

## LaRa (Lander Radioscience) on the ExoMars 2020 Surface Platform.

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### Abstract

The surface platform Kazachok will house the radio science experiment LaRa (Lander Radioscience) to support specific scientific objectives of the ExoMars 2020 mission. The LaRa experiment is described and the scientific objectives and strategies are detailed in this presentation.

### 1. Introduction

In the last decade, several missions and observations have brought new data on the planet Mars, obtained by either spacecraft orbiting around Mars or landers and rovers on the surface. Among other things, the information acquired will improve our understanding of Mars' interior, evolution and habitability. Data obtained by new space missions are driving further progress in this field. In 2020, the European Space Agency ESA and the Russian space agency Roscosmos will launch the ExoMars 2020 mission. It consists of a rover and a surface platform, and will land in the Northern hemisphere of Mars. Belgium contributes one of the scientific instruments on the platform: a radio transponder called *LaRa* for *Lander Radioscience*.

The LaRa experiment is designed to obtain coherent two-way Doppler measurements from the radio link between the 2020 ExoMars platform and the Earth, during at least one Martian year (see Figure 1). The Doppler measurements will be used to infer the relative radial velocity of the Earth and the lander, allowing to observe the variations in orientation and rotation of Mars in space (i.e. precession, nutations, and length-of-day variations) as well as polar motion. The ultimate objective is to obtain information on the Martian interior and on the sublimation/condensation cycle of atmospheric CO<sub>2</sub>. Rotational variations will allow us to constrain the moment of inertia of the whole planet, including its mantle and core, as well as the moment of inertia of the core, and seasonal mass transfer between the atmosphere and ice caps.

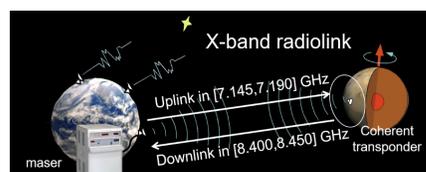


Figure 1. LaRa principle.

### 2. The LaRa instrument

As LaRa performs a coherent retransmission of the uplink carrier to the downlink carrier, the downlink frequency is scaled by a constant multiplier, the transponder ratio (880/749). By emitting the uplink signal from Earth, the masers in the ground stations ensure frequency stability of LaRa's radiosignal.

The LaRa instrument is built in collaboration with other Belgian actors under the lead of ESA PRODEX, and ROB providing the instrument specifications. It is composed of three antennas (one for receiving the signal from Earth and two for transmitting back to Earth) designed by UCLouvain (see Figure 2), and a coherent transponder (see Figure 3) designed by Antwerp Space.

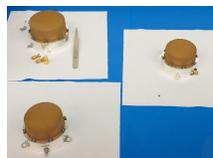


Figure 2. Flight Models of the LaRa Transmitting and receiving antennas. Flight Models.



Figure 3. Flight Model of the transponder while mounting the PCBs (Printed Circuit Board).

In 2018, various models of the instrument parts were developed: a Thermal Model (TM), Structural Model (SM), Engineering Model (EM), the Flight Model (FM). The EM, built to test LaRa's functionalities, has been tested at ESOC (European Space Operations Centre, Darmstadt) and has proven its coherence to

be better than requirements (Allan deviation of less than  $10^{-13}$  at 60 seconds).

The transponder design maintains the coherency of the signal, and the global precision on the Doppler is expected to be better than 0.05 mm/s with 60 second integration time. By comparison, the requirement for instrument precision was 0.02 mm/s with the same integration time.

During operations, the transponder will function when an Earth ground station is available and when the Earth is in the sky of the lander. The position of the lander will be determined from the first passes, as well as from the landing site characteristics and MOLA altimetric data [5]. LaRa will operate at least twice per week during the whole mission lifetime (twice per week in the minimum guaranteed mission and during the extended mission, with a possible relaxation to once per week during hibernation).

### 3. The LaRa science

Since Mars is oblate and rotating, and the equator is not parallel to the Mars-Sun line (the obliquity angle is about  $25^\circ$ ), the planet reacts as a spinning top to the gravitational torque exerted by the Sun. As a consequence, the rotation axis and the planet slowly move in space around the perpendicular to the orbital plane (see Figure 4). The time needed to perform one cycle around the orbit normal is presently about 171,000 years with a speed on the precession cone (so-called precession rate) of about 7.6 arcs/year. A first objective of LaRa is to accurately determine the precession rate. Because the precession is inversely proportional to the polar principal moment of inertia, LaRa will be able to determine Mars moments of inertia, which provide important constraints on the interior structure.

Because of the elliptical orbit of Mars and the orbital changes due to for instance interaction with other Solar System bodies, the gravitational torque on Mars changes with time. The variations in the torque induce periodic changes in the precession as well as variations in the obliquity angle, called nutations. The resulting motion of the pole due to precession and nutation is wiggly as illustrated in Figure 4. The periods of the nutations are related to the periods of the orbital motion and the orbital perturbations. The largest of these nutations has a period of half the orbital period ([1]-[3] [6] [7]). Observations of these nutations will lead to constraints on the physical state of the core (confirmation that the core is at least partially liquid), its density, shape, and size.

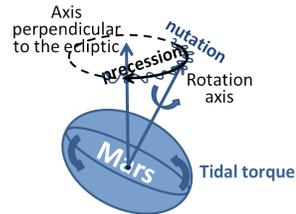


Figure 4. Representation of precession and nutation of Mars.

Additional rotation changes are due to exchange of angular momentum with the atmosphere. The rotation rate of Mars is approximately uniform, but variations in the length-of-day (LOD) have been observed and are mainly due to exchanges of mass and angular momentum between the atmosphere and surface. These exchanges occur mostly at seasonal periods as a result of sublimation/condensation of the  $\text{CO}_2$  polar ice caps, mass redistribution in the atmosphere, and seasonally changing zonal winds. LaRa will improve current estimates of the LOD variations (known to within about 15% [4]), providing the most accurate constraints on the distribution of atmospheric mass, angular momentum, and the ice caps.

### Acknowledgements

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