TASTE MISSION TO DEIMOS: Terrain Analyzer and Sample Tester Explorer with smallsat and miniaturized lander.

M. Lavagna[1], J. R. Brucato[2], M. Bechini[1], A. Capannolo[1], T. Fornaro[2], F. Fiore[3], A. Meneghin[2], D. Paglialunga[2], R. Piazzolla[3], G. Poggiali[2], J. Prinetto[1], G. Zanotti[1], [1]Politecnico di Milano-DAER, Milano, Italy, michelle.lavagna@polimi.it, michele.bechini@polimi.it; andrea.capannolo@polimi.it; jacopo.prinetto@polimi.it; giovanni.zanotti@polimi.it, [2]INAF-Astrophysical Observatory of Arcetri, Firenze, Italy, john.brucato@inaf.it; teresa.fornaro@inaf.it; andrea.meneghin@inaf.it; daniele.paglialunga@inaf.it; giovanni.poggiali@inaf.it; [3]INAF-Astrophysical Observatory of Trieste, Trieste, Italy, fabrizio.fiore@inaf.it; raffaele.piazzolla@inaf.it.

TASTE rationale: Deimos and Phobos are considered primary targets of investigation to understand the origin and evolution of Mars and more in general the terrestrial planets of the Solar System. To unveil the origin and evolution of Phobos and Deimos it is necessary to have detailed knowledge of both moons. In particular, the scenario of the formation (catastrophic impact vs asteroid capture) is still unclear and several questions need to be addressed [1]. To date, no spacecraft mission has explored Phobos or Deimos as a primary objective, but several Mars-observing spacecrafts have conducted remote, opportunistic observations of these bodies. Data acquired from these orbiters and ground-based telescopes seem to point out for a catastrophic collision as main scenario for the moons' formation, but several observations are also supporting the primitive asteroid capture [2]. The JAXA Martian Moons Exploration (MMX) mission [3], planned to be launched in September 2024 will investigate the origin of the two moons performing a sample return from Phobos' surface.

TASTE scientific instruments and goals: TASTE aims complementing MMX Phobos and Deimos investigation by focusing on Deimos surface, combining both **global remote sensing** observations from a close orbit and **direct in-situ analyses** of the surface thanks to a lander release on Deimos. With a synergy between orbital and in-situ investigations, the proposed mission will achieve several scientific objectives: i) Deimos global morphology and setting, ii) moon global elemental abundance, iii) landing site morphology and texture, iv) landing site organic content, v) surface composition and vi) landing site properties vs global surface properties.

TASTE is conceived as a Cubesat-in-Cubesat (CiC) mission: a 12U space asset composed by a **9U orbiter** and a **3U lander**. Starting from the successful experiences of Haybusa2 [4] and Insight missions [5], which demonstrated the Cubesat class applicability to space exploration, TASTE wants to step further in their exploitation for low-gravity environments scientific investigation, thanks to a miniaturized set of instrumentation for remote and in situ science for a comprehensive data collection.

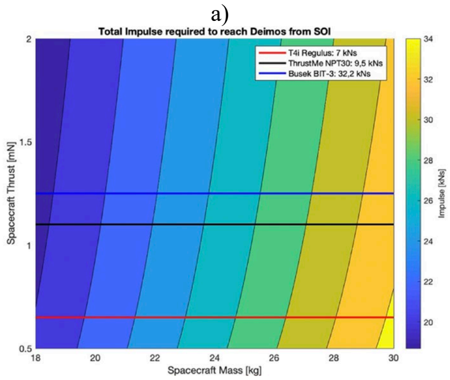
TASTE 9U orbiter embarks: a **miniaturized X-γ ray spectrometer**, to characterize planetary surfaces composition; this instrument is a revisiting of the payload designed and under development in the framework of the HERMES-TP and HERMES-SP EC\MUR\ASI projects; a commercial **multispectral camera**, to answer the scientific goals of global morphology, global elemental abundance, landing site morphology and texture assessment; thanks to a very low altitude orbit TASTE-Orbiter would contribute also to gravity field determination and internal structure understanding refinement.

TASTE 3U lander is equipped with a **miniaturized Surface Sample Analyser** (SSA), composed by a new Sample Acquisition Mechanism (SAM), conceived by PoliMi and a Surface Analytical Laboratory (SAL) developed by INAF-OAA; a commercial **VIS camera** complements the lander scientific instrument suite. TASTE-lander aims answering scientific questions about landing site organic contents, surface composition, landing site properties compare to global surface properties, gravity field determination and internal structure.

TASTE is conceived so that the **combination of remotely and in-situ collected scientific data** will provide crucial insight into the early development of Martian moon and a proper context to assess possible heterogeneities on the surface helping to unveil the origin of Mars system and increasing our knowledge on terrestrial planet formation and evolution. The miniaturized X-γ ray spectrometer is going to fly in 2022 as primary payload for the HERMES astrophysical mission in its 1U version installed on 6 3U Cubesat constellation [6]; the SAM is in its conceptual design phase at PoliMi, while the SAL, developed by INAF-OAA, inherits technology developed for AstroBio Cubesat (ABCS), a 3U CubeSat to be launched in 2021 as piggyback of ASI LARES2 spacecraft.

TASTE mission design and operations: TASTE 12U asset is assumed to take advantage of the numerous Martian missions planned for the near\medium future (in the framework of national and international campaign e.g. Mars Sample Return) to take a ride on board a mothership for the interplanetary leg, and to be released either at Mars Sphere of Influence (SOI) or at Mars bounded orbit. This flexibility is achieved thanks to the low thrust propulsion module embarked which allows spanning a wide range of total impulse devoted to gain the Deimos scientific orbit, as reported in Figure 1, with a 27,5 kg spacecraft and a 1.25 mN maximum thrust. At Deimos arrival, the "far range" phase allows a nearly full imaging of Deimos' surface through the orbiter's payload, while limiting the loss in resolution, while the next "close range" phase, by taking pictures of specific zones of interest, facilitates the 3U lander deployment and natural landing, and coordinates in situ and remote science operations.

a)



b)

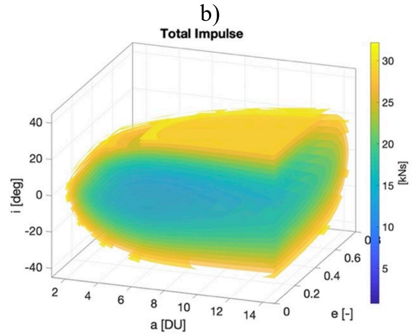


Figure 1. Transfer to Deimos requested total impulse: a) from SOI; b) from bounded orbit

For both phases, Quasi-Satellite Orbits (QSO) are explored as main option (see Figure 2). Their natural stability, and close range to Deimos, ensure very low to null station-keeping costs, and high-quality imaging of the surface [7]. Thirty-days operations suffice to provide the whole surface coverage along both the far and close-range phases, as shown in Figure 3. The selected close range QSO is shaped to comply with bouncing at touchdown minimisation, ensuring a landing velocity lower than the natural escape. Figure 4 highlights the achievable landing sites from the QSO, according to the release epoch, underlining the operations flexibility. **TASTE** space asset has a margined mass of 27, 57 kg, 4,5 kg devoted to the lander. Figure 5 and Figure 6 synthetically show the space asset and lander system design. The 3U lander thanks to its tilting mechanism [8] can adjust the landing attitude as needed to nominally operate SAM.

It has to be remarked that, even if TASTE is presented for the mission to Deimos, the lander design can be directly applied to in situ science for similar low gravity small bodies such as asteroids and comets, and the space asset can be easily tuned to comply with the different environmental conditions (illumination, dynamics, etc.) such as the Moon or the satellites of Jupiter and Saturn.

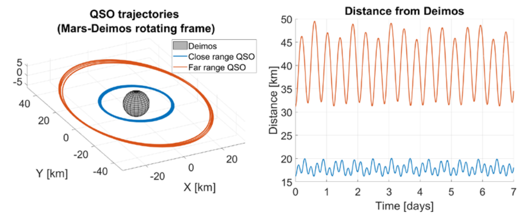


Figure 2. QSO for far and close-range scientific phases.

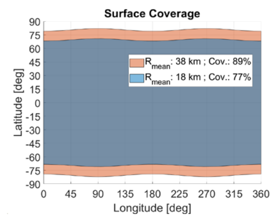


Figure 3. QSO Deimos Coverage

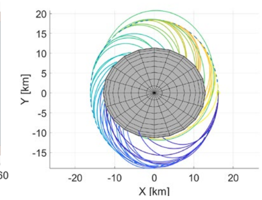


Figure 4. Lander free fall trajectories from QSO

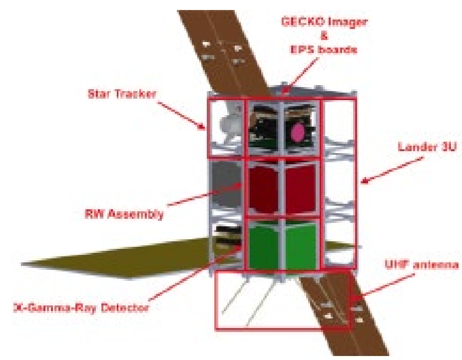


Figure 5. TASTE space asset overview

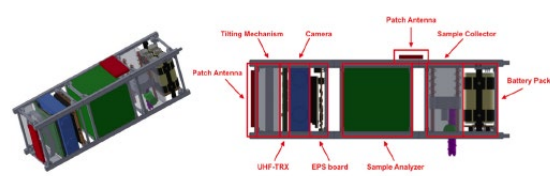


Figure 6. TASTE lander system overview

References: [1] Rosenblatt et al., (2016), *Nat. Geosci*, 9, pp.581–583 [2] Murchie et al., (1999), *JGR*, 104 (E4), pp.9069-907 [3] Campagnola et al., (2018), *Acta Astronautica*, 146, pp. 409-417 [4] Grott et al., (2019), *Nat. Astron.*, 3, pp. 971–976 [5] Banerdt et al., (2017), 48th LPSC No. 1964, id.1896 [6] Evangelista et al., (2020), *Space Telescopes and Instrumentation 2020: Ultraviolet to Gamma Ray*, 1144, pp. 241-256 [7] Wallace et. al., (2012), *Astrodynamics Specialist Conference,* p. 5067 [8] Tra-Mi Ho et al., (2017), Space Science Reviews, 208 (1-4)