QESA - QUARANTINE EXTRATERRESTRIAL SAMPLE ANALYSES FOR RETURNED SAMPLES

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Introduction: The upcoming Hayabusa II, Osiris Rex and Mars 2026 (statement of intent to explore the concept signed by ESA and NASA, April 2018) Sample Return missions, will bring back to Earth samples containing potential biohazards. To prepare for them, we have implemented a hyperspectral method [1] of analysis of grains, performed under BSL4 quarantine conditions, by combining several non-destructive imaging diagnostics. Our methodology was patented [2] and tested on meteorite grains [3-9].

Quarantine analyses: The QESA protocol combines Large Scale Infrastructure Facilities such as the European Synchrotron (ESRF) with lab-based microscopy analyses of Raman and IR spectroscopies. This combination of non-destructive X-rays, laser and IR spectroscopies records atomic (XRF: X-Ray Fluorescence) and molecular information (Raman, IR spectroscopies), speciation (XAS: X-ray Absorption Spectroscopy) and crystallinity (XRD: X-Ray Diffraction). Owing to the focused X-ray beams, the X-ray investigations are performed in the nm (≥ 20 nm) to µm range [10], while the lab-based spectroscopies are intrinsically in the 1-10 µm range. Another essential advantage of X-rays over all other probes are the penetration depths in opaque samples which are few hundred micrometers compared to the laser or IR ones of only a few nanometers.

BSL4 Extraterrestrial Sample Holder (ESH): Quarantine analyses are performed in a BSL4 dedicated sample holder, made of three nested containers, holding extraterrestrial grains of sizes Ø 20-1000 µm, in a transparent spectroscopically pure silica capillary, under controlled pressures of N_2. The containers feature thin Be windows for X-ray sensitive analyses of least absorption and transparent sapphire ones, for laser and IR spectroscopies. The 3 containers are permanently monitored by sensitive pressure and temperature sensors, guaranteeing their leak-proof capacity. This arrangement is meant both to prevent release to Earth atmosphere of potential biohazards but also to insure their insulation from toxic Earth agents such as O_2. Any potential hull breach of a container's window is signaled by pressure variations between the different partial N_2 pressures in the containers. A portable transport and storage vessel is associated to the sample holder and will be used for sterile disposal if necessary.

Update: Currently, a new miniature (≤ 2.5") triple-container ESH is designed, integrating a remote-controlled precision goniometer piezo drive, for 3D morphology probing of the grains by means of XCT (X-ray Computed Tomography), both in absorption and fluorescence modes and wireless RF pressure sensing for permanent monitoring. The new ESH has leak-proof laser-welded seals and is made by high-resolution optimized additive metal manufacturing techniques, from an alloy of high tensile strength (Ti or steel). The ESH upgrade will add new capabilities to our QESA methodology, rendering it more sensitive, safer and adapted to modern synchrotron requirements. The recent (April 24-27, 2018) 2nd Int. Mars Sample Return conference in Berlin recapped the need for re-addressing the sample analyses protocols in the perspective of 2026 sample return and we are actively carrying this out.

Goal: We are optimizing the ESH in view of performing non-destructive elemental, molecular and mineralogical nano-analyses of bio-geological samples in a quarantine environment, in the preliminary phase of Returned Samples analysis, prior to worldwide release. If Earth Life is any guide to Extraterrestrial Life, with microorganisms of ordinary low Z elements matrices but containing heterogeneous traces of intermediate Z ones, we are uniquely equipped for solving the crucial issue of identifying actual or fossil extraterrestrial traces of life on mineral samples returned to Earth by the future SRM operations.

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