EPSC Abstracts
Vol. 5, EPSC2010-776, 2010
European Planetary Science Congress 2010

Numerical simulations of the EJSM/Laplace gravity experiment

S. Finocchiaro (1), L. Iess (1), P. Racioppa (1), P. Tortora (2)
(1) Dipartimento di Ingegneria Aerospaziale e Astronautica – Università di Roma La Sapienza, Via Eudossiana 18, 00184 Rome, Italy, (2) Università di Bologna, Italy (stefano.finocchiaro@uniroma1.it, paolo.racioppa@uniroma1.it, luciano.iess@uniroma1.it, paolo.tortora@unibo.it/ Phone (1): +39-0644585976)

Abstract

EJSM/Laplace is a mission to the Jovian system jointly undertaken by NASA and ESA. The mission consists of two spacecraft: NASA's JEO (Jupiter Europa Orbiter) will explore the moon Europa, ESA's JGO (Jupiter Ganymede Orbiter) will be devoted to the study of Callisto and Ganymede.

The gravity science investigation of the Jupiter Ganymede Orbiter will provide crucial information on the interior structure of Ganymede and Callisto. Gravity fields and tidal deformations will be determined by means of precise Doppler tracking of the spacecraft in Ka-band (32.5-34 GHz). Additional science objectives carried out with the radio system are surface and atmospheric investigations using bistatic scattering and spacecraft-to-spacecraft radio occultations.

The key onboard instrument is a Ka-band Translator (KAT) which, complemented by suitable ground instrumentation, will enable a radio link characterized by a very high phase stability.

1. Introduction

In the initial phase of the mission JGO will be placed in a resonant orbit with Callisto, allowing 15 fly-bys of the moon. In the following phase (about 180 days), the spacecraft will be inserted in a circular and nearly polar orbit around Ganymede, at an altitude of 200km. The main scientific goals are[1]:

- Deep interior structure. The radial density distribution of the deep satellite interiors will be inferred from their moment of inertia factor and low-degree gravity field coefficients.
- Crust and lithosphere. Intrinsic density anomalies will be observed from higher degree gravity data in combination with laser altimetry.
- Subsurface water oceans. The detection of a global subsurface water ocean and its characterization requires the determination of the tidal deformations using gravity measurements and laser altimetry.
- Fundamental Physics. Test the time delay of photons propagating in the gravitational field of the sun and Jupiter during conjunctions

The Radio Science Instrument (RSI) is a system level experiment, which uses the on-board and ground instrumentation, combined with suitable orbit determination software. The main observable quantities are the spacecraft range (accurate to 20 cm, two-way) and range rate (to 3 micron/s at 1000 s integration time, two-way), exploiting the microwave radio links to and from the spacecraft[1].

The key element is the implementation of a Ka-band radio link in both legs (uplink and downlink) capable to operate, if necessary, also in a multi-frequency configuration when a complete cancellation of the plasma noise is required. In order to ensure the best data quality, all radio-metric measurements must be carried out in a coherent two-way mode, using highly stable frequency standards for the generation and down-conversion of the carrier[1].

3. Numerical Simulations

We report on the results of numerical simulations of the gravity measurements in the orbital phase around Ganymede. The main goal of the simulations is an assessment of the attainable accuracy in the retrieval of Ganymede's gravity field, both static and variable, during the JGO circular science phase. As an additional outcome, we have determined the accuracy in the estimation of the spacecraft orbit relative to Ganymede, an important information for the correct referencing of the laser altimetric measurements.

Range rate data have been simulated by introducing an additive white Gaussian noise corresponding to the expected end-to-end radio link performances. These data have been processed using a least squares filter in order to obtain the best estimate of the gravity moments and their associated covariances.

Different scenarios have been reproduced corresponding to operative altitudes of 200 and 500 km. The 500 altitude reduces the effects of possible errors in the estimation due to a mismodeling of the drag from Ganymede's exosphere. Indeed, the onboard power system is based upon large solar panels that increase considerably the area-to-mass ratio. Therefore the non-gravitational accelerations due to atmospheric drag have to be accurately modeled. Although we find that the gravity field estimation is marginally affected by an error in the modeling of the atmospheric drag, the effects on the recovery of the trajectory are significant.

4. Summary and Conclusions

The covariance analysis shows that the experiment is able to meet the requirements for the estimation of the Ganymede's gravity moments both in the lower (200 km) and the higher orbit (500 km). We find that the higher operative altitude (500 km) reduces the accuracy of the estimation, although the degradation is still compatible with the mission objectives. For example, the accuracy in the retrieval of the degree 10 coefficients is degraded by only a factor of 2.5 going from 200 km to 500 km. These results show that, although at 500 km the effect of the drag is drastically reduced, the weaker gravitational perturbations on the orbit are even more significant.

While neutral particle drag does not jeopardize the estimation of the gravity field coefficients, it affects the reconstruction of the spacecraft trajectory. In the absence of accurate modeling, or in case of a patchy exosphere, atmospheric drag may prevent an orbital reconstruction to the level required by the laser altimeter. In this case the crossover technique and other methods (such as the use of stochastic dynamical models) may be required to improve the orbit determination.

References

[1] Asmar, S., Folkner, W., Iess, L., and Tortora, P.: Galilean Satellites Gravity Investigations and Interior Structure with Future Missions, American Geophysical Union, Fall Meeting 2009, abstract #P51E-1172.

[2] Asmar, S. W., J. W. Armstrong, L. Iess, and P. Tortora (2005), Spacecraft Doppler tracking: Noise budget and accuracy achievable in precision radio science observations, *Radio Sci.*, 40, RS2001.