Developing European Curation for MMX Samples

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Curation of extraterrestrial samples is imperative for maximizing science return. Despite Europe's established meteorite and overall museal curation expertise, it currently lacks specialized infrastructure for samples directly returned from space. An opportunity to enhance capabilities in this area is provided by the Martian Moon eXploration (MMX) mission. MMX is led by the Japan Aerospace Exploration Agency (JAXA) and is planned to return >10g of core and regolith material from Phobos to Earth in July 2029 [1, 2].

Cooperative discussions between partnering space agencies and European institutions regard possible transfer of a portion of the anticipated MMX sample collection for long-term curation in European institutions, following the period of initial description at JAXA and the initial scientific analysis conducted by the MMX Science Sub-Teams (i.e., post-2030). Leading this initiative are the Centre National d'Études Spatiales (CNES) and the Museum National d'Histoire Naturelle (MNHM) in France and the German Aerospace Center (DLR) in Germany. Both are actively engaged in designing advanced curation facilities to receive, curate, and handle Phobos samples.

The Centre National de la Matière Extraterrestre (CNME, National Center for Extraterrestrial Materials) is a joint program supported locally by the National Museum of Natural History (MNHN), Sorbonne University and the Institut de physique du globe de Paris (IPGP) and, at the national level, by the French spatial and scientific research agencies (CNES and CNRS). The CNME will be built in the historical Geology and Mineralogy Gallery of MNHN in the center of Paris. The CNME will be designed to ensure long-term curation of unrestricted extra-terrestrial samples allocated to France from past and future space missions such as MMX, together with existing major collections of extra-terrestrial samples including: the national meteorite collection from MNHN, large polar micrometeorites collections and terrestrial analogues from the geology/mineralogy collections. The CNME will consist in a clean-room infrastructure, divided in separated modules with ISO7 to ISO5 environments, together with an adjacent laboratory for sample preparations and experiments not requiring a cleanroom environment. The CNME curation team will work under the supervision of CNES on the recently funded MARCUS project to build a dedicated apparatus for small sample (solid and gas) handling under restricted conditions (pure nitrogen glove boxes) and bio-contained environment. Instrumentation in the CNME will focus on acquisition of the basic properties on samples (from µm to cm scales), including optical 2D and 3D microscopy and imaging, weighting, magnetic susceptibilities, scanning electron microscopy, Raman and infrared (IR) microspectroscopy, XRD, with a dedicated suite of instruments to achieve initial characterization and cataloging of samples before allocation.

At the DLR Institute for Planetary Research in cooperation with the Museum für Naturkunde in Berlin, the Sample Analyses Laboratory (SAL) and its extension, the Sample Curation Facility are currently being setup [3]. The target date for completion is in the summer of 2024. It is mainly dedicated to the analyses of unrestricted extra-terrestrial materials from sample return missions. SAL will focus on spectroscopic, geochemical, mineralogical analyses at microscopic level. The instrumentation includes a Malvern Panalytical Empyrean X-ray diffraction (XRD), a JEOL iHP200F Field Emission - electron microprobe analyzer (FE-EMPA), a Field Emission - scanning electron microscope (FE-SEM), Keyence VHX-7000 3D microscope, and a vis-IR-microscope (Bruker Hyperion 2000), all housed in a clean room that is currently being built. Samples will be processed, handled and analyzed in pure nitrogen or vacuum conditions to minimize alteration and contamination.

Within the European Centre for Space Applications and Telecommunications (ECSAT) site of the European Space Agency (ESA), the recently established Vulcan Analogue Sample Facility (formerly SACF) is actively involved in the development of a robust European network dedicated to both existing and prospective extra-terrestrial analogue sample procurement, production, and supply chain management. The Vulcan Facility is further oriented towards advancing the scientific investigation of planetary analogues encompassing lunar, Martian, and other celestial bodies. This is accomplished through the provision of state-of-the-

art benchtop instrumentation for fundamental analyses encompassing geochemical, mineralogical, and crystal lattice properties (SEM-EDS, XRD, FTIR and Raman). Additionally, the Vulcan Facility offers geotechnical property characterization capabilities (ViseSize particle size analyser, pycnometer, and TGA). Concurrently, Vulcan lends support to the curation of extra-terrestrial materials and associated technology development initiatives (glovebox systems and a Double-Walled Isolator [DWI] with robotic arm equipped with a micromanipulator). The strategic focus of Vulcan on analogue samples is anticipated to play a pivotal role in addressing the curation and research challenges associated with upcoming and future extraterrestrial sample return missions.

Between partners of any joint sample return activity, a tightly-coordinated approach on curation protocols, and mutually high level of technical proficiency and training, is fundamental to achieving the main goal of long-term curation: preparing for techniques that have yet to be conceived, enabling testing theories that have not yet been developed, and catering for the ideas and needs of future scientists.

The implications of capability development in Europe for handling returned samples extend beyond the MMX mission. Establishing these curation facilities and developing a collaborative framework for distributed long-term curation will increase the readiness of European involvement in future sample return missions. In particular, developments in sample handling and curation infrastructure may be synergistic with that required by the long-term curation of Martian samples that are planned to be returned by the NASA/ESA Mars Sample Return (MSR) campaign.

References

1. Kuramoto K, Kawakatsu Y, Fujimoto M, et al (2022) Martian moons exploration MMX: sample return mission to Phobos elucidating formation processes of habitable planets. Earth, Planets and Space 74:. https://doi.org/10.1186/S40623-021-01545-7
2. Usui T, Bajo K, Fujiya W, et al (2020) The Importance of Phobos Sample Return for Understanding the Mars-Moon System. Space Sci Rev 216:49. https://doi.org/10.1007/s11214-020-00668-9
3. Bonato E, Helbert J, Schwinger S, et al (2023) The Sample Analysis Laboratory at DLR and its Extension to Curation Facility for MMX. In: 86th Annual Meeting of the Meteoritical Society. pp 6035–6035
4. Aliz Zemeny and Kamini Manick (2023) Lunar Highland Simulant Selection of The Luna Analogue Facility Dust Chamber For Future Missions – Space Resources Week, Luxembourg