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THE CNME PROJECT, A NATIONAL CURATION CENTER FOR EXTRATERRESTRIAL SAMPLES IN FRANCE.

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Introduction: Significant advancements are underway in the development of curation facilities specifically designed to safeguard pristine extraterrestrial samples retrieved via space missions. Following the successful return of samples from the asteroids Ryugu and Bennu by the Hayabusa2 [1] and OSIRIS-REx missions [2], additional samples from the Martian moon Phobos, spearheaded by the MMX JAXA-led mission [3], and from the Martian surface, as part of the NASA/ESA Mars Sample Return (MSR) mission [4], are slated for return to Earth within the next decade. Advanced curation research is currently ongoing [5, 6] at major curation facilities operated by JAXA and NASA [4,5,7], while other facilities are under construction, such as the SAL in Berlin [8]. Several laboratories in France possess specialized expertise in handling extraterrestrial samples obtained from space missions or from existing collections of extraterrestrial materials (meteorites and micrometeorites). Here, we present an overview of a project launched in 2023 to establish the National Center for Extraterrestrial Materials (CNME) in France. This facility will reside within the renowned Geology and Mineralogy Gallery of the National Natural History Museum (MNHN) in Paris (see Figure 1)

The CNME project: this project is supported, at the national level, by the French space and scientific research agencies (CNES and CNRS) and, locally, by the MNHN, Sorbonne University (SU) and the Institut de Physique du Globe de Paris (IPGP). A key objective of CNME will be to ensure the long-term curation of a fraction of samples from the future MMX JAXA-led mission [3]. As a result of on-going agreements between JAXA, the European (ESA), German (DLR) and French (CNES) space agencies, a fraction of Phobos (MMX) samples are expected to be transferred to the CNME in

Paris and to the SAL facility in Berlin [8]. In the long term, a module of CNME will be designed to receive safe Martian samples, once their release from restricted confinement of the Sample Receiving Facility (MSR-SRF) has been approved.

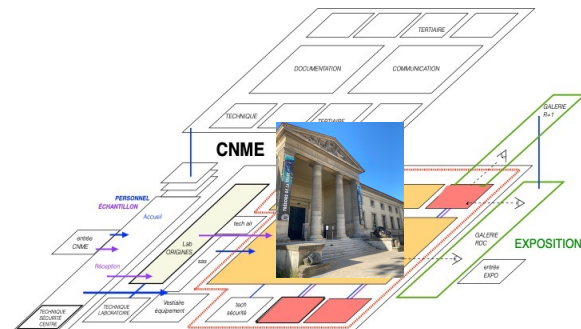


Figure 1: The CNME will be located in the historical Geology and Mineralogy Gallery (insert) of the MNHN in the center of Paris. It will be modular to host current collections of extraterrestrial materials (meteorites, micrometeorites, ...) and samples from space missions

The CNME will ensure the long-term curation of the MNHN historical meteorite collection that includes a large array of Martian samples (Shergottites, Chassignites, Nakhilites) [9] and several emblematic primitive chondrites (e.g. CI-chondrite Orgueil, Paris). The MNHN meteorite collection is actively used for cosmochemistry research projects and constantly grows with new additions every year. The CNME will also have the responsibility for the long-term curation of micrometeorite collections recovered from both Greenland and Antarctica [10-13], including the Concordia micrometeorites collection currently located

in a dedicated curation cleanroom at Univ. Paris-Saclay/IJCLab. These collections contain thousands of micrometeorites with minimal terrestrial weathering [13, 14]. In addition to these collections, the CNME will ensure the long-term curation of samples from the Chinese mission Chang'E-5 [15] recently donated to France. The curation and first-order analysis of lunar samples requires specific development, which will be carried out in close collaboration with teams from several laboratories with expertise in lunar regolith studies (IPGP, CRPG,...) and with scientists involved in other lunar projects such as Chang'E-6/DORN (IRAP, IPGP, CEA) [16].

The design of CNME is modular to allow flexible configurations of different environments for the curation of sensitive samples from different space missions and collections of extraterrestrial materials. The CNME clean-room infrastructure will be divided into modules going from class ISO7 to ISO5 [17] environments. Each module will contain secure cabinets and glove boxes under controlled atmospheres (dry and purified N₂...). It will host a laboratory dedicated to sample preparations. In the long-term perspective of MSR, the CNME team is involved in the MARCUS project to develop, under the supervision of CNES, a dedicated apparatus for small sample (solid and gas) handling under strictly controlled clean and dry N₂ atmosphere conditions. The CNME will include a dedicated space for developments and rehearsal activities with this apparatus.

Instrumentation in CNME will consist of a dedicated suite of instruments, to achieve initial characterization and cataloguing of samples with sizes ranging from a few μm up to cm-scales, including optical microscopy, weighing, magnetic susceptibility measurements, scanning electron microscopy, XRD, Raman and infrared (IR) micro-spectroscopy with a dedicated suite of instruments, to achieve initial characterization and cataloguing of samples. The CNME team and collaborators will gather expertise from curation to samples handling (micromanipulation, fragmentation...), first-order characterization by non-invasive and non-destructive techniques and dedicated sample preparation (e.g., thin and ultra-thin sections, polished sections, ...) in clean-room environments.

Dedicated sample holders preserving an ultradry N₂ atmosphere (vessels and capillary tubes) will be designed to allow safe transfer of mm to sub-mm grains between international curation facilities and laboratories. The aim is to prevent contamination of the samples while enabling a large spectrum of sample analyses. Samples will be manipulated or micro-manipulated with non-magnetic tools and stored in shielded cabinets to avoid magnetic contamination (by

the geomagnetic field or magnetic tools). The magnetic environment will be periodically monitored to identify any putative contamination [19]. New technological solutions will be studied for curation of volatile elements [18] contained in samples expected to be returned in the long-term by future space missions, including the return of ices and gas samples from cometary objects or planetary atmospheres.

A specific setup will be developed at IAS in order to allow a multi-scale (from mm down to a few μm) IR reflectance micro-imaging characterization of samples. The analysis, performed within a dedicated bench in a controlled atmosphere (e.g., N₂), will be fully non-destructive and non-invasive with no need for specific sample preparation. Other setups for sample preparation and/or first-order characterization are currently evaluated in French laboratories with the aim to build a national network of experts in curation-related activities and archiving data related to existing and future sample collections. At the international level, the CNME team will collaborate with other teams currently managing major curation centers worldwide.

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