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Basic requirements for packaging and transporting returned extraterrestrial samples from landing site to curation facility

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Abstract

In perspective of a possible European sample return mission, we summarize basic requirements of the transportation box, which should transport returned extraterrestrial samples from landing site to curation facility.

1. Introduction

EURO-CARES (European Curation of Astromaterials Returned from Exploration of Space) is a Horizon2020 research program aimed at creating a roadmap for the implementation of a European Extra-terrestrial Sample Curation Facility. This facility would receive returned samples from sample return missions (SRM) to asteroids, Mars or Moon.
The returned extra-terrestrial samples must be kept clean in order to minimize the risk of forward contamination (i.e. from terrestrial environment and from the container itself transporting them).
This work is aimed at identifying the requirements of the transportation box which should contain the Sample Return Capsule (SRC), which in turn contains the extra-terrestrial samples returned to Earth. After packaging of SRC in the box, the latter is transported from landing site to curation facility, where it will be opened and the samples will be recovered and analyzed.
Transportation box design differs depending on the mission scenario, i.e. restricted (samples having significant role to understand processes of chemical evolution and/or origin of life and hence required to be preserved in special conditions) or unrestricted.

2. Regulations

Packaging and transport of samples must guarantee safety of people performing these operations and hence must be done according to the World Health Organization (WHO) rules [1]. WHO discerns three types of samples: Category A, i.e. potentially causing permanent or fatal diseases, Category B, i.e. potentially causing minor diseases, and not hazardous. Restricted samples, e.g. from Mars and Europa, should be treated as “Category A” samples (unless they are sterilized), since it is not known if they could contain simple forms of life which could cause disease in humans. Lunar and asteroid samples are instead not hazardous.
A triple packaging must be applied to Category A samples: 1) primary receptacle; 2) durable, leak-proof secondary package (plastic material); 3) rigid, cushioned outer layer. An additional layer should be considered if samples need to be preserved in special conditions or to be monitored during transport.
Even if not hazardous, lunar and asteroid samples however need a package aimed at avoiding Earth contamination.

3. General requirements

The primary receptacle coincides with the SRC, hence its design depends on the mission requirements and is beyond the scope of this work.
In order to avoid fluid leakage (e.g. phase transition in restricted samples), SRC should be surrounded by absorbent material. Polypropylene is the most commonly used and is suitable for transportation boxes, since is a low-density material and outgasses only at very high temperatures.
The plastic material of the secondary package must have a low outgassing rate (i.e. $<10^{-7}$ Torr/s). A trade-off analysis was performed for materials having this requirement, i.e. Polyurethane, Teflon, Neoflon and Kalrez [2]. Polyurethane and Kalrez were discarded because of their high permeability and cost, respectively, and therefore Teflon and Neoflon would be the best choice.

The outer package must be rigid and resistant to breakage, hence a trade-off analysis was performed on metallic alloys, and based on Young's modulus, outgassing rate, density (lighter materials should be preferred), thermal conductivity (samples may need to be thermally insulated) and cost. Stainless steel is by far the lowest outgassing material and the easiest to clean, has a low thermal conductivity and is the cheapest material. The only weakness is its high density, and this may be an issue for packaging of large SRC. In that case, aluminium alloy may be preferred.

The outer has to be filled with an inert atmosphere, in order to inhibit oxidation within the sample. Argon is more inert than nitrogen, but however we suggest the latter, due to its wider availability and lower cost.

The overpack should be required when the box environment needs to be controlled in stronger detail, e.g. real-time contamination monitoring inside the outer and inner packages. This is the case for restricted samples, which should be preserved with special care. ISO containers could be used to this end. Contamination of the environment inside the box can be monitored by different instruments, which should be selected on the basis of mission requirements (i.e. a GCMS should be preferred if a high sensitivity is required, whereas QCM's are much less mass demanding, e.g. [3]).

4. Basic design

Basing on the requirements identified above, the transportation box should be based on a layered configuration: i) primary receptacle, coinciding with SRC and possibly surrounded by polypropylene (restricted case); ii) Teflon/Neoflon secondary package (optional for unrestricted samples); iii) metallic outer package, filled with nitrogen; iv) ISO container (overpack) with an internal laboratory for environment control, required only in the restricted case. Schematic views of transportation boxes in unrestricted and restricted case are shown in Figures 1 and 2, respectively.

5. Transport

There are no mass limitations for box transport by ground or ship. The weakness of these solutions is the much larger journey duration. Any aircraft might be used for transporting unrestricted samples. Only cargo aircraft may be used for transporting restricted samples, unless the total sample mass is lower than 50 grams [1]. However, the transport of a box filled with pure nitrogen is allowed only on military aircrafts, and hence this solution might be preferred.

Moreover, the box must be properly labelled and marked, according to [1]. It should be taken into account to add additional marking in the case of non-nominal scenario (e.g. broken or damaged SRC).

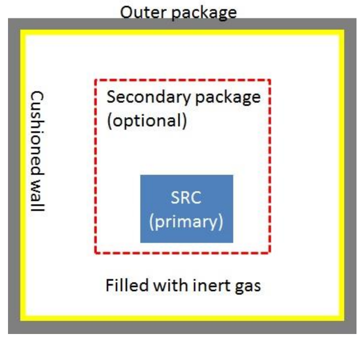

Figure 1. Schematic view of transportation box structure for unrestricted missions.

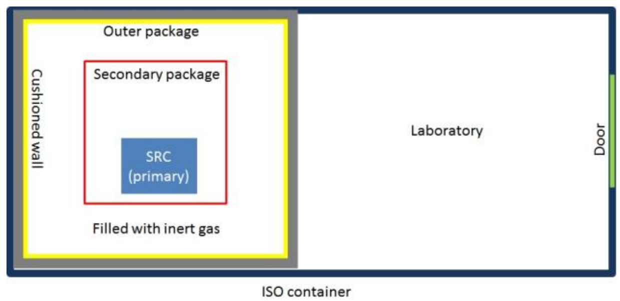

Figure 2. Schematic view of transportation box structure for restricted missions.

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