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Status of the Ganymede Laser Altimeter (GALA) for ESA's Jupiter Icy Moons Explorer (JUICE) Mission

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Abstract

The Ganymede Laser Altimeter (GALA) is one of ten instruments selected for ESA's Jupiter Icy Moons Explorer (JUICE) mission. The scientific goals of the GALA instrument cover a wide range of questions in the areas of geology, geophysics and geodesy of the icy satellites of Jupiter, Ganymede, Europa and Callisto. Here we will present an overview on the scientific goals as well as on the status of the instrument development, operational concepts and the current performance analysis.

1. Introduction

In 2013 ESA selected the Jupiter Icy Moons Explorer (JUICE) as the first L-class mission within the Cosmic Vision Program. This mission will explore Jupiter, its magnetosphere and satellites first in orbit around Jupiter before going finally into polar orbit around Ganymede the largest of the Galilean moons [1]. Ganymede is a typical icy moon containing mainly H_2O ice at the surface and about up to 40% H_2O by mass in its interior. Ganymede is unique in having an intrinsic magnetic dipole field and the satellite has undergone phases of intense geological activity during its evolution. This is most evident in the so-called bright terrain characterized by extension and tectonism covering roughly two thirds of the surface. The bright terrain is distinct from the heavily cratered and older dark terrain. The Ganymede Laser Altimeter (GALA) is one of ten payloads onboard the spacecraft and is developed under responsibility of the DLR Institute of Planetary Research in collaboration with industry and institutes from Germany, Japan, Switzerland and Spain. Its major objectives are to measure the surface topography and the tidal deformation of the satellite.

2. The JUICE Mission

JUICE will be the first orbiter around a moon (other than Earth's moon) in solar system exploration. Its launch is currently planned for June 2022 followed by an interplanetary cruise of 7.6 years. Jupiter orbit insertion will take place by the end of 2029. The spacecraft will perform a 3-years Jupiter-orbiting tour including two flybys of Europa at 400 km altitude and multiple flybys at Ganymede and Callisto with a minimum altitude of 200 km. Finally, JUICE will enter into a near-polar orbit around Ganymede. After Ganymede orbit insertion the initial highly elliptical orbit will naturally evolve into a 5000-km circular orbit followed again by a highly elliptical (500 x 10,000 km) phase due to perturbations by Jupiter. During one of the pericenter passages an orbit maneuver will bring the spacecraft into a 500-km circular orbit in which it will be staying for at least 132 days until end of nominal mission. The latter phase will be the main period for GALA taking data. In addition data will be taken at Europa, Ganymede, and Callisto at closest approaches of flybys in the Jupiter orbiting phase.

3. GALA Science

GALA has two main objectives: (1) by range measurements it shall obtain Ganymede's topography on global, regional and local scales. This will reveal how surface features have formed and how they are connected with the shallow interior ice shell. Global shape measurements will tell us whether the satellite is in hydrostatic state with respect to rotational and tidal forces. (2) Obtaining range measurements distributed in time along the orbital cycle, tidal variations of surface elevations will be measured. The tidal amplitudes are indicative for the presence of a subsurface ocean and would (together with complementary measurements) constrain the ice-I shell thickness [2]. In addition, GALA will provide surface roughness maps on global, regional and local scales that will be set into context with the geological surface record. With GALA the orientation of the polar axis can be determined and rotational models, including possible longitudinal librations, will be improved. GALA will use a digital filter but will also be capable of transmitting digitized return signals. With the latter, a better separation of albedo, surface roughness and local slopes can be expected. An important objective is to relate the surface roughness to different terrain types on Ganymede. To characterize surface roughness at Ganymede laser footprints of 50 m and high shot frequencies will be used in the Ganymede orbit phases. Analysis of the digitized sample of the return pulse by GALA provides the data-sets for surface roughness. Furthermore, surface roughness measurements will be used to characterize possible landing sites for future landers. A laser altimeter can obtain data on surface albedo at the corresponding laser wavelength, in this case 1064 nm. The icy satellites all show high reflectivities in the 1-micron range. As the altimeter carries its own light source, the albedo measurements do not depend on corrections of photometric (illumination) effects. Hence, more controlled measurements of albedo –though restricted to the narrow bandwidth of the laser– are possible. Laser altimeter observations become particularly important in areas of permanent shadow, where camera observations are not at all possible. Such measurements will complement the data sets from the near-infrared spectrometers. Correlation of albedo with geological units and the relation to Ganymede's magnetic field and interaction with the Jovian magnetosphere will be searched for.

4. The Instrument

GALA is a single-beam altimeter: a laser pulse (at 1064 nm wavelength) is emitted by using an actively Q-switched Nd:YAG laser firing at 30 Hz in nominal operation. A small fraction of the pulse is guided through fiber optics onto the detector characterizing the outgoing pulse and time of emission. After about 3 msec (assuming 500 km altitude) the Lambertian reflection of the pulse from the surface of Ganymede is received by a 26-cm aperture telescope and transferred to the detector, an Avalanche Photo Diode (APD). The signal is digitized at a sampling rate of 200 MHz and transferred to the range finder module, which determines (a) the time of flight between the emission and receiving of the pulse (b) the pulse shape, in particular the pulse-width, and (c) the energy of the received pulse. From the time of flight of the wave-package and the spacecraft position and attitude, the distance for each shot can be converted into height above a reference surface in post-processing of the data. The pulse-width is a measure of the surface roughness and slope at the scale of the laser footprint (50 m diameter at 500 km altitude orbit). An estimate of the albedo is obtained by comparing the energy of the emitted pulse with the one of the received pulse. Here we will report on the overall status of the technical development of GALA.

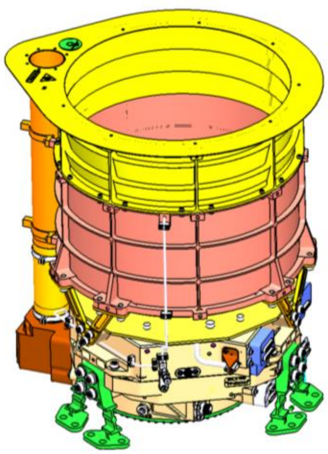

Figure 1: GALA Tranceiver (Transmitter + Receiver)

5. References

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