IAC-24-A3.4A.5

The MMX Rover IDEFIX: Getting ready for launch and preparing Science Operations

Stephan Ulamec[1*], Patrick Michel[2], Matthias Grott[3], Susanne Schröder[3], Heinz-Wilhelm Hübers[3], Yuichiro Cho[4], Olga Prieto Ballesteros[5], Naomi Murdoch[6], Pierre Vernazza[7], Jörg Knollenberg[3], Jens Biele[1], Simon Tardivel[8], Christian Krause[1], Cedric Delmas[8], Hirdy Miyamoto[4]

1 Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), 51147 Cologne, Germany, stephan.ulamec@dlr.de
2 Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, CS 34229, 06304 Nice Cedex 4, France
3 Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), 12489 Berlin, Germany
4 University of Tokyo, 113-0033 Tokyo, Japan
5 Centro de Astrobiologia (INTA-CSIC), 28850, Torrejón de Ardoz, Spain
6 Institut Supérieur de l'Aéronautique et de l'Espace (ISAE-SUPAERO), Université de Toulouse, 31055 Toulouse, France
7 Laboratoire d'Astrophysique de Marseille (LAM), 13388 Marseille, France
8 Centre National d'Etudes Spatiales (CNES), 31401 Toulouse, France
* Corresponding Author

Abstract

The Martian Moon eXploration (MMX) mission by the Japan Aerospace Exploration Agency, JAXA, is going to explore the martian moons Phobos and Deimos. Both moons will be investigated remotely from the MMX mother spacecraft, which will also collect samples from the surface of Phobos, and a small rover, IDEFIX, will be delivered to Phobos surface. The Rover carries a scientific payload of four instruments: RAX, a Raman spectrometer to measure the mineralogical composition of the surface material, miniRAD a radiometer measuring the surface brightness temperature of both regolith and rocks, NavCam, a stereo pair of cameras looking ahead to image the terrain and also support navigation,and two WheelCams looking at the wheel-surface interface, and thus investigating the properties and dynamics of the regolith. The cameras, will serve for both, technological and scientific needs. Landing of the rover is foreseen in late 2028, and will take place during the rehearsal of the first landing operations of the main spacecraft. IDEFIX will be released from an altitude of about 40 m, fall to the surface, bounce a few minutes, upright itself and drive and carry out scientific investigations for about 100 days. The flight model of the rover has been delivered to JAXA/MELCO where it is going to be integrated to the main spacecraft and will undergo further qualification and functional tests. Operational sequences, e.g. defining the interplay between locomotion and science instruments are currently being prepared. Launch of the MMX mission is planned for October 2026. The Rover is a contribution by the Centre National d'Etudes Spatiales (CNES) and the German Aerospace Center (DLR) with additional contributions from INTA and Univ. Valladolid (Spain) as well as U. Tokyo and JAXA.

1. Introduction

The Martian Moons eXploration (MMX) mission by the Japan Aerospace Exploration Agency, JAXA, is going to explore the martian moons, Phobos and Deimos remotely, but will also return samples from Phobos, and deliver a small Rover to its surface [1,2]. The mission will help to understand the formation and evolution of both moons. Their origin is under debate since a very long time [3,4]. Models exist suggesting that they may be captured asteroids or that they may have formed during a massive impact on Mars [4,5].

The rover IDEFIX, provided by the Centre National d'Etudes Spatiales (CNES) and the German Aerospace Center (DLR) with additional contributions from INTA and Univ. Valladolid (Spain) as well as the University of Tokyo and JAXA will be delivered to the surface of Phobos during a rehearsal of the landing of the main spacecraft. It has a payload of four scientific instruments, that will analyse the physical, dynamical and mineralogical properties of Phobos´ surface. [6,7].

2. IDEFIX design and payload

The rover with an allocated mass of 29.1 kg, (including the mechanical support system (MECSS) and communications system, which will stay on the main spacecraft) is based on a carbon fiber structure, a locomotion system with four individually controlled wheels and a power system with a solar generator and re-chargeable batteries.

The ground segments are established in CNES in Toulouse as well as DLR in Cologne, Germany. All communications between the rover ground segment and the flight segment are linked via the MMX spacecraft and the JAXA ground segment and ground stations.

Figure 1 shows the rover design, fully deployed in the on-Phobos configuration. Figure 2 shows the Service Module (SEM), which is inside the chassis and accommodates electronics, batteries communications unit and instruments.

The rover, attached to the mechanical support system (MECCS) has been delivered to JAXA/MELCO and is now integrated to the main spacecraft and undergoing acceptance and functional tests on the MMX spacecraft level. Figure 3 shows the fully integrated IDEFIX rover flight model prepared for environmental tests at CNES.

IDEFIX is accommodating four scientific instruments:

2.1 Navigation cameras NavCams

The stereo NavCams will be looking in front of the rover with a resolution of ~1 mm at 1 m distance and are key for navigation and analysis of the rover location, attitude and locomotion. Besides of the relevance for the system, the images will allow e.g. interpretation of the terrain, crater and grain/boulder size-frequency distribution, space weathering and heterogeneity of the surface material [8].

2.2 Wheel cameras WheelCams

The two WheelCams are placed on the underside of the rover and each aimed at a different rover wheel. The WheelCam images of the surface will be used to characterize the regolith particles (e.g., size distribution, morphological characteristics). Images of the wheel-regolith interface and the rover tracks will be used to constrain the bulk mechanical properties of the surface material that can be derived from e.g., the sinkage and slippage of the wheel. Finally, using coloured LEDs it will be possible to study the mineralogical composition of the regolith from reflectance and albedo measurements, and to asses space weathering by comparing inside and outside of the rover tracks [9].

2.3 Raman spectrometer RAX

RAX is a compact Raman spectrometer with a mass of 1.5 kg, able to analyse the mineralogy on a spot about 8 cm underneath the rover chassis. Heterogeneity of surface grains can be determined and the mineralogy of the material, measured in-situ will complement orbital spectroscopic data and will be important for putting in context the samples which will be returned to Earth [10].

2.4 Radiometer miniRAD

The miniRAD instrument will investigate the surface temperature and surface thermo-physical properties of Phobos by measuring the radiative flux emitted in the thermal infrared wavelength range. The measurements will constrain porosity and grain properties of the surface material [11].

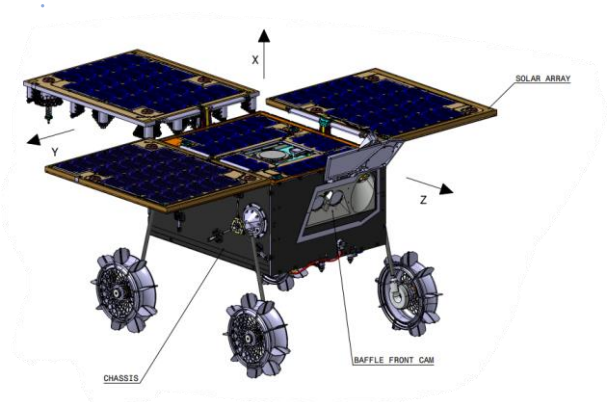

Fig. 1. IDEFIX in on-Phobos configuration with deployed solar generator (image: CNES)

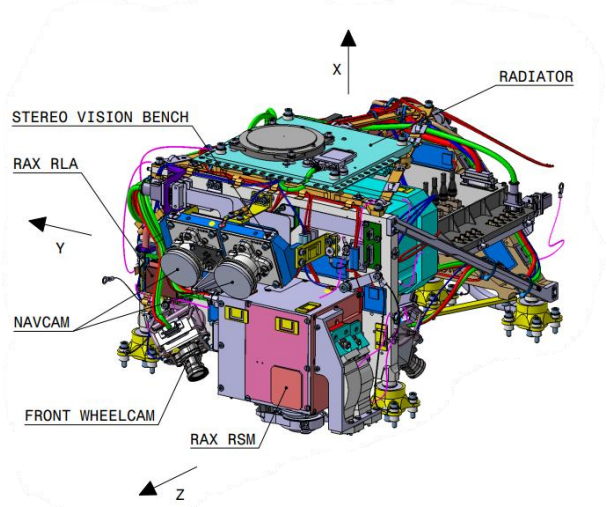

Fig. 2. IDEFIX SEM without MLI. The subunits of RAX indicated are RLA (laser) and RSM (spectrometer) (image: CNES)

3. Project status

The IDEFIX rover was delivered to JAXA in February 2024, after undergoing its environmental test program in Europe. It is now attached to the main spacecraft, where tests of the complete MMX system are performed at MELCO in Kamakura. Figure 4 shows

the fully integrated IDEFIX rover flight model before shipment to Japan.

The test program is performed both, with the flight model, attached to the MMX spacecraft, but also for operational and planning preparation with a representative "flat rover" at CNES in Toulouse.

After having finished these tests IDEFIX will be ready for launch with MMX. The launch is now foreseen for 2026 [12], arrival at the martian system in 2027 and landing of the rover in late 2028 after a landing site selection exercise.

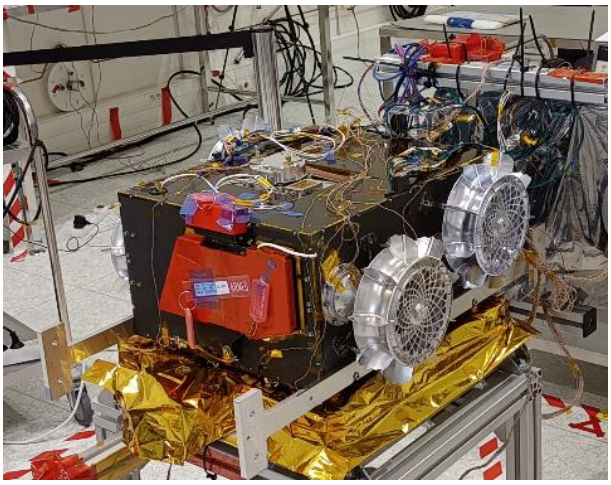

Fig. 3. IDEFIX flight model (FM) during tests at CNES. Note that solar generator is not integrated in this configuration. (image: CNES)

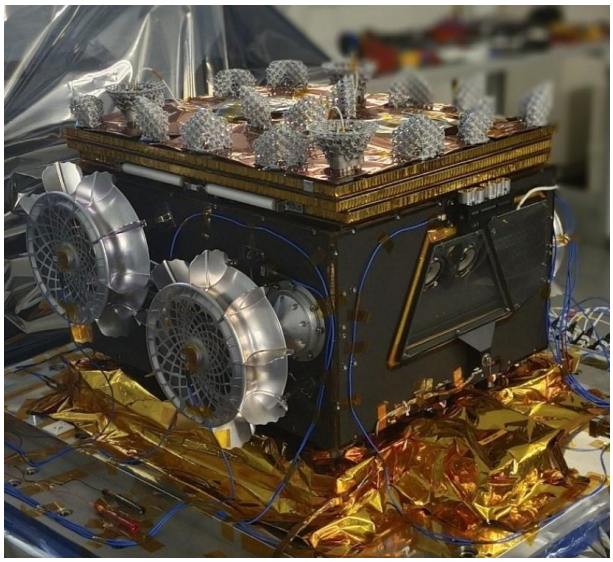

Fig. 4. IDEFIX FM in cruise configuration. On the top the crushable material to protect the solar generator pre-deployment. The legs with wheels are in-folded (image: CNES)

6. Conclusions

The rover IDEFIX after passing final tests with the MMX spacecraft is going to be ready for launch in October 2026 [12]. Ground segment and Operations centers for IDEFIX are built up and the operational phases after launch are being prepared.

Rover operations on the surface of Phobos are planned to begin mid-December 2028. The data obtained with the rover will support the landing of the MMX spacecraft and significantly enhance the science return of the overall MMX mission. As a technology demonstrator, IDEFIX will be the first rover with wheels, moving in a low gravity environment.

It is currently planned that MMX will leave Mars orbit in November 2030 and return Phobos samples to Earth in July 2031 [12].

Acknowledgements

MMX is a JAXA mission with contributions from NASA, CNES and DLR. The Rover will be provided by CNES and DLR with additional science contributions from Japan and Spain.

The authors would like to thank the teams of MMX and the Rover as well as the programmatic support to realize this project.

References

[1] Kawakatsu, Y., Kuramoto, K., Usui, T., Sugahara, H., Ootake, H., et al., Preliminary design of Martian Moons eXploration (MMX), *Acta Astron*. 202, pp. 715–728, 2023

[2] Kuramoto, K., Kawakatsu, Y., Fujimoto, M., *et al*., Martian Moons Exploration MMX: Sample Return Mission to Phobos Elucidating Formation Processes of Habitable Planets. submitted to *Earth, Planets and Space*, 74:12, 2022

[3] Rosenblatt, P., The Origin of the Martian Moons revisited, *Astron. Astrophys. Rev*., Vol. 19:44, 2011

[4] Kuramoto, K., Origin of Phobos and Deimos Awaiting Direct Exploration, *Annu. Rev. Earth Planet. Sci*. 2024. 52:495–519, 2024

[5] Usui, T., Bajo, K.i., Fujiya, W., *et al*., The Importance of Phobos Sample Return for Understanding the Mars-Moon System. *Space Sci Rev.*, 216**:**49, 2020

[6] Michel, P., Ulamec, S., Böttger, U., Grott, M., Murdoch, N., Vernazza, P., Sunday, C. Zhang, Y., Valette, R., Castellani, R., Biele, J., Tardivel, S., Groussin, O. and Jorda L., The MMX rover: performing in-situ surface investigations on Phobos, *Earth, Planets and Space*, 74:2, 2022Ulamec, S. Michel, P., Grott, M., Böttger, U.,

Hübers H.-W., *et al*., 70th International Astronautical Congress, IAC-19-A3.4B8, 2019

[7] Ulamec, S., Michel, P., Grott, M., Böttger, S. Schröder, U., Hübers, H.-W., Cho, Y., Rull, F., Murdoch, N., Vernazza, P., Prieto-Ballesteros, O., Biele, J., Tardivel, S., Arrat, D., Hagelschuer, T., Knollenberg, J. Vivet, D. Sunday, C., Jorda, L. Groussin, O., Robin, C and Miyamoto, H., Science Objectives of the MMX Phobos Rover, *Acta Astron*., Vol. 210, pp. 95-101, 2023

[8] Vernazza, P., Jorda, L., Tardivel, S., Baroukh, J., Groussin, O, *et al*. Surface science on Phobos with the navigation cameras of the MMX IDEFIX rover. submitted to PEPS

[9] Murdoch, N. *et al*, The WheelCams on the IDEFIX rover. PEPS, In prep.

[10] Cho, Y., Böttger, U., Rull, F., *et al*.., In-situ science on Phobos with the Raman spectrometer for MMX (RAX) onboard the MMX rover: preliminary design of instrument and feasibility of Raman signal detection. *Earth, Planets and Space*, 73:232, 2021

[11] Grott, M., Knollenberg, J., Hamm, M., et al., In-Situ Radiometric Investigation of Phobos Using the MMX Rover's miniRAD Instrument, 53rd Lunar and Planetary Science Conference, abstract 2678, 2022.

[12] Miyamoto, H., Kuramoto, K., Kawakatsu, Y., Fujimoto, M., et al. Martian Moons eXploration MMX, Rescheduled for Launch in 2026, 45th COSPAR Scientific Assembly, 2024