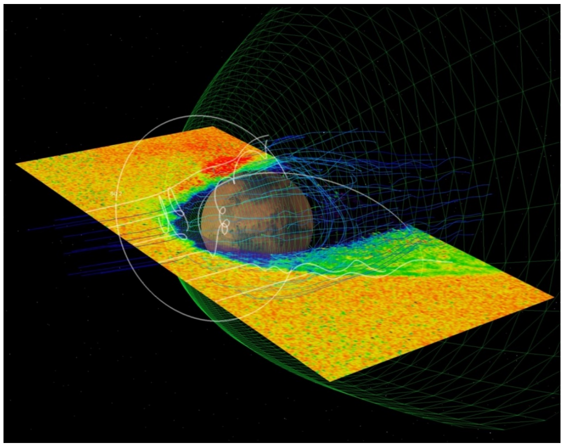

Figure 15: ESCAPADE will use two high-energy Photon small spacecraft in Mars orbit to understand Mars' unique magnetosphere (Credit: NASA/UCB/R. Lillis)

ESCAPADE is being developed under NASA's Small Innovative Missions for Planetary Exploration (SIMPLEx) program in the Science Mission Directorate (SMD). ESCAPADE is one of three missions selected in 2019 by NASA's SIMPLEx program to conduct compelling planetary science and provide more opportunities for flight experience to the science community.

The two spacecraft are planned for launch in 2024 to Mars ridesharing aboard a NASA-provided commercial launch vehicle. ESCAPADE will undergo a NASA preliminary design review and a confirmation review in the summer of 2021 to evaluate whether the mission proceeds to implementation and flight.

The ESCAPADE high-energy Photon pair (Figure 16) each carry an 8.5kg payload consisting of heliophysics instruments to measure electric fields, magnetic fields, and charged particles in the Martian environment. The 120 kg spacecraft is powered by a deployable solar array delivering 260 W of power at Mars, canted at a fixed angle that minimizes electrostatic and magnetic noise while maximizing solar illumination.

The spacecraft structure consists of two decks supported by struts, separated by the propellant tanks, simplifying the avionics and thermal management. The thermal management has two primary control zones: the "instrument deck" and the lower "propulsion deck." Most avionics are integrated on the upper "instrument deck," reducing harness length and complexity. Propulsion is provided by the bi-propellant Hyper Curie engine as well as a nitrogen cold gas RCS system used for smaller maneuvers, to desaturate the momentum wheels, and supplying pressurant for the primary propulsion system tanks.

The ESCAPADE communications system operates at X-band and includes a pair of ranging transceivers to enable deep space navigation. Four low-gain and two medium-gain antennas maintain communication when the spacecraft is not pointed at Earth, and a high-gain radial line slot array antenna relays the science data when Earth pointed, all interfacing with the DSN. The ESCAPADE Photons are also equipped with other in-house subsystems including star trackers and reaction wheels for precision pointing, supplied from Rocket Lab by Sinclair Interplanetary, a subsidiary acquired in April 2020.

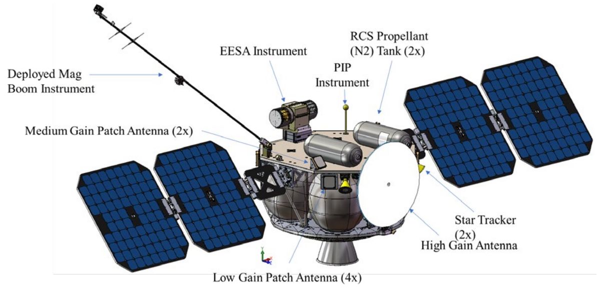

Figure 16: ESCAPADE Photon deployed configuration

After launch as secondary payloads on a commercial launch vehicle provided by NASA, the two spacecraft will each execute a series of burns with the Hyper Curie engine to establish phasing orbits and align for the Trans-Mars Injection (TMI) burn, like the approach described above for launch on Electron. As ESCAPADE will launch as a rideshare mission with an uncertain launch date and trajectory, the Photons must have on-board propulsion capabilities to target a single TMI escape date, alignment, and energy. Following an 11-month interplanetary cruise and several trajectory correction maneuvers (TCMs), the two Photons will then perform Mars Orbit Insertion (MOI) burns and insert themselves into elliptical orbits around Mars. An 11-month primary science mission follows.

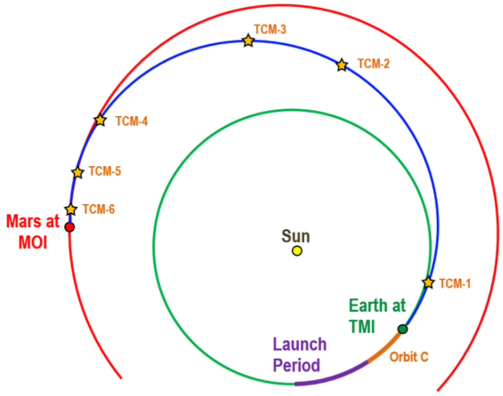

Figure 17: The ESCAPADE Photons will perform all the burns necessary to establish the escape trajectory (if required), trajectory correction maneuvers, and Mars orbit insertion (Credit: NASA/UCB/Advanced Space)

CONCLUSION

This paper described ongoing planetary small spacecraft missions that leverage Rocket Lab's deep space mission capabilities. High-energy Photons are in development for the NASA CAPSTONE, Rocket Lab Venus 2023, and NASA ESCAPADE missions to the moon, Venus, and Mars, respectively.

The high-energy Photon can launch on Electron to precisely target escape asymptotes for planetary small spacecraft missions with payload masses up to ~40 kg without the need for a medium or heavy lift launch vehicle. The high-energy Photon can also launch as a secondary payload or on other launch vehicles, like Neutron, with even greater payload masses to deep-space science targets.

Regular, low-cost Decadal-class science missions to planetary destinations enabled by small high-ΔV spacecraft, like the high-energy Photon, and dedicated small launch vehicles, like Electron, support expanding opportunities for scientists and increasing the rate of science return.

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