ABSTRACT

Navigation Services of the Mars Network

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Prepared for the
59th Annual Meeting of the Institute of Navigation
Albuquerque, New Mexico, USA

June 23 - 25, 2003

The Mars Network (MN) will provide proximity-based navigation services to support Mars exploration. The MN will collect radiometric tracking data from links between a relay orbiter and a user such as a surface asset, another orbiter, or an approaching spacecraft. The Electra transceiver, currently in development, is being designed for the dual use as a communication and radiometric tracking device. Electra will reside on MN elements and users of the MN.

The current baseline for Electra is to formulate and collect 1-way and 2-way coherent integrated carrier phase data that will be nominally processed as Doppler data. An Electra transceiver can also make an open loop recording of a selected frequency band, a capability useful for critical events or scenarios with very low signal-to-noise ratios (SNRs). Since Electra radiometric tracking capabilities are implemented in software, it will be possible to augment Electra (including those already at Mars) with additional data types (such as ranging using a pseudo-noise sequence) at a later date. Furthermore, since Electra has an onboard processor, it is also possible that future missions could compute navigation solutions in-situ using an Electra.

The first Mars Network element to carry Electra is the Mars Reconnaissance Orbiter (MRO) that will launch in 2005. MRO's primary mission is science related; however, an additional mission is to participate in the MN. In fact, each Mars orbiter launched after MRO will carry some version of the Electra transceiver. Current Mars Exploration Program plans also include placing a dedicated communications and navigation satellite (referred to as the 'telesat') in orbit at Mars after 2009.

Electra navigation services fall into several categories: surface asset positioning, approach navigation, orbit determination, and EDL trajectory determination. Each of these services and the anticipated performance of the MN at providing the service will be discussed in the paper.

In surface asset positioning, either 1-Way or 2-Way coherent Doppler data from the proximity link is used to determine the position of a Mars surface asset. These data can be augmented with direct-to-Earth (DTE) Doppler and range taken by the Deep Space Network (DSN) to any of the assets with a DTE capability. The combination of the proximity data and the DTE provides good observation geometry such that with 2-Way links it is possible to achieve position accuracies of 10 m (1-σ) or less.

In approach navigation, 1-Way Doppler data from a link between an MN orbiter and the Mars approach vehicle is used (in conjunction with DTE data) to determine the Mars approaching spacecraft's trajectory. This service's primary objective is to support approach phase trajectory correction maneuver (TCM) planning for Mars incoming spacecraft. However, the data could also be used for trajectory knowledge updates after the TCMs to support Mars lander entry guidance. In order to collect this data, Electra must have an optional 1-Way X-Band receive capability (referred to as the 'X-Band slice'). Currently, the X-Band slice is planned for the Electra transceiver on the MN telesat. Analysis indicates that this service provides an order of magnitude improvement in trajectory knowledge over standard techniques using only DTE Doppler and range, provided both vehicles have ultra stable oscillators.

The orbit determination case is similar to the surface asset positioning service except here the user is in orbit rather than on the surface of Mars. The data types include 1-Way and 2-Way carrier phase as before.

Entry, Descent, and Landing Trajectory is a critical event that can be supported by the Mars Network if the network asset has been positioned to view the EDL event at the appropriate time. If so, it is envisioned that a 1-Way signal could be transmitted from the entry vehicle and tracked by the Mars Network asset. The data would then be sent back to Earth for post-processing to determine the entry trajectory. Another scenario could be to turn this link around and the entry vehicle could collect the data and use it in conjunction with its IMU data for its EDL navigation and guidance.