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AFFORDABLE, DEEP SPACE-CAPABLE TT&C RADIOS FOR SMALL SPACECRAFT BY ROCKET  
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**Abstract**

Rocket Lab is moving up the value chain with the Photon small spacecraft and down the value chain with spacecraft components, adding new components to the Sinclair Interplanetary family of reaction wheels and star trackers as capabilities are incrementally demonstrated on Photon. Rocket Lab is also committed to enabling regular, low-cost Decadal-class science missions to planetary destinations with high-V spacecraft like Photon to support expanding opportunities for scientists and to increase the rate of science return.

Perhaps the most critical subsystem for planetary missions is the RF communications subsystem that performs the tracking, telemetry, and command (TTC) operations. Planetary missions, and other missions operating above the GPS constellation, are unique in their dependance upon radiometric navigation techniques for orbit determination. Radiometric navigation is enabled by a coherent transponder to perform specialized ranging and doppler measurements using unique waveforms in combination with large aperture ground assets like NASA's Deep Space Network and the European Space Agency's Deep Space Antennas. Specialized capabilities like high spectral purity, high power efficiency, and extremely low bit rates are required for deep space TTC radios to close uplink and downlink at long ranges. Operators also must have assured communications access to spacecraft, particularly in the case of fault recovery. TTC radios for these types of missions must therefore have high reliability and high tolerance to radiation, particularly for single string space missions.

Deep space TTC systems have historically been accessible only to well-funded government programs due to the required specialized engineering and low volume production demands. However, with the advent of low-cost deep space access with Electron and Photon, the potential to return Decadal-class planetary science, and an increasing demand from users who require navigation in GPS-denied environments, radios with coherent transponders are an increasingly important element of the supply chain.

Rocket Lab is commercializing a family of modular, high performance, and affordable deep space radios with coherent transponders for resource constrained small spacecraft missions. The foundation of the family is a single-board radio weighing ;300g with precision, low power digital signal processing, a high efficiency transmitter, and a coherent transponder with software selectable turnaround ratio and ;40 nsec of ranging delay variation. The radios have specialized capabilities like DSN-compatible waveforms, timekeeping and time transfer, hardware command decoders, and forward error correction encoding and decoding. L-, S-, C-, and X-band variants are available with a Ka-band variant currently in development.