EPSC Abstracts
Vol. 11, EPSC2017-852, 2017
European Planetary Science Congress 2017

ExoMars Lander Radioscience LaRa, a Space Geodesy Experiment to Mars.

V. Dehant (1), S. Le Maistre (1), **R.M. Baland** (1), M. Yseboodt (1), M.J. Péters (1), Ö. Karatekin (1), A. Rivoldini (1), and T. Van Hoolst (1)
(1) Royal Observatory of Belgium, Brussels, Belgium (v.dehant@oma.be)

Abstract

The LaRa (Lander Radioscience) experiment is designed to obtain coherent two-way Doppler measurements from the radio link between the ExoMars lander and Earth over at least one Martian year. The instrument lifetime is larger than the one Earth year of nominal mission duration. The Doppler measurements will be used to observe the orientation and rotation of Mars in space (precession, nutations, and length-of-day variations), as well as polar motion. The ultimate objective is to obtain information / constraints on the Martian interior, and on the sublimation / condensation cycle of atmospheric CO_2.

The LaRa instrument consists of a coherent transponder with up- and downlinks at X-band radio frequencies. The signals will be generated and received by Earth-based giant antennas belonging either to the NASA deep space network (DSN), the ESA tracking network, or the Russian ground stations network.

We will describe the experiment and discuss important aspects of the radio tracking data analysis, which uses dedicated software developed for determining the variations in the ExoMars lander position relative to the Earth, as a function of time.

1. Introduction

The X-band transponder LaRa is designed to obtain two-way Doppler measurements at the instrument accuracy level of 0.05 mm/s @ 60 second integration time (0.02 mm/s @ 60 second integration time for the instrumental contribution) from the radio link between the ExoMars lander and the Earth over at least one Martian year.

These Doppler measurements will be used to obtain the orientation and rotation of Mars in space (precession and nutations, polar motion, and length-of-day variations). The ultimate objectives are to obtain information on Mars' interior and on the sublimation/condensation process of CO_2. This is possible since one will be able to obtain the moment of inertia of the whole planet that includes the mantle and the core, the moment of inertia of the core, as well as the seasonal mass transfer between the atmosphere and ice caps.

The LaRa experiment will be used jointly with the other experiments of the ESA ExoMars Payload, as well as the InSight (Interior exploration using Seismic Investigations, Geodesy, and Heat Transport) NASA mission, in order to obtain the maximum amount of information about the interior of Mars and consequently about its formation and evolution. These objectives are in compliance with the ExoMars objective "To investigate the planet's deep interior to better understand Mars's evolution and habitability".

2. The instrument

The LaRa instrument is a coherent transponder using one uplink and one downlink at X-band. There is a corresponding ground segment of the experiment since the signal is observed by the NASA Deep Space Network (DSN), Roscosmos (NPOL) Ground Stations (GS), or the ESA tracking stations (ESTRACK).

The LaRa transponder will be switched-on for receiving the uplink signal from the Earth ground station. It will re-transmit the signal coherently for one hour towards the ground station. This sequence will be repeated twice per week. The longer the mission lifetime, the best it is for reaching the LaRa objectives. The minimum guaranteed mission is one Earth year. This period will be followed by an extended operation period as long as the available power allows it.

3. Ground segment operation

The ground operations of LaRa are crucial for the realization of the experiment. The LaRa transponder receives the signal from the Earth ground station directly and transmits it back to Earth coherently. The operation of LaRa from the lander point of view corresponds to a simple switch on-off command. The timing of this command is determined and coordinated by the ground segment. The operation of LaRa from the ground segment point of view depends mainly on the availability of the ground station, the position of Mars in the ground station sky, and on the position of the Earth in the lander sky. There are other constraints that will be detailed in the next paragraphs.

The role of the ground segment is to transmit from Earth an uplink signal to LaRa on the surface of Mars and receiving a signal back from LaRa, in X-band (see Figure 1).

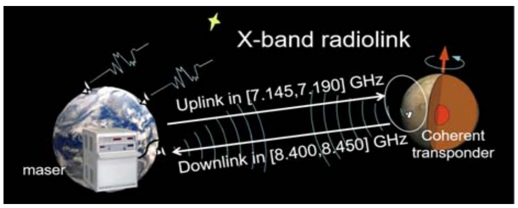

Figure 1: Ground Station and LaRa X-band links.

Knowing a priori a first high-precision approximation of the Doppler between the ground station at the emitting time and the lander at the receiving time, the ground station can emit a signal pre-compensated for this Doppler so that LaRa receives at Mars a frequency near 7.16 GHz (in [7.145, 7.190] GHz). At the ground station, a very precise uplink signal computation will be necessary for the initial sent signal so that the signal arriving at the lander is in the lock-in bandwidth of LaRa, i.e. so that the signal is “pre-compensated”. This is a key feature of the ground station necessary to achieve successful acquisition lock with the LaRa receiver; this is a procedure well known by the ESTRACK and DSN ground stations.

The LaRa experiment planning consists of 2 sessions/week during the minimum guaranteed period of the mission, and 1 or 2 sessions/week during the rest of the mission. These sessions are planned according to the geometry of the Earth and Mars relative position, the position and orientation of the lander, the day/night successive situation, the solar activity, the operation of the other Surface Platform payload instruments, and the ground station availability.

4. Objectives

Rotational variations will allow us to constrain the moment of inertia of the entire planet, including its mantle and core, the moment of inertia of the core, and seasonal mass transfer between the atmosphere and the ice caps. The LaRa experiment will be combined with other ExoMars experiments, in order to retrieve a maximum amount of information on the interior of Mars. Specifically, combining LaRa Doppler measurements with similar data from the Viking landers, Mars Pathfinder, Mars Exploration Rovers landers, and the forthcoming InSight-RISE lander missions, will allow us to improve our knowledge on the interior of Mars with unprecedented accuracy, hereby providing crucial information on the formation and evolution of the red planet.

Acknowledgements

This work is financially supported by the Belgian PRODEX program managed by the European Space Agency in collaboration with the Belgian Federal Science Policy Office.