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Starting a European Space Agency Sample Analogue Collection (ESA^{2}C) and Curation Facility for Exploration Missions.

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1. Introduction

Since 2014, the Natural History Museum (NHM) has been the prime contractor to the European Space Agency (ESA) for defining and initiating the development of a Sample Analogue Collection and supporting Curation Facility in support of the Robotic Exploration mission preparation programme. The ESA Sample Analogue Collection (ESA^{2}C) will support the ongoing or future technology development activities that are required for human and robotic exploration of Mars, Phobos, Deimos, C-Type Asteroids and the Moon. The long-term goal of this work is to produce a useful and useable resource for engineers and scientists developing technologies for ESA missions.

2. Analogue Requirements Definition

The complex mission architectures and diverse target bodies of interest means that a variety of different analogue materials are required to test all systems that come into contact with the target body, whether these be part of the spacecraft system, such as landing and/or roving systems (e.g. wheels), sample collection systems (e.g. drills or scoops) or scientific payload. The analogue materials must replicate as far as possible the expected 'geological' environment of the target body in terms of both physical/mechanical properties and chemical/mineralogical properties. Defining a set of well-characterised analogue materials, with both appropriate geotechnical and chemical properties, which could potentially be used as part of an 'end-to-end' methodological approach for testing, evaluation and verification of requirements during mission development would be highly advantageous. Figure 1 shows a simple flow chart identifying the main mission architecture elements that are relevant to any exploration mission and identifying the broad categories of analogues required for testing and verifying different engineering and payload technologies.

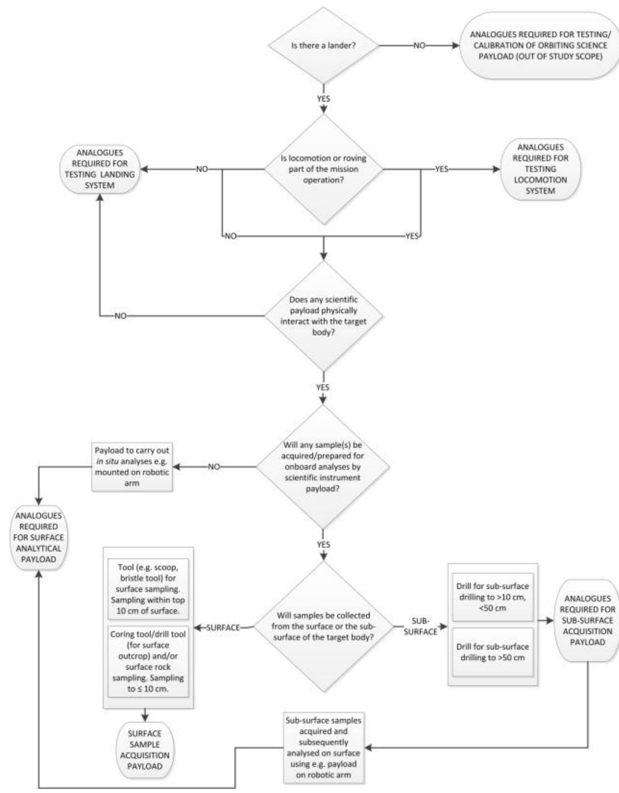

Figure 1. Flow diagram showing an overview of mission architectures/operations applicable to Solar System robotic exploration missions and where analogue samples would be applicable for technology testing.

3. Analogues Samples Definition

In addition to ensuring that the samples as accurately as possible represent the physical and chemical properties of the target bodies of interest, it is important to select materials that can be readily obtained both now and in the future, in enough volume that will ensure a sustainable collection. As is the case for the existing NASA lunar and martian analogues (JSC-1A and JSC-Mars-1A) [1] we have selected samples that are available from commercial suppliers to mitigate the risk of materials becoming unavailable and to ensure large quantities can be sourced if necessary. Additionally, as our chosen suppliers provide materials to a number of industries e.g. construction, large-scale civil engineering projects, we are confident in the quality control procedures in operation during material production, which should allow for good reproducibility in sample properties over time. Samples selected include a variety of aggregates from the olivine-rich basalts from the Upper Lava Formation of the Paleogene Antrim Lava Group of Northern Ireland and clay samples from Cyprus, Spain and Senegal. Table 1 shows a summary of the materials selected as being suitable for inclusion in the ESA^{2}C.

Table 1. Summary of samples forming the initial ESA2C

Analogue Material Type		Physical Description	Relevant Target Body	Mineralogy
Basalt	Basalt Rock	150-200 mm gabion stone	Mars, Moon	Feldspar ($Ab_{35-46}Or_{1-2}An_{52-64}$) Olivine ($Fo_{54-60}$) Pyroxene ($En_{36-39}Wo_{44-46}Fs_{16-18}$) Ilmenite
	Basalt Aggregate	19 mm, 10 mm, 6 mm and 3 mm and down (dust)	Mars, Moon	
Clay Granules	Sepiolite	Granular materials up to ~10 mm in size	Mars, Mars' moons, C-type asteroids	Palygorskite-sepiolite group with smectite component (>95%). Minor calcite, dolomite, quartz, mica (<5%)
	Attapulgite			Palygorskite-sepiolite group with smectite component (>90%). Minor Ca plagioclase, calcite, dolomite (<10%)
	KM Granules			Smectite group minerals (>90%). Minor quartz, calcite, mica, chlorite (kaolinite?) (<10%).
Clay powders	KMA	Very fine grained with 75 % <75 µm size	Mars, Mars' moons, C-type asteroids	Smectite-group minerals (>95%). Minor quartz, feldspar, calcite, magnetite (<5%)
	KM2			Smectite group minerals (>95%). Minor quartz, calcite, dolomite feldspar, magnetite
	KMSR			Smectite group minerals (>90%). Minor quartz, calcite, mica, feldspar, chlorite (<10%).

4. Analogue Characterisation

During 2016 we carried out a detailed characterisation of the analogue samples' physical and chemical properties [2,3]:

Chemical properties

• Whole-rock chemistry – major, minor and trace element analyses by ICP-AES and ICP-MS.

• Mineralogy – analytical SEM, EPMA and XRD (whole-rock).

Physical properties

• Grain size and shape – sieving and visual inspection, X-ray micro-CT.

• Bulk density and porosity – mass-volume measurement and helium pycnometry, X-ray micro-CT.

• Shear strength (aggregate and powder samples) – shear box apparatus.

• Compressive and tensile strength – UCS testing and Brazilian indirect tensile method.

5. Sample Analogue Curation Facility

This unique venture will build on the Robotic Exploration mission preparation programme by establishing methodologies and protocols/procedures for curating the ESA^{2}C, as well as defining and validating the distribution mechanisms and information exchange protocols for the analogue materials. Underpinning the work will be the development of the ESA^{2}C database that will be undertaken by the NHM in the coming year. Samples will be available to suitable qualified PIs and we welcome requests for information on the samples we have already acquired and characterized.

As part of ongoing work, additional samples to those shown in Table 1 were acquired for the ESA^{2}C. Anorthosite blocks were acquired from a Norwegian quarry and basaltic sand/gravel and basaltic/hyaloclastite blocks were collected from the Askja Region in Iceland. Additionally, sample mixtures will be made up using the characterised clays and basalts for varying grain sizes and clay:basalt ratios to better replicate the Phobos/Deimos/C-Type Asteroids and Martian regoliths. We will continue to seek sources of new materials for potential acquisition and subsequent characterization to enhance the initial collection. A critical part of our work is to actively collaborate with our colleagues in the space mission engineering and planetary sciences communities to ensure that the ESA^{2}C is a relevant and practical resource for technology development.

Acknowledgements

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References

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[3] Manick K. et al.: 48th Lunar and Planetary Science Conference, 20-24 March 2017, The Woodlands, Texas, 2017.