The Electra Proximity Link Payload for Mars Relay Telecommunications and Navigation

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Abstract

The coming decade of Mars exploration poses significant challenges in the areas of telecommunications and navigation. The demand for increased science data volume return from the surface, the need for energy-efficient communications to enable small scout-class mission concepts, the desire to reliably gather critical engineering telemetry during high-risk mission phases such as entry, descent, and landing, and the goal of robustly navigating in the Mars reference frame, all drive the need for a telecommunications and navigation infrastructure in Mars orbit, offering services and capabilities well beyond what can be obtained on conventional direct-to-Earth radio links. In support of this vision, NASA is developing the Electra Proximity Payload, a telecommunications and navigation payload that will fly on each Mars orbiter, beginning with the 2005 Mars Reconnaissance Orbiter (MRO) and with subsequent flight on the 2009 Mars Telesat Orbiter (MTO).

Starting with the needs of anticipated Mars exploration missions, we derive a set of functional requirements for the Electra payload. Key implementation trades are discussed, leading to the selection of a flight-reprogrammable software radio architecture and a frequency-agile design to enable flexible relay support to a wide range of potential users over multiple Mars opportunities. The Electra payload for MRO will provide UHF command and telemetry relay services, compliant with the Consultative Committee on Space Data Systems (CCSDS) Proximity-1 Link Layer standard. Details of the Proximity-1 implementation, as well as extensions of that standard, will be described. Relative to previous Mars UHF transceiver designs, Electra offers improved channel coding, options for full-duplex as well as low-loss half-duplex operations, support for a wide range of symbol rates, multi-bit open loop sampling, and highly flexible acquisition and tracking algorithms. Use of a flight-reprogrammable FPGA combined with a generic microcontroller in the transceiver's digital baseband module allows extensive reconfigurability of both symbol-level modem algorithms and higher-level functionality over the relay orbiter's mission lifetime, in support of new or unanticipated mission support scenarios. The Electra payload for MTO will augment these capabilities with an X-band receive capability, enabling for the first time high-performance directional relay communications at Mars.

Detailed performance specifications and interface characteristics for the Electra payload will be presented. Based on these specifications, data return simulations through the Mars Reconnaissance Orbiter and Mars Telesat Orbiter will illustrate potential Mars relay data return for representative user missions. The combination of Electra's X-band capability with MTO's communications-optimized orbit offers the potential for science data return in excess of 10 Gb/sol by the end of this decade, two to three orders of magnitude beyond the capabilities of typical lander direct-to-earth links. Options for tailoring the Electra payload for future landers, rovers, aerobots, etc., will be described, with the goal of achieving significantly reduced mass, volume, and power. Finally, a technology survey will highlight areas for future evolution of Mars in situ telecommunications and navigation capabilities.