NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mars Exploration Program

Electra-Lite Mars Proximity Link Communications and Navigation Payload Description

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Jet Propulsion Laboratory
California Institute of Technology

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Electra Development Overview

The Mars Exploration Program (MEP) has identified the need for establishing a robust Mars infrastructure to provide mission-enabling and enhancing telecommunications and navigation services to future MEP elements. To this end, the Program has funded development of a standardized proximity link communications and navigation payload, known as the Electra UHF Transceiver (EUT), for flight on each strategic orbiter, starting with the 2005 Mars Reconnaissance Orbiter.

Electra will serve as the heart of a constellation of Mars network nodes efficiently relaying high rate in-situ mission science and engineering data, providing accurate navigation data and a precision timing reference for synchronizing spacecraft and in-situ assets that otherwise could not be achieved. Electra will be carried as a MEP-provided payload on future Mars science orbiters, starting with the 2005 Mars Reconnaissance Orbiter (MRO), providing a low-cost approach towards developing a Mars orbital communications infrastructure. After completion of their primary science mission, these spacecraft will continue to operate in Mars orbit utilizing the capabilities of the Electra payload to provide proximity link telecommunications and navigation services to other Mars missions. These user missions, including landers, rovers, and other potential mission concepts, will incorporate Electra-compatible transceivers - i.e., compliant with the physical, link layer, and coding and modulation standards described in the Proximity-1 Space Link Protocol[1], as documented by the Consulatative Committee on Space Data Standards (CCSDS) - in order to establish proximity links with Electra-equipped Mars orbiters.

Since the mass, volume and DC power specifications for the standard Electra EUT may be inappropriate for a Mars lander with stringent mass and energy constraints, a smaller lander UHF radio is desired. This new development, referred to as Electra Lite (ELT), retains the core functionality, performance and reprogrammability of the standard orbiter EUT. The ELT design leverages the current Electra EUT design as much as possible, offering a number of advantages, including:

- Assured compatibility with Mars orbiter EUTs via use of common software/firmware;
- Reduced non-recurring engineering costs (NRE) since the current EUT architecture will be maintained to the greatest extent possible;
- Reduced recurring engineering costs via parts commonality with the standard EUT, providing a major reduction in EEE parts costs (shared lot and upscreen charges);
- Reduced ground support equipment (GSE) and Ground Data System (GDS) costs since the standard EUT GSE and GDS will be usable for Electra Lite integration and test and mission operation activities.

ELT development is a collaborative effort between Jet Propulsion Laboratory (JPL) and L-3

[1] Proximity-1 Space Link Protocol, Consultative Committee for Space Data Systems, Recommended Standards CCSDS 211.0-B-4 (http://public.ccsds.org/publications/archive/211x0b4.pdf), CCSDS 211.1-B-3 (http://public.ccsds.org/publications/archive/211x1b3ec1.pdf), and CCSDS 211.2-B-1 (http://public.ccsds.org/publications/archive/211x2b1.pdf), 2006.

Communications Cincinnati Electronics (L3CE). JPL is responsible for the software and firmware embedded in the Baseband Processor Module (digital slice), while L3CE is responsible for development of the remaining modules as well as integration, test and delivery of Engineering Model (EM) and Flight Model (FM) radios to the end user. The first FM ELTs are being delivered to the 2011 Mars Science Laboratory (MSL) Project.

Note that Discovery mission proposers requiring relay-communication services from Mars Exploration Program orbiters, as described in the *Mars Relay Description for Discovery Proposals* document in the Discovery AO Program Library, are free to use any CCSDS Proximity-1 compliant radio in their spacecraft flight system. The purpose of this document is simply to ensure that proposers are aware of the Mars Exploration Program's ELT transceiver development, to introduce the high-level ELT specifications, and to encourage consideration of the use of this radio for applicable mission concepts based on the advantages cited above.

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Electra Lite (ELT) Description

The Electra Lite UHF Transceiver (ELT), is a fully-reconfigurable transceiver operating in the 390-450 MHz band. As shown in Figure 2, the ELT incorporates a modular design with functional elements residing in three stacked modules (from top down): A Receiver/Modulator (RFM) slice, a Baseband Processor Module (BPM) slice, and a Power Amplifier-Power Supply Module (P/A-PSM) slice. Key ELT specifications are provided in Table 1. The ELT command/response and data interfaces are shown in Figure 3.

The ELT BPM's software-defined radio architecture enables extensive reprogrammability of the transceiver's signal processing capabilities, even after launch, allowing rapid tailoring of the radio to any unique mission requirements. The ELT RFM's frequency-agile design supports operation over the full range of UHF frequency channels defined in the CCSDS Proximity-1 Link Protocol, with transmission and reception tunable across the 390-405 MHz and 435-450 MHz sub-bands, respectively.

Spacecraft interfaces include command and control functions via a MIL-STD-1553B interface, and high-speed transmit and receive data interfaces over a Low-Voltage Differential Signaling (LVDS) interface.

Unlike the larger orbiter EUT design, which can support both half-duplex and full-duplex operations during flight, the ELT must be configured at the time of manufacture to either half-duplex or full-duplex configuration. (The ELT design for the 2011 Mars Science Laboratory mission utilizes the full-duplex design option.) This is the primary design modification that results in the significant mass and volume reductions for the ELT.

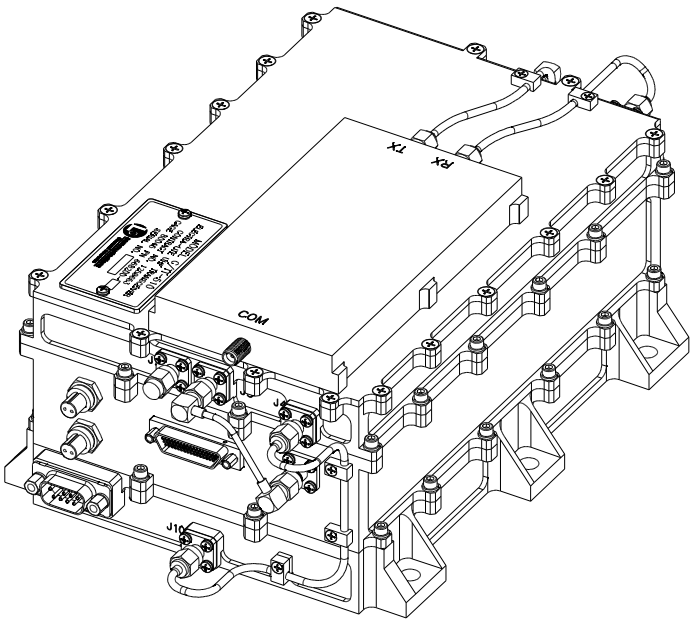

Figure:2 Isometric View of Electra Lite Transceiver

Parameter	Electra Lite
Transmit (Tx) Frequency	390 to 405 MHz
Receive (Rx) Frequency	435 to 450 MHz
Duplex Mode	Half-duplex or Full-duplex (selected at build)
Operational Modes	FD: Rx, Rx/Tx
Tx/Rx Rate	1,2,4,8,…,4096 ksps
Modulation	Manchester, NRZ-L, BPSK, QPSK, Mod Index 60 & 90 deg
Coding	K=7, R=1/2 Convolutional Encode/Decode
Spectrum Record	Open Loop Signal Sampling, <100 ksps, 1-8 bits/sample quadrature
Rx Noise Figure	FD = 4.5 dB, HD = 3.9 dB
RF Tx Power	FD: 8.5 W; HD: 10.5 W
Protocols	CCSDS Proximity-1 Space Link Protocol
Reconfigurability	In-flight reprogrammability for all Xilinx FPGA and Sparc microcontroller functions
Doppler Tracking	1-way or 2-way Carrier Phase Measurements
Mass	3000 g (FD configuration with Diplexer)
Volume	~2872 cm^3 (FD configuration with Diplexer)
Dimensions (l,w,h)	20.3 cm x 13.1 cm x 10.8 cm (FD configuration with Diplexer)
DC Power – Rx Mode	18.5 W (Worst-case, End-of-life)
DC Power – Tx/Rx Mode	60.2 W (Worst-case, End-of-life)
Parts Grade	B+
TID	6.5 krad

Table 1: Key ELT Specifications

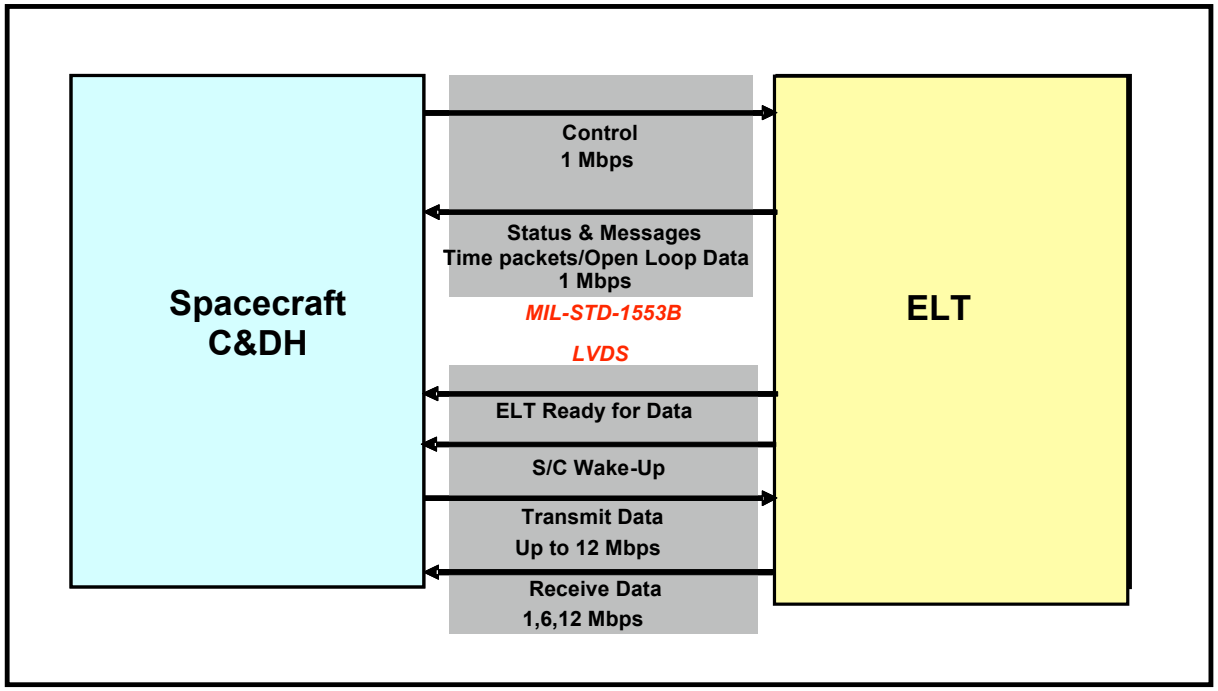

Figure 3: Electra Lite – Spacecraft Bus Interfaces

Acknowledgment

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