ESA'S SAMPLE ANALOGUE CURATION FACILITY (SACF), AND EXPANDING ESA'S EXPLORATION SAMPLE ANALOGUE COLLECTION (ESA^{2}C). D. J. P. Martin and L. Duvet, European Space Agency ECSAT, Fermi Avenue, Harwell Campus, Didcot, Oxfordshire, OX11 0FD, UK (dayl.martin@esa.int).

Introduction: The European Space Agency's Sample Analogue Curation Facility (SACF) and associated analogue collection were developed to support ESA's Human and Robotic Exploration mission preparation programme. The main aim of this activity is to provide a long-term resource of planetary analogue materials for research and technology developments both within ESA and the wider scientific community.

Origins: The SACF and ESA's Exploration Sample Analogue Collection (ESA^{2}C) began their development at the Natural History Museum (NHM), London, who was the prime contractor to the activity from 2014 through to 2018. During this time, the NHM identified suitable and readily available resources for the analogue collection, obtained ~1 ton of various analogue materials, procured a range of analytical equipment and laboratory supplies, and performed baseline characterization of many of the analogue materials [1-3]. Since Q3-4 of 2018, the SACF has relocated to the Harwell Campus where it is now collocated with ECSAT, the UK ESA Centre.

Sample Analogue Curation Facility: The main aims of the SACF is to:

- curate a range of planetary analogues and simulants representing geological materials from various Solar System bodies.
- research and develop new analogues and simulants to fulfil current requirements within ESA and the wider research community.
- use the geological and sample expertise within the facility to support current missions and mission architectures within ESA.
- support learning and public outreach events with the analogue samples available at the SACF.

The dedicated facility on the Harwell Campus consists of an analytical laboratory for baseline characterization of the analogue materials, a sample preparation room for altering existing samples and creating new simulants, and a curation room for long-term storage of the analogue collection.

ESA^{2}C: The ESA Exploration Sample Analogue Collection (ESA^{2}C) is the reserve of analogues and simulants curated by the SACF. Currently, the ESA^{2}C collection consists of analogues representing various rock and soil types on the Moon, Mars, and Phobos that were collected from easily accessible sources (e.g. quarries) allowing replenishment of these analogues over time. Presently, the ESA^{2}C collection consists of 82 analogue and simulant materials, of which many are available in a range of prepared forms including polished blocks, cores, and powders for various applications. Also in the collection are a series of simulants that were developed during various international efforts including EAC-1, MGS-1, and OPRH2. Although some of the samples in the collection are voucher specimens (i.e. not available for loan due to their small quantities) [1], data pertaining to their properties and other information are available.

Much of the collection is available for loan for research projects, technology development and testing, and public outreach. Activities that have made use of the ESA^{2}C collection so far include in situ resource utilization studies (ISRU, e.g. plant growth in regolith) and technology developments (3D printing, ceramic coatings etc.), hypervelocity impact studies, geotechnical / chemical / spectral investigations of Mars analogues to aid the interpretation of ExoMars data, and as reference pieces for public outreach and engagement events. Loans have so far been allocated to projects in the UK, France, Hungary, Italy, Luxembourg, the USA, Hong Kong, and Australia. Within ESA, the SACF is supporting a number of mission teams and activities including PROSPECT, ExoFit, ExoMars, and the Mars Sample Return campaign. Support for these mission teams includes loaning of analogue materials, sample preparation, handling and analysis, and geological mapping and image analysis.

Expanding the ESA^{2}C collection: There are many planetary terrains and geological units that are not represented by the simulants currently available to the international community. Therefore, the SACF plans to expand the ESA^{2}C collection by creating a range of simulants produced in-house that represent some of these 'missing' simulants.

Lunar Dust Simulant: One such example is a 'lunar dust simulant' with grain size, shape, hardness, and abrasiveness representative of lunar regolith. This simulant would focus on the finer fraction (<25µm) of lunar regolith and would be used for testing parts that are designed to operate at the lunar surface. Such applications for the abrasive property include instruments with moving parts that will be in contact with the lunar surface, and parts designed to operate for long periods of time at the lunar surface such regolith transporters, storage units, conveyers (and other ISRU machinery), robotic arms, and actuators (etc.).

Another potential application for this simulant would be to test the potential for instruments to overheat on the lunar surface when coated with regolith. Apollo 15, 16 and 17 astronauts encountered problems with the overheating of the battery unit and associated radiators on the lunar roving vehicle due to a coating of fine regolith that was highly thermally insulating, so laboratory testing with a suitable simulant would help to minimize any problems that may be encountered at the lunar surface [4].

A major problem encountered by the Apollo astronauts on all of the missions was the degradation of seals in suits and sample containers during their stay at the lunar surface. Development of seals designed to repeatedly operate at the lunar surface is essential for long-term missions and habitation at the lunar surface, and the lunar dust simulant could be used to effectively test the reusability of seals in the laboratory.

Source materials. One of the most representative terrestrial materials for creation of a lunar dust simulant would be Mistastin anorthosite, found in the Labrador province of Canada [5]. This material contains a high proportion of feldspathic glass and products of impact shock metamorphism, resulting in a more ideal starting material for simulating agglutinates and other shocked components found in lunar regolith. However, this material is difficult to obtain given its remote location, so may not be ideal as a sustainable analogue source material. Therefore, current efforts are focused on using an already sourced anorthosite from Sirevåg, Norway as the base material to create an initial version of the lunar dust simulant.

Lunar Pyroclastic Simulant: Pyroclastic deposits, found during the Apollo 15 and 17 missions, are of high interest within the ISRU area of research because of the potential for extracting trapped volatiles from within the pyroclastic glass beads. However, there are no pyroclastic simulants available for study at the time of writing, meaning some ISRU technologies cannot be tested with appropriate simulant materials. Such a simulant will be available either as a 'pure' pyroclastic deposit (i.e. only the glass beads, more representative of e.g. 74220) or as a pyroclastic-rich regolith simulant (a mixture of pyroclastic glass and a lunar regolith simulant, similar to Apollo samples 74240 or 15401).

Such samples would be useful not only for volatile extraction purposes, but may also be used for testing sample handling and processing equipment due to the varied flow properties of samples that contain higher proportions of spherical particles (in contrast to most lunar regolith samples that are dominated by highly angular particles). Also, as some Apollo regolith samples contain small proportions of glass beads (<1 wt%), the addition of a small portion of pyroclastic glass to any developed regolith simulant may be beneficial for more representative tests of certain technologies.

Simulant Recipes: Alongside developing new simulants for the ESA^{2}C collection, the methods to create the simulants, or 'recipes', will be also be publicly available. These recipes will detail source materials, processing steps, and the properties of the final products to allow reproduction of the simulants to take place outside of the SACF if required. This is particularly important for volatile samples (icy simulants, for example) where transporting the material is challenging and/or highly expensive.

Apollo Regolith Research: In order to create simulants with more representative properties of lunar regolith, a variety of analyses will be performed at the SACF on three lunar samples to further understand their physical properties. The samples will be sieved to obtain the finest size fraction, then subject to X-Ray Computed Tomography (XRCT) in collaboration with the Diamond Light Source, the UK's synchrotron facility also located on the Harwell Campus. A variety of simulants will also be analysed in the same way to enable direct comparison between Apollo sample and lunar simulant datasets. The electrostatic properties of the Apollo samples will also be investigated to further understand the particle interactions between material exposed to space weathering. As these physical properties may influence the way the material is handled and stored, it is of vital importance for designing more representative simulants and for adequate testing of ISRU technologies.

Future Scope: The need for a greater range of simulants will increase as Solar System exploration continues. The continued development of simulants is, therefore, vital for adequate testing of technologies being developed for future missions.

Also, new acquisitions to the ESA^{2}C collection will be characterized for a range of their physical and chemical properties to expand the available information for the analogues in the collection. For more information related to the SACF and ESA^{2}C collection, and to inquire into loaning of samples, please visit http://sacf.esa.int.

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References: [1] Smith C. L. et al. (2018) *LPSC XLIX,* Abstract #1623. [2] [2] Manick K. et al. (2017*) LPSC XLVIII,* Abstract #1220. [3] Manick K. et al. (2017) *LPSC XLVIII,* Abstract #1222. [4] Gaier J. R. (2005) NASA/TM-2005-213610. [5] Grieve R. A. F. (1975) GSA Bulletin 86 (12): 1617-1629.