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Phobos Eclipses data acquisition cyclogram for the Mars MetNet Precursor Lander.

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Abstract

MetNet is a mission for Martian Atmospheric Measurement studies. We present an areographic temporal pattern description of Phobos solar eclipses for the establishment of an observational strategy to detect such events with the MetNet mission.

1. Introduction

The MetNet project is being fulfilled in collaboration between the Finnish Meteorological Institute, the Russian Space Research Institute, the Russian Lavoschkin Association and the Spanish National Institute for Aerospace Technology. Mars MetNet Precursor Lander (MMPL) is planned to be launched as a secondary part of the Russian mission Phobos-Grunt.

In order to detect solar eclipses by Phobos we will use the data provided by a Solar Irradiance Sensor device (MetSis, http://metnet.fmi.fi) which is part of the scientific payload. These eclipses could be used as complementary information for the localization of the MMPL landing site on Mars, as well as to study atmospheric properties using shadow density measurement in different spectral intervals.

2. Eclipses Parameterization

In a first step, with the aim of choosing the currently best set of the parameters needed for a precise prediction of eclipses, the observed Phobos eclipses with known position coordinates have been analyzed. Available observations are: a) 3 detections from Viking I in 1977 [5], b) 15 events detected by Mars Orbiter Laser Altimeter (MOLA), from 1999 to 2004 [3], c) 4 events directly observed from Mars Exploration Rover-B (MER-B) in 2004 [2] and 2010 [6] and d) 1 observation from MER-A in 2004 [2].

Phobos projection onto the Sun disc plane has been modelled as seen from a Mars observer, as an ellipse centered at Phobos center projection. Initial and final contact points of any possible eclipse are then determined when the resulting ellipse intersects the Sun disc. Fig. 1 shows the offsets and mean offsets of the predictions for observed eclipses by MER and MOLA applying different set of parameters.

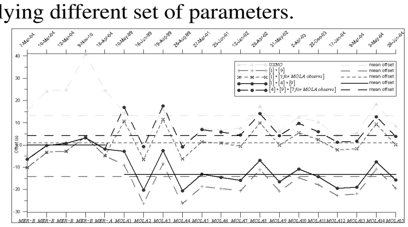

Figure 1: Offsets for the predictions of observed eclipses.

In a second step, in order to generate a chronogram of the shadow path across de surface of Mars, models for the latitudinal and longitudinal Phobos shadow motion had been derived studying the intercepting point of the line through the centers of the Sun and Phobos with the Mars surface. To provide an observational plan including observations within the whole shadow area, the shadow size has been also modeled projecting Phobos as an ellipsoid [8] on Mars surface.

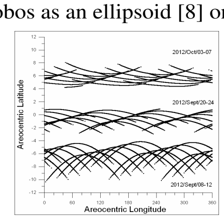

Figure 2: Shadow center pattern in 3 periods of 5 days. The shadow motion would be symmetric with respect to the equator when the Phobos center shadow latitude is equal to zero and Phobos is in its orbital nodes.

Conditions for Phobos eclipses on Mars are met twice a Martian year, covering a range of latitudes of about $[-70°, 70°]$. Phobos footprint moves rapidly over the Mars surface, covering mean stripes of about $166.824°$ every 7.657 h per day (Fig. 2). The instant at which each passage occur on a specific place is determined by the observer longitude.

3. Observational Strategy

As one of the MMPL main goals is to demonstrate the landing concept, the mission is aiming at an equatorial insertion with high enough atmospheric pressure to support the aerobraking unit. The latitude range is estimated within a band of $\delta\varphi = \pm 5°$. The operations control of the lander payload will be executed according to a predefined command sequence at regular time intervals. Dealing with the strategy of implementing the eclipse data acquisition cyclogram, the following considerations must be taken into account:

1) The MMPL landing site latitude will determine the observational dates. Fig. 3 shows the latitudinal cycle of the shadow restricted to the $\delta\varphi = \pm 5°$ latitudinal landing site band. The landing site longitude determines the time for the initial and final contacts of each eclipse.

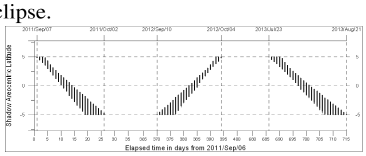

Figure 3: Date intervals for the 3 eclipse seasons within the latitude band of $\delta\varphi \pm 5°$.

2) The 2-D shadow becomes more elongated as it moves away from the subsolar point. For the forecasted latitude band, the shadow size departs from a nearly circular shape with a radii of 30 km to an elliptical shape, with major axis ranging from 62.5 km up to 700 km along the shadow track and minor axis from 56.5 km up to 57.6 km. This rapidly growth of the shadow size simultaneously occurs to a shadow speed rise, so shadow passages duration for a fixed point on the surface of Mars remain of the same order, lasting about 30–50 seconds for a central passage.

3) With a shadow mean velocity on Mars of $3°/\mathrm{min}$, Phobos eclipses will last about 55 minutes to cover the $166.824°$ longitude stripes. Measurements shall be taken every second to accomplish approximately 3 km precision for positioning the lander.

4) Solar eclipse mode will be activated for daytime in pre-calculated time windows during 1h (55 minutes to cover a whole stripe plus 2.5 minutes margin before and after each transit to ensure detection) with delays of 7.657 h at the UTC of the beginning of the first complete transit for each eclipse season.

5) The constriction of a landing site longitude band before the separation of the MMPL from the Phobos-Grunt would allow to modify the primary cyclogram. For example, for a $30°$ boundary in longitude, 10 minutes of observations (plus 2 minutes for margin error) with a frequency of 1 second would be implemented.

4. Summary and Conclusions

A chronogram of the latitudinal and longitudinal Phobos shadow path across the surface of Mars has been derived combining the annual cycle of the latitude and the diurnal cycle of the longitudinal shadow motion. The model and the applied parameters have been validated using the observations of eclipses of Phobos. Parameters given in [1], [4] and [9] used in our parameterization model fits observations with a mean offset of 0.002 seconds for MER observation, and parameters given in [7] and [9] with 2.240 seconds for MOLA observations. Finally, considering the MMPL constrains the data acquisition cyclogram is described.

Acknowledgements

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