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GETEMME: A MISSION TO EXPLORE THE MARTIAN SATELLITES

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Abstract. GETEMME (Gravity, Einstein's Theory, and Exploration of the Martian Moons' Environment) is a proposition of mission towards martian's moons. The spacecraft will initially rendezvous with Phobos and Deimos in order to carry out a comprehensive mapping and characterization of the two satellites and to deploy passive laser retro-reflectors on their surfaces. In the second stage of the mission, the spacecraft will be transferred into a lower 1500-km Mars orbit, to carry out routine laser range measurements to the Phobos and Deimos reflectors. Also, asynchronous two-way laser ranging measurements between the spacecraft and stations of the ILRS (International Laser Ranging Service) on Earth are foreseen. An onboard accelerometer will ensure a high accuracy for the spacecraft orbit determination. The inversion of all range and accelerometer data will allow us to determine or improve dramatically on a host of dynamic parameters of the Martian satellites system. From the complex motion and rotation of Phobos and Deimos we will obtain clues on internal structures and the origins of the satellites. Also, crucial data on the time-varying gravity field of Mars related to climate variation and internal structure will be obtained. Ranging measurements will also be essential to improve on several parameters in fundamental physics, such as the Post-Newtonian parameter β as well as time-rate changes of the gravitational constant and the Lense-Thirring effect. Measurements by GETEMME will firmly embed Mars and its satellites into the Solar System reference frame.

Keywords: space mission, Mars, planetology, relativity

1 Mission scenario

GETEMME (Gravity, Einstein's Theory, and Exploration of the Martian Moons' Environment) is an interplanetary mission to Mars and its two satellites Phobos and Deimos consisting of one spacecraft with four embedded landers. The Spacecraft will fly to Mars with an electric propulsion system.

After 700 days of flight GETEMME will rendezvous with Deimos, stay in orbit for three months and fly to Phobos afterwards. During these rendezvous phases two passive landers will be deployed on each moon. We assume a baseline of the lander's delivery from a low (few radii) Phobos or Deimos orbit and "dropping" the packages by ejection, reducing orbital velocity as shown in figure 1. The Landers will undergo an unpowered, uncontrolled (but pre-calculated) free fall (touchdown velocity of the order of 8 m/s for Phobos and 5 m/s for Deimos) to a selected landing site (within a 1-km landing error ellipse). The touchdown is damped by crushables. Uprightening is carried out automatically by opening the shell cover or the lever arm, thereby also removing the protective cover hat from the reflector optics. A maximum surface slope of between 30° and 45° can be tolerated with the baseline reflector design, thus, no active pointing is foreseen. Two landing sites will be chosen each for Phobos and Deimos, near the equator, approx. 20° east and west of the sub-Martian point, sub-Martian latitude ±5°, (corresponding to an error ellipse semimajor axis of about 1 km on Phobos and 0.5 km on Deimos). The proposed Lander design is based on a shell-like structure that protects all electronics (as well as the reflectors) during impact with crushable shock absorbers and opens after landing.

Then the spacecraft will finally travel to a circular Mars orbit and stay there for one Martian year for scientific operations. The mission will be completed after at least 2 years of nominal operations. An onboard accelerometer will ensure highly accurate spacecraft orbit determination. Major part of scientific operations will be devoted

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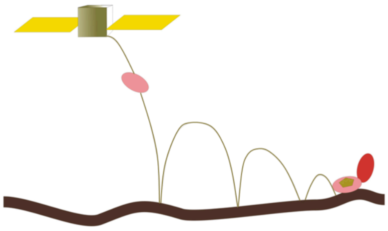

Fig. 1. Delivery scheme of Landers on the Martian Moons.

to rangig measurement between the spacecraft and the landed reflectors. We adopt a ranging schedule, where the orbiter is in a suitable position for successful range measurements to the reflectors within incidence angles of ±10° from the vertical (taking into account uncertainties in surface tilt and the reflector orientations on Phobos and Deimos). At 1500 km above ground the orbiter will move 8.3 times around Mars per 24 hour. It will therefore be in opposition to Phobos every 280 minutes and to Deimos every 190 minutes. Ranging will be carried in selected time slots. A measurement interval will last at least 15 minutes for Phobos and 50 minutes for Deimos. The total number of ranging measurements to all 4 reflectors is 1 000 000 (measurement goal). Earth ranging can generally be performed more than 8 times per 24 hours, with one measurement interval lasting approx. 135 minutes. We anticipated the use of multiple Earth stations to warrant ranging measurements not disrupted by the rotational cycle. The total number of ranging measurements is 500 000.

2 Mission objectives

2.1 *Planetology of martian's system*

Monitoring the satellite orbits accurately is a powerful way to quantify physical parameters related to interior. As an example, tidal dissipation inside Mars provides a phase lag between the tidal bulge and the line of sight Mars-satellite. Such lag induces a torque that provides exchange of angular momentum between rotation of the primary body Mars and orbital motion of the tide raising satellite. Benefitting from equatorial orbits, the tracking of the GETEMME spacecraft will provide high accuracy estimates for the tidal Love numbers k_2, k_3 and the dissipation factor Q at Solar, Phobos, and Deimos tidal frequencies. The quantification of these parameters and their dependence on frequency will be a major step for solving the origin and fate of the Martian moons, as well as improving our knowledge of the interior of Mars (Mignard 1981; Efroimsky & Lainey 2007). Similar parameters for Phobos and Deimos will be derived by the study of the moon rotations. The gravity field of Mars undergoes temporal variations. During one Mars year, CO_2 sublimates from the North polar cap to the atmosphere, condenses at the South polar cap, and vice versa. Thanks to the equatorial orbits of Phobos,

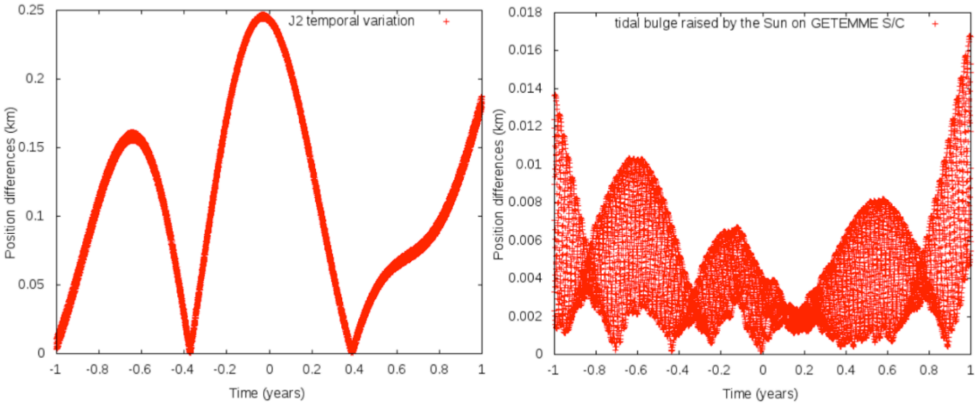

Fig. 2. Left: post-fit residuals with/without temporal variations of Mars J_2 over 2 years after fitting initial state vectors of GETEMME S/CCaption of the left panel. **Right:** post-fit residuals with/without the Solar tidal bulge raised on Mars over 2 years after fitting initial state vectors of GETEMME S/C.

Deimos and GETEMME spacecraft, this CO_2 cycle will be accurately measured. Annual and semi-annual seasonal variations of low-degree harmonics as well as length of day variations will be greatly constrained (see figure 2 - left). Estimated to be on the order of 10^{-11} yr^{-1}, the secular variation of J_2 will also be known with an accuracy of 1.5×10^{-17} after two years of data. This effect is observed on the Earth and has been attributed to the relaxation of the mantle released from ice loads of the ice age. If detected on Mars, such effect will bring important information on the past climate of Mars, as well as on Mars interior. The quantification of Mars nutation and Chandler wobble, with possible free core nutation (FCN) signal may provide strong input for the interior modeling, including the size of the Martian core.

2.2 *Relativity tests*

Ranging data, provided by GETEMME, will also drastically lead to a major improvement of the Martian satellites' ephemerides (Lainey et al. 2007). At the centimeter level of accuracy, General Relativity has to be used to describe correctly the motions of the two moons and the impact of curvature on the light propagation. By using the first parameterized post-Newtonian (PPN) approximation of General Relativity (Will 1993), GETEMME data can give new highlights on several of the ten PPN parameters, in particular PPN β which plays an important role in the relativistic perihelion's precession formula. Hence, when using the GETEMME ranging dataset to build new precise ephemerides of Phobos and Deimos around Mars, one can measure with high precision their periapsis precession. Then, a local determination of PPN beta can be performed and this result will improve actual determination usualy obtained in the gravitational field of the Sun, e.g. by using planetary ephemerides (Fienga et al. 2010).

Another relativistic effect can be constraint by GETEMME ranging data. Indeed Lense-Thirring precession is a relativistic correction to the precession of a gyroscope near a large rotating mass such as the Earth, i.e. a gravitomagnetic frame-dragging effect. It is a prediction of General Relativity consisting of secular precessions of the longitude of the ascending node and the argument of pericenter of a test particle freely orbiting a central spinning mass endowed with a specified angular momentum. This effect have been detected by observing the motion of geodetic LAGEOS satellite around the Earth at the level of 10^{-1} (Ciufolini & Pavlis 2004) and a space project named LARES (Ciufolini et al., 2010) has been recently proposed to reach a determination at the level of $10^{-2/-3}$. With GETEMME, we can detect this effect because we are sensitive to this relativistic precession of Phobos and Deimos orbits due to the rotation of Mars. As illustrated on figure 3, one can expect a detection of this effect at the level of accuracy of 10^{-4}.

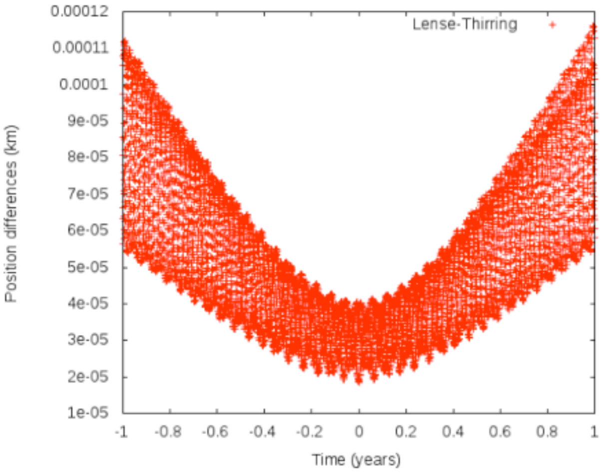

Fig. 3. post-fit residuals with/without the Lense-Thirring effect due to Mars rotation over 2 years after fitting initial state vectors of GETEMME S/C.

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