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Surface Gravimetry on Dimorphos with GRASS on Juventas

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Introduction

The gravimeter for small solar system objects (GRASS) [1] is an innovative and compact sensor that can measure absolute surface accelerations in the order of nano-g. It is payload onboard the Juventas CubeSat which will land on Dimorphos, the moonlet of the binary asteroid system Didymos. GRASS will measure the local gravity vector and its temporal variations at the landing site in order to constrain the geological substructure as well as the surface geophysical environment.

The instrument is currently under development at the Royal Observatory of Belgium in cooperation with EMXYS in Spain and the Belgian Royal Institute of Space Aeronomy.

The average gravitational force expected on Dimorphos' surface is around 4.5 x 10^{-5} m s^{-2} (or 4.5 mGal). Apart from the self-gravitation of the body, centrifugal forces and the acceleration due to the main body of the system contribute to the surface acceleration. The temporal variation of the signal is driven by the dynamical state of Didymoon with respect to Didymain and the related librations. Figure 1 illustrates the Didymos system, with its main body and the moonlet Dimorphos. While for the main body a shape model exists, for Dimorphos currently a three-axial ellipsoid is assumed (Figure 2).

Mission overview

GRASS will fly onboard the Juventas CubeSat [2], which is part of the Hera mission [3,4]. Hera is part of the international Asteroid Impact and Deflection Assessment (AIDA) cooperation, consisting of ESA's Hera and NASA's Double Asteroid Redirection Test (DART) mission. DART consists of a kinetic projectile that will impact on the secondary body of the binary asteroid system Didymos, whereas Hera will visit the system afterwards to investigate the aftermath of the impact and addresses further more general scientific questions.

Hera will be launched in 2024 and arrive at Didymos in the very end of 2026. Juventas will be released mid-2027 to contribute to asteroid research and mitigation assessment objective of the Hera mission by using radar and radio measurements. At the end of the mission, Juventas will soft-land on Dimorphos' surface and start with GRASS its dedicated mission phase for geophysical investigation. The local surface acceleration vector measurements will be complemented by a detailed shape model as well as radar and radio science measurements.

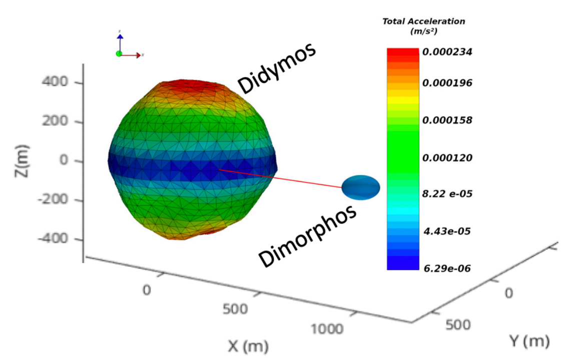


Figure 1: Surface gravity in the Didymos system

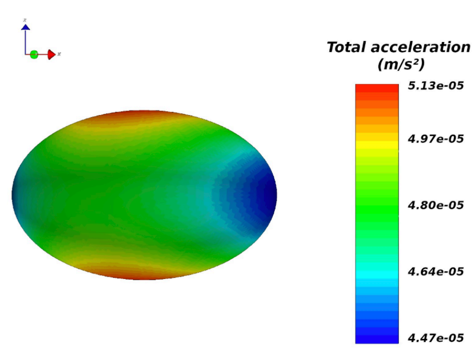


Figure 2: Surface gravity on Dimorphos

GRASS science objectives

GRASS focuses on the determination of the mass of Dimorphos, constraining the local geological substructure (mass anomalies, local depth and lateral variations of regolith) and surface geophysical environment (tides, dynamic slopes and centrifugal forces) and indirectly, in synergy with other instruments, on a global gravity solution and the interior structure of the moonlet.

Scientifically, this is important to understand the origin and evolution of the asteroid moonlet itself and the binary system as a whole. Additionally, these quantities are also relevant to characterize the kinetic impact technique for asteroid deflection. Furthermore, GRASS will demonstrate its abilities to be possibly employed in other missions to small bodies, as the knowledge of gravitational accelerations induced by small bodies with irregular shapes is crucial for any landing or rover mission as well as for proximity operations.

Table 1 gives an overview of the science objectives.

Table 1: GRASS science objectives

Objective	Measurement
S#1 **Local subsurface inhomogeneities and global mass of Dimorphos.**	Determination of local gravity vector at landing location with accuracy of <1% in direction and amplitude.
S#2 **Dimorphos dynamical state**	Investigation of surface acceleration variations due to rotation kinematics, tides and orbital dynamics. Measurements as for S#1, but for several locations along the orbit of Dimorphos around Didymos.
S#3 **Global gravity solution, interior structure and surface mass transport**	Synergy of data with other instruments (radar, radio, CubeSat decent, star trackers) to obtain holistic view of gravity and interior.

The GRASS instrument

GRASS is compliant with the CubeSat form factor and power restrictions. The gravimeter measurement principle is based on the displacement and deflection of a flat spring due to the gravitational field. A capacitive transducer translates this deflection and the modulation of the measured g-vector by rotation allows the rejection of the zero-g bias. In addition, no leveling is required (Figure 3),

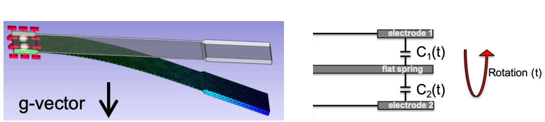


Figure 3: GRASS measurement principle

In order to obtain the full 3-dimensional gravity vector, two of these rotating gravimeters are required, ideally aligned orthogonally to each other. Figure 4 shows the two-axes gravimeter.

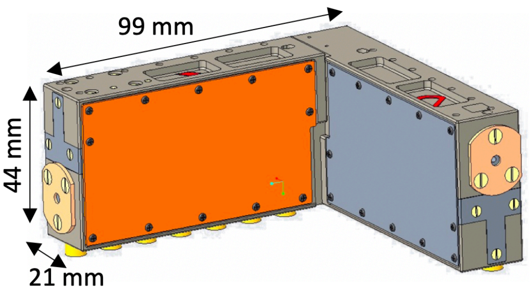


Figure 4: CAD view of the two-axes gravimeter

Surface operations

A single measurement of the gravimeter lasts for several minutes as it includes a number of slow rotations of the sensor head for good performance. Three different operational modes are foreseen: Health Check (HC), Science measurement (SCI), Calibration measurement (CAL). Addressing S#1, a single measurement of the local surface acceleration vector at the landing location shall be sufficient. But in order to obtain a robust measurement and also to monitor the dynamical state of Didymoon over its orbit around Didymain (S#2), the surface acceleration vector will be measured every 30° along the orbit. That corresponds to 12 measurements with a temporal separation of about 1 hour. Three calibrations are foreseen along one orbit. In Figure 5 they are distributed evenly, but this might change depending on the landing location (e.g. when there is a dusk/dawn transition to be considered). At least on orbit of Dimorphos around Didymos is anticipated to be covered.

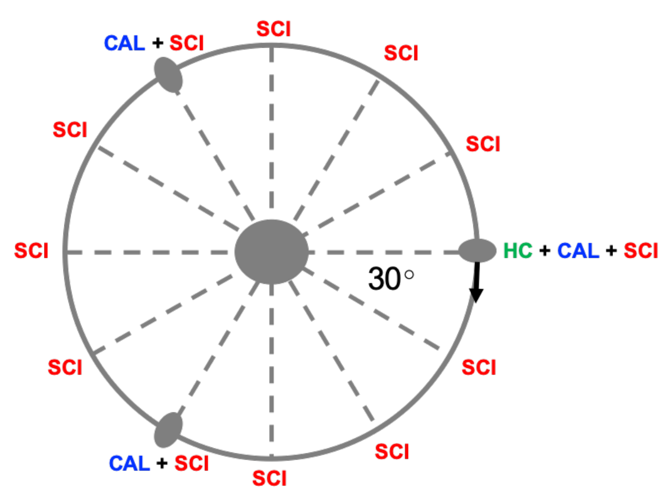
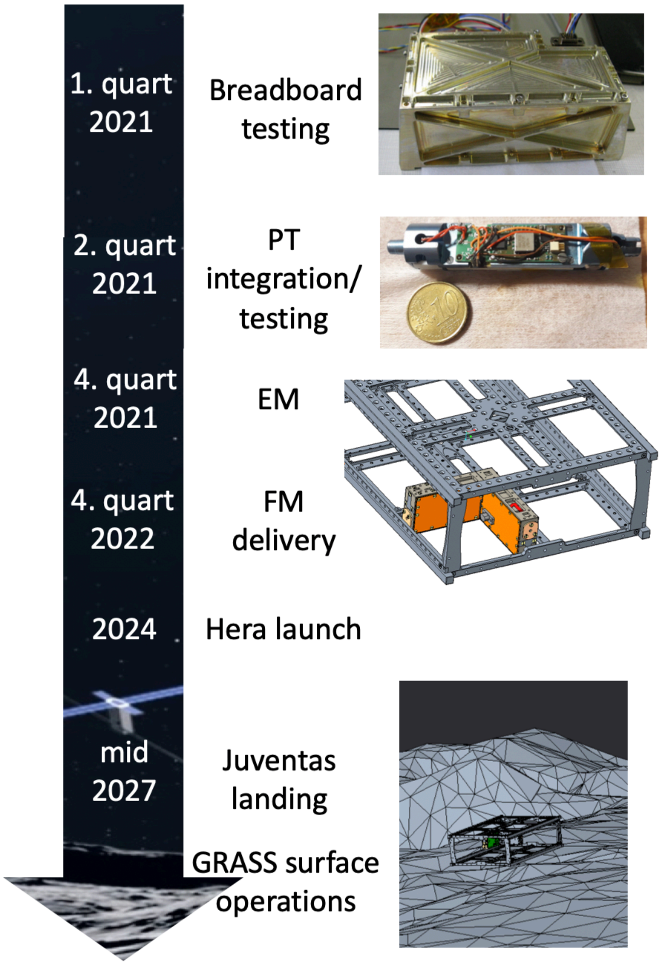


Figure 5: Operational concept during the orbit of Dimorphos around Didymos

Project timeline



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References

[1] van Ruymbeke, M. et al., EGU2016-9313, EGU General Assembly, Vienna, Austria, 2016.

[2] Karatekin et al., Juventas CubeSat for the Hera mission, PDC 2021

[3] Michel et al., The ESA Hera mission: planetary defense and science return, PDC 2021

[4] Küppers et al., The measurement goals and payload of the Hera mission to Dimorphos, PDC 2021