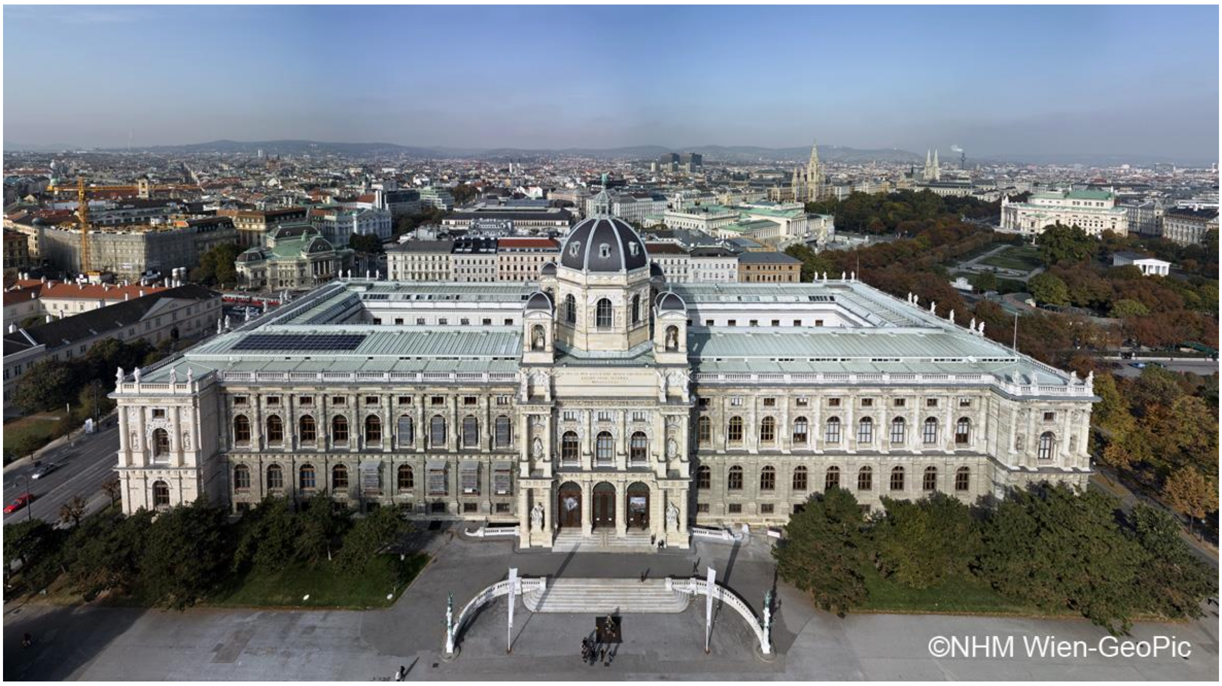
Horizon 2020
EURO-CARES WP3 Meeting

Designing a European Extraterrestrial Sample Curation Facility

Final programme & Book of abstracts

13-16 April 2016
Natural History Museum, Vienna, Austria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Horizon 2020
EURO-CARES WP3 Meeting

Designing a European extraterrestrial sample curation facility

International meeting to offer an interface between the EURO-CARES consortium and the scientific and industrial community. The Work Package 3 focuses on building design, curation, and storage of the samples.

Scientific Organizing Committee

Ludovic Ferrière
Aurore Hutzler
& the WP3 team

Local Organizing Committee

Ludovic Ferrière
Aurore Hutzler
Anna Berger

Acknowledgments

The organizers would like to thanks the Natural History Museum Vienna for hosting the event, and especially Prof. Christian Koeberl, the Museum Director. We are grateful to Wolfgang Taigner and Ingrid Viehberger for their help with the logistics.

For their support, Cleanroom Technology Austria and Leica as well as the Swiss Embassy, the French Embassy, and the French Institute in Vienna.

Wifi is available in the conference rooms:

SSID: eurocares_meeting

Pwd: eurocares2016nhm

For any questions:

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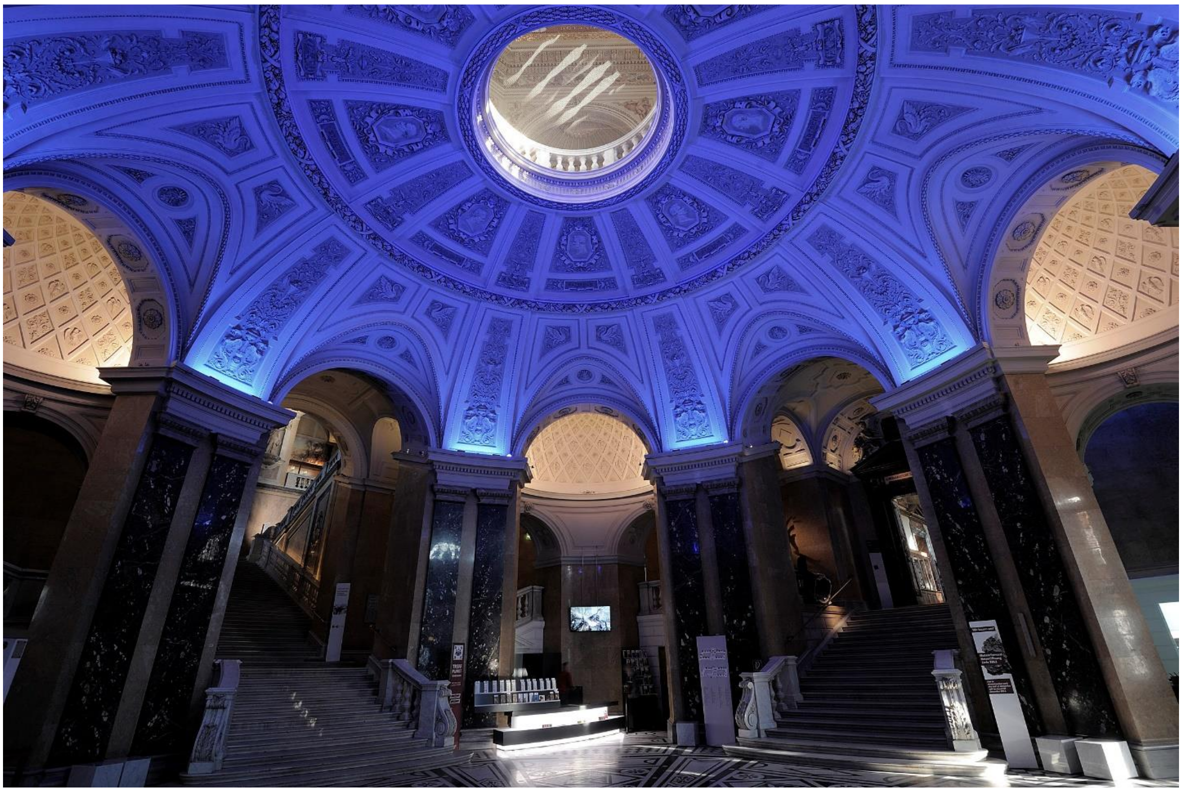

EURO-CARES WP3 Meeting

Designing a European Extraterrestrial Sample
Curation Facility

NHM Vienna, Austria, 13-16 April 2016

Agenda

Wednesday, April 13th: EURO-CARES and Experts meeting

11:30 Arrival to the NHM and registration

12:30 Lunch at NHM

14:00 Welcome words and Logistics

14:15 Quick presentation of the EURO-CARES project

Work Package status, evolution since the last meeting – 5-10’ each PI with critical aspects to be further considered in each WP with direct implications on the WP3.

WP3 introduction – status – work done and in progress

15:45 Coffee break / Group photograph

16:00 Experts presentations and discussions (10-15’ max.)

Experts (in alphabetical order)

- Judith Allton: Curation / (Genesis) Laboratories design
- James "Sandy" Ellis: *Systems required for high containment* (Engineer perspective)
- Nicole Spring: Curation of samples (especially "Cold curation")
- Sandra Häuplik-Meusburger: Building / Architecture
- Narendrakrishnan Neythalath: Robotics
- Peter Mani: Micromanipulation of samples / Sample contamination/protection
- Uwe Mueller-Doblies: Risk based design of containment facilities
- Michel Viso: Facility or facilities? / Concept
- John Vrublevskis: Double Walled Isolators and Robotics (remote manipulator)
- Ryan Zeigler: JSC curation / Focus on the various infrastructure aspect

18:15 Free time (hotel check-in, tour of the Museum…)

19:10 Backstage - Up to the roof / Champagne glass on the roof

20:30 Dinner at restaurant Mediterran im Schubert [http://restaurant-schubert.at/]

Thursday, April 14th: Open meeting

9:00 Registration

9:45 Welcome talk by the general director of the Museum – Prof. Dr. Christian Koeberl

9:55 Logistics

10:00 EURO-CARES and WP3 introduction

10:15 SESSION "Curation"

- 11:00-11:20: Coffee break
- 12:35: Group photograph (on the main stairs inside the NHM)
- 12:45-14:00: Lunch (up to the participants)

14:00 SESSION "Architecture and Design"

- 15:40-16:00: Coffee Break

17:30 Tour of the Meteorite Hall & Museum (Optional)

Friday, April 15th: Open meeting

9:00 Registration

9:30 SESSION "Cleanliness and Planetary Protection"

- 10:45-11:05: Coffee break
- 12:30-14:00: Lunch (up to the participants)

14:00 SESSION "Manipulation techniques - Pot-pourri"

- 15:20-15:40: Coffee break

17:30 Tour of the Meteorite Hall & Museum (Optional)

Saturday, April 16th, 9:30: Wrap-up meeting

Session schedule

Invited talks are 20-25' + 5' questions, other talks are 10' + 5' questions.

Thursday, April 14th: Open meeting

SESSION "Curation"

- 10:15 Curating NASA's Past, Present, and Future Astromaterial Sample Collections. Ryan Zeigler (invited talk)
- 10:45 Mars Sample Return: End to End Curation from Return to Earth to Sample Distribution - Report from iMARS Phase II. Caroline Smith

Coffee break – 11:00 -11:20

- 11:20 The Maintenance and Development of a Specialised Cold Curation Facility for Pristine Astromaterials. Nicole Spring (invited talk)
- 11:50 EURO-CARES Extraterrestrial Sample Curation Database: Basic Concepts. Luigi Folco
- 12:05 Curation of Extraterrestrial Samples: What are the Main Issues? Ludovic Ferrière

SESSION "Architecture and Design"

- 14:00 Architecture as the Interface Between Humans and Technology. Sandra Häuplik-Meusburger (invited talk)
- 14:30 Architecture students from the Technical University Vienna:
    - Robert Baumgartner & Stephan Asboth
    - Iina Koskinen
    - Maurice Nitsche

Additional student projects will be presented as posters, available and open for discussion during the meeting in the conference room.

Coffee break – 15:40 -16:00

- 16:00 Risk Based Design of Containment Facilities. Uwe Mueller-Doblies (invited talk)
- 16:30 Facility or Facilities? That is the Question! Michel Viso (invited talk)

Friday, April 15th: Open meeting

SESSION "Cleanliness and Planetary Protection"

- 9:30 Evolution of the Lunar Receiving Laboratory to the Astromaterial Sample Curation Facility: Technical Tensions Between Containment and Cleanliness, Between Particulate and Organic Cleanliness. Judith Allton (invited talk)
- 10:00 Human Mars Mission Contamination Tracking. Gernot Groemer
- 10:15 The Cleanroom Balance. Roman Czech
- 10:30 Planetary Protection Issues on Sample Returned from Mars: Analytical Approach to Detect Sign of Life. John Brucato

Coffee break – 10:45 -11:05

- 11:05 Some Technology Challenges for a Facility Handling Samples from Mars. James “Sandy” Ellis (invited talk)
- 11:35 EuroCares WP6 Sample Transport/Portable Receiving Technologies-Update to Activities. Lucy Berthoud
- 11:50 *Discussion on Cleanliness and Biocontainment*. Allan Bennett & Thomas Pottage

SESSION "Manipulation techniques - Pot-pourri”

- 14:00 Remote Manipulation (RM) System for Mars Sample Receiving Facility (MSRF) - Outline of Activities and Early Results of European Space Agency (ESA) Technology Development. John Vrublevskis (invited talk)
- 14:15 Analytical techniques in Double Walled Isolator and BLS4+ Sample Return Facilities. John Bridges
- 14:30 Double Walled Isolator (DWI) System for a Mars Sample Receiving Facility (MSRF) - Outline of Activities and Early Results of European Space Agency (ESA) Technology Development. John Vrublevskis (invited talk)
- 15:05 Robotic Handling and Robotic Inspection - Profactor's Expertise. Gerald Fritz

Coffee break – 15:20 -15:40

- 15:40 Manipulation of Samples in Mini Environments. Peter Mani (invited talk)
- 16:10 Instrumentation Requirements for Sample Curation Facility. Ian Franchi
- 16:25 Industrial Sample Preparation for Electron Microscopic Investigations. Robert Ranner
- 16:40 Storage and Usage of Analogue Samples in an Extraterrestrial Sample Curation Facility. Jutta Zipfel.

Evolution of the Lunar Receiving Laboratory to the Astromaterial Sample Curation Facility: Technical Tensions between Containment and Cleanliness, between Particulate and Organic Cleanliness

J. H. Allton[1], R. A. Zeigler[1], and M. J. Calaway[2], [1]NASA/Johnson Space Center, Mail Code XI2, 2101 NASA Parkway, Houston, TX 77058 USA (judith.h.allton@nasa.gov), [2]Jacobs Technology, Inc.

The Lunar Receiving Laboratory (LRL) was planned and constructed in the 1960s to support the Apollo program in the context of landing on the Moon and safely returning humans [1]. The enduring science return from that effort is a result of careful curation of planetary materials. Technical decisions for the first facility included sample handling environment (vacuum vs inert gas), and instruments for making basic sample assessment, but the most difficult decision, and most visible, was stringent biosafety vs ultra-clean sample handling. Biosafety required handling of samples in negative pressure gloveboxes and rooms for containment and use of sterilizing protocols and animal/plant models for hazard assessment. Ultra-clean sample handling worked best in positive pressure nitrogen environment gloveboxes in positive pressure rooms, using cleanable tools of tightly controlled composition. The requirements for these two objectives were so different, that the solution was to design and build a new facility for specific purpose of preserving the scientific integrity of the samples. The resulting Lunar Curatorial Facility was designed and constructed, from 1972-1979, with advice and oversight by a very active committee comprised of lunar sample scientists. The high precision analyses required for planetary science are enabled by stringent contamination control of trace elements in the materials and protocols of construction (e.g., trace element screening for paint and flooring materials) and the equipment used in sample handling and storage. As other astromaterials, especially small particles and atoms, were added to the collections curated, the technical tension between particulate cleanliness and organic cleanliness was addressed in more detail. Techniques for minimizing particulate contamination in sample handling environments use high efficiency air filtering techniques typically requiring organic sealants which offgas. Protocols for reducing adventitious carbon on sample handling surfaces often generate particles. Further work is needed to achieve both minimal particulate and adventitious carbon contamination [2]. This paper will discuss these facility topics and others in the historical context of nearly 50 years' curation experience for lunar rocks and regolith, meteorites, cosmic dust, comet particles, solar wind atoms, and asteroid particles at Johnson Space Center.

References: [1] Allton J. H. et. al.(1998) Adv. Space Res.v.22, no. 3,373-382. [2] Calaway M. J. et al. (2014) NASA/TP-2014-217393.

Keywords: Astromaterial curation facility, Biosafety containment, Ultra-clean sample handling

EuroCares WP6 Sample Transport/Portable Receiving Technologies- Update to Activities

L. Berthoud[1], J. B. Vrublevskis[1], M. Guest[1], J. Holt[2], J. C. Bridges[2], E. Palomba[3], F. Dirri[3], A. Longobardo[3], T. Pottage[4], A. Bennett[4]; [1]Thales Alenia Space UK Ltd, 660 Bristol Business Park, Coldharbour Lane, Bristol, UK, BS16 1EJ (lucy.berthoud@thalesaleniaspace.com), [2]Space Research Centre, Dept. of Physics and Astronomy, University of Leicester, LE1 7RH, UK; [3]IAPS-INAF, Via Fosso del Cavaliere 100, 00133 Roma, Italy. [4]Public Health England, Porton Down, Salisbury, SP4 OJG, UK.

The objective of this work is to propose methods for the recovery and transport of Mars or Lunar/asteroid samples from a landing site to the permanent curatorial facility. Initially a review of previous sample return recoveries was performed and compared to current designs for Mars sample return missions. The first part of the work concerns preparations for recovery, including the choice of terrestrial landing and recovery location. After this, a survey of current knowledge of the actual recovery and initial inspection of samples is described, followed by an analysis of international transport logistics to the curation facility. Preparation for recovery has considered sample quantity, sizes, masses and forms ie: rock, regolith, ice, brine and gas. A preliminary assessment of nominal and non-nominal active capsule landing scenarios has been carried out and it is noted that current Mars Sample Return architectures include passive aero shell delivery. Ground recovery of intact and non-intact samples and the possibility/necessity for a portable or on-site quarantine or containment laboratory are discussed. Secure packaging of the sample capsule from landing site to curation laboratory is critical.

Analytical Techniques in Double Walled Isolator and BLS4+ Sample Return Facilities

J. C. Bridges[1], J. M. C. Holt[1], L. J. Hicks[1], J. B. Vrublevskis[2] and L. Berthoud[2]. [1]Space Research Centre, Dept. of Physics and Astronomy, University of Leicester, LE1 7RH, UK (j.bridges@le.ac.uk), [2]Thales Alenia Space UK Ltd, 660 Bristol Business Park, Bristol BS16 1EJ, UK.

Restricted, Category V Earth Return planetary protection protocols [1] impose a number of procedural requirements on the handling of material returned from target bodies like Mars and Phobos. Double Wall Isolation (DWI) will address these concerns and is a crucial component in the containment system for samples delivered to a specialist curation facility. The advantage of this system is that it maintains both containment and ultra-cleanliness of the samples. Management of sample quarantine is critical and the DWI approach protects the samples from terrestrial contamination ingress, cross contamination, and provides mitigation of risk to our biosphere, from intrinsic sample pathogens. A key to the effectiveness of this system is development of a set of standard interfaces between the DWI and the scientific instruments that are necessary to analyse the samples.

Using martian meteorites as analogues, the full range of techniques required to characterise samples usually follows a chain from optical microscopy, polished section preparation, electron microscopy and mass spectrometry. However, the DWI and/or BLS4+ environment required to satisfy planetary protection constraints [1] mean that this chain of analyses is challenging for returned samples where planetary protection is a constraint. One example is the loss of material and use of resins during polished section preparation for meteorites. Other analyses may necessitate the use of a high resolution optical microscope and relatively complex remote manipulation of a microscopic sample, all self-contained within the DWI. Such interfaces (e.g. power or light conduit & data) may be straightforward. However, other decisive instruments will probably include X-Ray Tomography, to investigate the sample interior, and electron microscopy to characterise the surface topography and composition. These instruments require extensive ancillary interfaces to high power (high tension supplies), active or passive cooling/heating, focused electron (or ion) beams, high energy X-rays, three dimensional sample articulation, high vacuum containment and specialist gases. Such interfaces present a number of complex technical challenges and will be assessed as part of an ESA study [2] for their compatibility with the unique functional requirements of the DWI system.

References: [1] Debus, A. (2006) The European standard on planetary protection requirements. Research in Microbiology 157(1): 13-18 [2] ESA Work Plan ref. Work Plan ref. E914-005MM.

Keywords: Mars Sample Return, Double Walled Isolator, BLS4.

Planetary Protection Issues on Sample Returned from Mars: Analytical Approach to Detect Sign of Life

J. R. Brucato[1], A. Meneghin[1] and the EURO-CARES team, [1]INAF-Astrophysical Observatory of Arcetri, L.go E. Fermi 5 Firenze, Italy (jbrucato@arcetri.astro.it).

Given the extreme difficulty to describe all possible living processes based on terrestrial biochemistry, no single approach will be able to guarantee a success in detecting life on samples returned from Mars. A multiple approach, that includes chemical and microscopic analysis, is fundamental to have comprehensive life detection. Consequently, multiple analytical techniques need to be accommodating in the sample curation facility with high biological containment to distinguish between abiogenic and biogenic signatures. At this stage of our study we are facing procedures for life detection and biohazard assessment in returned samples. Among a wide number of proposed techniques, here a new inclusive approach is proposed where different techniques are discussed and prioritised. This study will have implications on preliminary architectural/functional design of the sample curation facility.

Clean Room Balance

R. Czech, Cleanroom Technology Austria GmbH, IZ-NÖ-Süd, Strasse 10, Objekt 60, A-2355 Wiener Neudorf, Austria (roman.czech@czech.at).

A clean room is a very delicate system which can only successfully meet its high performance levels if it is planned, operated and maintained correctly. A clean room is in principle comparable to a balance. Already a slight imbalance on one side can bring the whole system to tip. Missing information during the planning phase can make the finished clean room useless. In the last years much has happened within the standardization procedures in order to prevent such planning errors. Nevertheless a lot of sensitivity and experience is still required to build a clean room.

Keywords: Clean room, Planning, ISO 14644, Air-Filter, Particles

Some Technology Challenges for a Facility Handling Samples from Mars

James “Sandy” Ellis, Vice President, Merrick Canada ULC, 580 Terry Fox Drive, Kanata, Ontario K1H 7N6 (sandy.ellis@merrick.com).

The presenter (Sandy Ellis) will provide a summary of an innovative design solution which was engaged by JPL/NASA for the Mars Sample Return Facility. This US-based located facility is one of three approaches commissioned by NASA/JPL typical of their project analysis and development process. Merrick’s solution provided a hybrid solution that started with the field capture method of the returning vehicle transported to the sample return facility. The presenter will discuss the hybrid approach of cabinet-line glove-boxes, combined with traditional BSL4 space used for testing of the sample. Unique to the design process included specialized (Merrick patent) double-gloves used in the glovebox design, decontamination systems and specialized chemical/biological positive-air HEPA filtered suits. In addition, Sandy will provide an outline of the various mechanical and electrical solutions contemplated for the new facility. These systems and design approach have been based on proven technologies used in high containment applications which have been customized by Merrick and its technical Life Sciences Team. The presenter will conclude the presentation providing an assessment to the risks associated with a facility of this nature. Of course, the primary goals of conducting safe-science and protecting the samples and the Earth are fundamental pillars of the project’s success.

Keywords: Glovebox, BSL4, Decontamination, Double-gloves, Safe-science

Curation of Extraterrestrial Samples: What are the Main Issues?

L. Ferrière, Natural History Museum, Burgring 7, A-1010 Vienna, Austria (ludovic.ferriere@univie.ac.at).

Curation mainly consists in the collection, handling, documentation, preparation, preservation ("into the indefinite future"), and distribution of samples for research. Curation of extraterrestrial samples (and especially in the case of mission returned samples), due to their rarity and pristine state, should follow some very strict rules.

Meteorites have been curated for a few hundreds of years, being part of natural history collections (the oldest meteorite collection, initiated in 1778, being located at the NHM Vienna), whereas the curation of mission returned samples is only about 45 years old, with the return of lunar samples in the framework of the Apollo program.

In the case of meteorites, no planetary protection measurements are taken and they are typically stored in ambient conditions (very rarely in N_2 cabinets) after basic characterization. Meteorites are in contact with a large number of materials, liquids (in some cases the cutting is even done with tap water), and other unknown/undocumented contaminants.

In the case of mission returned samples, in order to preserve the scientific value of these precious samples, contamination, but also physical and chemical alteration must be minimized, understood, and properly recorded (i.e., a record should capture every action carried out on the sample). They are permanently stored in high-level clean environments in inert gas conditions to prevent alteration. Specific handling, sub-sampling, and preparation techniques should be developed and adapted for the different types of samples. In the case of (possibly) biohazardous samples, sterilization such as by dry heat and/or gamma radiation (knowing that it is detrimental to some scientific investigations) should be envisaged.

The main identified issues are in the handling and preparation of the samples, but also in the sampling and storing of gas and of all other adsorbed volatiles traces of extraterrestrial organic material, as well as in the sterilization methods.

Keywords: Curation, Meteorites, Mission returned samples, Sample handling & preparation, Storage

EURO-CARES Extraterrestrial Sample Curation Database: Basic Concepts

L. Folco[1], J. R. Brucato[2], A. Meneghin[2], M. Gemelli[1] and the EUROCARES Consortium. [1]Dipartimento di Scienze della Terra, Università di Pisa, Via S. Maria 53, I-56126 Pisa, Italia (luigi.folco@unipi.it), [2]INAF - Osservatorio Astrofisico di Arcetri, L.go E. Fermi 5, 50125 Firenze, Italy.

We describe here the basic concepts of database that will be used in EUROCARES whose general purpose is to collect - and partly make available to the public - all the information about the following sample categories:

- Pristine samples (extraterrestrial ... and analog samples? - to be discussed at the meeting)
- Aliquots and preparates (e.g. various mounts) for classification purposes and allocation to external laboratories
- Allocated and returned aliquots and preparates
- Residual masses of pristine samples

A dedicated software will be created as a logbook to track and document all the actions performed on the (sub)samples inside EUROCARES and in external laboratories. All these information will be stored inside the software, according to the following data sets:

- Identification (e.g., origin, imaging, state of matter, mass)
- Classification (e.g., structural, compositional)
- Preparation (e.g., type of preparate, aliquot description)
- Location (e.g., location in the facility)
- Allocation (location outside the curation facility)
- Documentation (e.g. internal/external data and reports, scientific publications)
- Public (selected data, e.g. sample description and availability for research).

All these information will be obtained and documented during the following **procedures/actions**:

- Cataloguing (identification, location)
- Classification (to be meant as preliminary classification)
- Pre-Delivery (preparation and allocation)
- Post-Delivery (returned sample for research check, storage)

The above points will be presented in detail at the conference.

Keywords: Database, Curation, Sample return space missions, Planetary materials

Instrumentation Requirements for Sample Curation Facility

I.A. Franchi, Planetary & Space Sciences, Open University, Milton Keynes, MK7 6AA, UK (Ian.franchi@open.ac.uk).

An essential component of any sample curation facility is the instrumentation required to characterise and understand the nature of the samples. This task is necessary to perform bio-hazard assessment and meet Planetary Protection criteria in the case of samples from Mars (or other restricted Category V samples). It is also necessary for both restricted and un-restricted Category V samples in order to ensure the optimum preservation of the samples in the curation facility and allocation of material to researchers.

As part of the EURO-CARES study it is clear that a wide range of instrumentation is being proposed or considered as a necessary element of the curation facility. This instrumentation has major implications for the requirements and design of the bio-containment environments that the facility will house and indeed on the overall curation facility itself, in terms of services, laboratory/cleanroom floor area, as well as staffing levels and their associated accommodation requirements. All of which adds significant complexity to the curation facility and major capital and running costs.

This presentation will attempt to summarise the instrumentation identified to date within the EURO-CARES project, and attempt to rationalize into where this equipment should or can be sited within the facility, and identify where rationalization can be achieved.

Robot Handling and Robotic Inspection – Profactor's Expertise

Gerald Fritz, Profactor, Im Stadtgut Zone A 2, 4407 Steyr, Austria (gerald.fritz@profactor.at).

Nowadays robotic skills in production systems are mainly pre-programmed in robot applications. Even in state of the art binpicking systems extraction strategies are hardcoded to meet requirements from environment, tools and objects. This also applies for the manipulation task itself, the gripping position; contact points, forces applied on the handled component has to be derived from the example taught by the human. The talk will present different approaches to make the process more flexible by (a) digitizing the objects online, (b) support the grasp approach by modeling the environment and limit the programming effort during task planning and execution. The applications covered are manipulation of industrial objects and different robotic inspection use cases.

Human Mars Mission Contamination Tracking

G. E. Groemer, Austrian Space Forum, Sillufer 3a, 6020 Innsbruck, Austria (gernot.groemer@oewf.org).

Searching for evidence of extant or extinct life on Mars, exploring its geological history and ultimately establishing a permanent human presence are considered major drivers for human-robotic missions as proposed in the Global Exploration Strategy [1] of 14 space agencies recently. However, reducing the potential forward and backward contamination –likely to happen for both robotic and human explorers- remains a key challenge for mission designers.

The Austrian Space Forum has been leading an initiative to simulate human-robotic surface excursions on Mars by developing high-fidelity spacesuit simulators [2] and deploying them in Mars-analog regions on Earth since 2006. One of the research highlights has been the development of a simple technique using fluorescent microspheres which are mimicking various surface properties of biological particles [3].

We present insights into the challenges of both dust control and biological barriers during those simulations, such as during the AustroMars mission in Utah (2006 [4], Fig. 1), the Dachstein Ice Cave mission (2011 [5]) and the MARS2013 mission (Northern Sahara, 2013 [5,6]).

Fig.1: Mylar-foil shielded spacesuit simulators for tracking the contamination vectors during the AustroMars mission.

References:

[1] GES 2007 The Global Exploration Strategy: Framework for Coordination, http://bit.ly/1jet150
[2] G.E. Groemer et al. (2011), Acta Astronautica 68, 1-2, p 218-225
[3] Groemer, G (2008), Planet. Space Sci. 12, 2
[4] Sattler, B., Selch, F., Klammer, S., Grömer, G., Sipiera, P., Mars2030 - AustroMars Science Workshop, 2006. Published by Austrian Space Forum, 2007., p.13-17
[5] Groemer, G., et, al. (2014), Astrobiology 14:5, p360-376
[6] G. Groemer, et al. (2014), Astrobiology 14:5, pp 391-405

Keywords: Human Exploration, Contamination vector tracing, Fluorescence

Architecture as the Interface between Humans and Technology

S. Häuplik-Meuburger and S.-H. Lu, Vienna University of Technology, Institute for Architecture and Design, Hochbau 2, Karlsplatz 13, A-1040 Vienna, Austria (haeuplik@hb2.tuwien.ac.at and lu@hb2.tuwien.ac.at).

As a discipline, architecture aims at creating an optimized design that is compatible with technological, scientific, design, and human factors requirements. The design process is usually multidisciplinary and interrelates with involvement of different disciplines.

The presentation will introduce selected work and research activities at the department Hochbau 2 of the University of Technology in Vienna.

The main part of the presentation will emphasize the role of architecture and building design as the intermediary between the human element and the built environment. Examples, mainly drawn from 'Space and Extreme Environment Architecture' will show the importance of this element for creating functional, healthy and creative environment.

Keywords: Architecture, Multidisciplinary design process, Space and Extreme Environment Architecture, Human Factor Design

Manipulation of Samples in Mini Environments

P. Mani, tecrisk GmbH, Gryphenhübeliweg 34, 3006 Bern, Switzerland (pm@tecrisk.com).

In an extra-terrestrial mission – e.g. to Mars - aimed at bringing back samples, two aspects must be considered: First, planetary protection, which basically corresponds to biosafety measures depending on the classification of the mission and second sample protection. While the first issue is much easier to take care of, the second is extremely difficult.

Using 10 g for the detection of organic molecules and assuming that we are able to detect femtograms of organic material then the maximal acceptable contamination of the sample should be below 10-7 ppb only! This is an extremely low contamination, as only minute pieces of abraded material from any container would cause severe problems.

The micro-world and the nano-world are different from the macro-world. Effects negligible at the macroscopic level become important at the micrometre scale, and vice versa. With this, it becomes obvious that material properties play a very important role in the design of manipulators for very small samples like e.g. dust particles.

The two main challenges in robotics are to ensure a clean and sterile environment so that the manipulator does not contaminate the samples and to ensure precise tele-operation of the manipulator.

Risks of biohazard and sample contamination are analysed and discussed in the frame of requirements for a European **E**xtra-terrestrial **S**ample **C**uration **F**acility (ESCF).

References: P. Mani et.al., MSRF Summary Report, ESA February 2012.

Keywords: Containment, Mini-Environment, Microrobotics, Sample manipulation

Risk Based Design of Containment Cacilities

U. U. Mueller-Doblies[1]

Any containment facility catering for novel risks will have to satisfy internal *and* external stakeholders that it is safe. This can only be achieved on the basis of a good characterization of the physicochemical properties of the potential hazards to be handled and the activities to be carried out on these. With material that is extraterrestrial the range of known terrestrial hazards has to be extended to include biological, chemical and physical properties that would not be realistic on earth but are feasible to develop in the different environment of a remote astronomical object. Systematic prospective risk analysis is a powerful tool [1] to inform the safety case for such a novel risk activity while containing the cost. Due to the bespoke and unique design of such a facility, a lot of new development will be required to establish the suitability of existing engineering, architectural and (bio)safety standards and to develop new construction standards that will satisfy the barrier requirements. Regardless of how careful such a design is, it will never be able to reduce the risk to zero, and the residual risk will need a broad societal support across more than one generation.

Dealing with poorly characterized hazards and creating equally uncharacterized risks requires robust and well accepted risk assessment and management models.

A challenge in developing appropriate risk control models is the need for exploring the full spectrum of event trees and integrating these into the risk control model in a way that is simple enough not to fail through human error in the implementation and maintenance of the facility. Methodologies from other high hazard industries may help with this development including layer of protection analysis (LOPA); Hazard and Operability Studies (HAZOP); Failure Mode Effect

Analyses (FMEA), Bowtie Biological Risk Assessments (BBRA). How these approaches can be used for unknown biological risks will be discussed.

References:
1) Brodsky, B. and U. Mueller-Doblies. *Future Development of Biorisk Management – Challenges and Opportunities*. In **Laboratory Biorisk Management.** J. Gaudioso and R. Salerno, Editors. 2015. CRC Press: Boca Raton p. 207-230

Keywords: Quantitative Risk Assessment (QRA), Layer of Protection Analysis (LOPA), Bowtie Biological Risk Assessments (BBRA), Risk communication, Risk live cycle management

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Industrial Sample Preparation for Electron Microscopic Investigations

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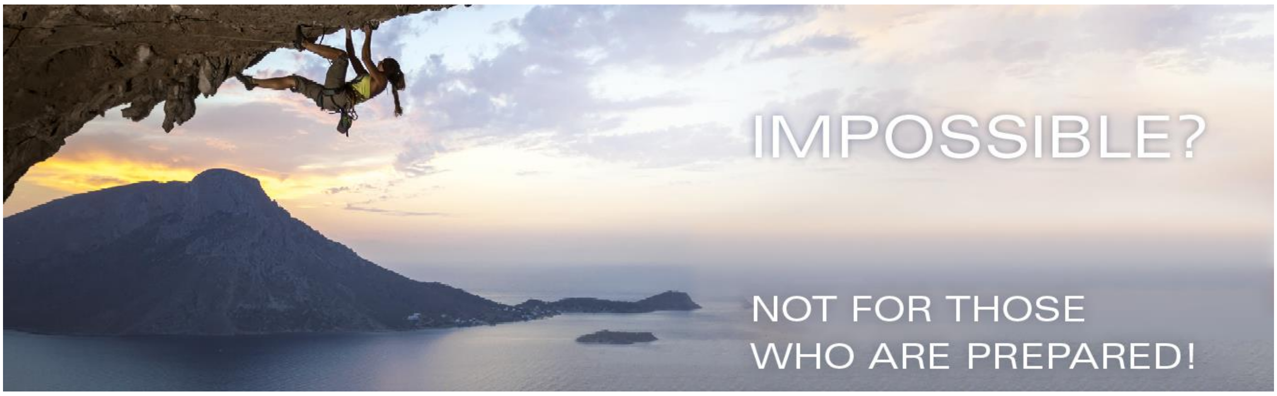
Leica Microsystems offers the most comprehensive product portfolio for preparation of biological, medical, and industrial samples. Concentrating on workflow solutions we provide a product range that is perfectly aligned to all your needs for precise sample preparation in TEM, SEM, and AFM investigations. Each Leica solution consists of several instruments that are perfectly geared to one another to form a seamless workflow for your sample.

Perfect preparation makes the difference between trying and achieving, between failure and success, between results and excellent results.

An overview of Leica EM sample preparation instruments as well as workflow solutions for industrial materials, perfectly prepared for electron microscopic investigations, will be given in this talk.



Mars Sample Return: End to End Curation from Return to Earth to Sample Distribution - Report from iMARS Phase II.

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The return of samples from Mars is of paramount scientific interest and will be an international undertaking. iMARS, (the international Mars Architecture for the Return of Samples) was chartered in 2006 by the International Mars Exploration Working Group (IMEWG), to develop a plan for an international Mars Sample Return (MSR) mission potentially occurring in the timeframe 2018-2023. iMARS Phase I work took place in 2007-2008 and resulted in a consensus on the architecture for an international mission and suggestions for the next steps of campaign definition [1]. MSR mission(s) remain a high-priority in the exploration of Mars and a number of important developments have occurred since the iMARS Phase I work. In early 2014, IMEWG reconstituted iMARS with the objectives of incorporating developments since 2008 and to expand on the scientific management aspects of returned Martian samples. iMARS Phase II has developed a credible structure and process for ensuring that the best possible science is accomplished with returned samples, the world is protected from contamination, and pristine samples are preserved for the future.

Curation of the Mars samples is a critical interface between scientific and planetary protection activities within and outside and Sample Receiving/Curation Facility(ies). Curators will ensure that samples are handled, sub-sampled, stored and transported in compliance with yet-to-be-determined cleanliness and planetary protection requirements. Curators will be responsible for creating and maintaining a detailed documentary history for each sample, from initial reception through long-term use in scientific studies. This curatorial record must capture every action carried out on samples in addition to relevant information from scientific and Planetary Protection investigations.

References: [1] iMARS Working Group, 2008. Preliminary Planning for an International Mars Sample Return Mission. (http://mepag.nasa.gov/reports/iMARS_FinalReport.pdf).

Keywords: Mars Sample Return, Curation, iMARS

The Maintenance and Development of a Specialised Cold Curation Facility for Pristine Astromaterials.

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The Subzero Facility for Curation of Astromaterials at the University of Alberta consists of a purified Ar glove box enclosed within a freezer chamber; enabling handling of samples at or below -10 °C in an inert atmosphere [1]. Originally designed for the manipulation and characterization of the Tagish Lake meteorite, an ungrouped carbonaceous chondrite with a high organic content that has been kept at sub-zero temperatures since it's fall onto a frozen lake in 2000 [1-6], the facility also represents a test bed for the development of sample handling facilities ready for sample return from targets containing organic compounds, ices, or other volatile components. The facility differs significantly from similar facilities elsewhere, and from previous cold curation test-beds [7-8] due to the enclosure of the glove box within the low-temperature environmental chamber. Keeping samples in a cold, as well as inert, environment has the benefit of reducing terrestrial contamination from known volatiles released from laboratory building and handling materials, slowing the rates of oxidation, hydrolysis and that of bacterial and fungal growth [1,9], therefore preserving the integrity of the sample material for longer periods of time.

We can provide several recommendations based on insights obtained from the commissioning and initial use of the facility that are relevant to planning and implementation of curation methods for future sample return missions, collection of freshly fallen meteorites, curation of volatile bearing meteorites and other astromaterials.

References: [1] Herd, C. D. K. et al. (2016) *Meteoritics & Planetary Science* 51, Nr 3, 499–519. [2] Brown, P. G. et al. (2000) Science 290:320–325 [3] Grady M. M et al. (2002) *Meteoritics & Planetary Science* 37:713–735. [4] Zolensky, M. E. et al. (2002) *Meteoritics & Planetary Science* 37:737–761. [5] Hildebrand A. R et al. (2006) *Meteoritics & Planetary Science*, 41:407–431. [6] Hilts R. W. et al. (2014) *Meteoritics & Planetary Science* 49:526–549. [7] Fletcher L. A., Allen C. C., and Bastien R. (2008a) (abstract #2202), *39th Lunar and Planetary Science Conference*. [8] Fletcher L. A., Bastien R., and Allen C. C. (2008b) *Meteoritics & Planetary Science* 43:A43. [9] Toporski J. and Steele A. (2007*) Astrobiology 7:389–401.*

Facility or Facilities? That is the Question!

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Mars sample return mission (MSR) will be a wide international cooperation led, *de facto,* by the United-States. The basic hypotheses are i) the mission is returning 500g of Martian samples plus some gas in one return container landing in Utah or Australia, ii) the samples are considered as a unique asset of mankind and are managed by an International Dedicated Committee, iii) MSR is a restricted Earth return mission according to the COSPAR planetary protection policy.

In the former French-US project to return sample in the early two-thousands we began to cope with this question of sample handling and quarantine leading to the edition of the “draft protocol” [1]. The rough functional analysis lead to the description of 4 different activities: opening of the container and sorting/identification of the various samples, quarantine analyses for life detection and biohazard, curation and finally science analysis of the samples.

The opening of the return container as well as the identification and the splitting of the samples will be done in a unique, highly specialized, dedicated facility the Receiving Facility. The level of cleanliness, confinement and safety is summarized under the designation PPL4 (planetary protection laboratory with a Bio-Safety Level 4). We state that the samples can then be moved with the appropriate containment and safety from one PPL4 to another. These curation facilities will have specificity to assume several functions (identification, rough characterization, preservation subsampling…) under strict containment for the very long term. These curations facilities could or would have the possibility to conduct specific, concerted quarantine operations for life detection and biohazard testing during an appropriate period of time. The definition of these functions will lead to specific requirements needed to design these quarantine and curation facilities (Q&CF).

It is likely that the main players (US, Europe, Japan…) will require the handling of some samples in an institutional Q&CF. Europe (ESA as well as EU) could be a major player in this MSR effort and probably will require samples to be handled at home. In this draft protocol we reckoned that 10 years will be require from the formal “go” decision to the end of the certification of the Q&CF.

References:

[1] DRAFT TEST PROTOCOL FOR DETECTING POSSIBLE BIOHAZARDS IN MARTIAN SAMPLES RETURNED TO EARTH; J. D. Rummel, M. S. Race, D. L. DeVincenzi, P. J. Schad, P. D. Stabekis,.M. Viso, S. Acevedo; NASA/CP—2002-211842, 2002, pp

Keywords: Mars sample return, Life detection, Biohazard, Planetary protection, Biosafety

Double Walled Isolator (DWI) System for a Mars Sample Receiving Facility (MSRF) - Outline of Activities and Early Results of European Space Agency (ESA) Technology Development

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Inside a future Mars Sample Receiving Facility (MSRF) there are several critical systems[1] that are required to perform all the identified operations[2] in the required environment to the required level of safety. One of these critical systems is the Double Walled Isolator (DWI) system which is required to simultaneously maintain containment (i.e. nothing gets out) and maintain ultra-cleanliness (i.e. nothing gets in) for the returned sample material. The DWI system will consist of approximately 40 individual DWIs, each dedicated to a particular science investigation or operation and transport of equipment & sample material between DWIs achieved by the use of Double Walled Rapid Transfer Port (DWRTP) boxes.

Within the framework of the European Space Agency (ESA) "Mars Robotic Exploration Preparation (MREP) Technology Development programme a Double Walled Isolator (DWI) 'Breadboard' is being designed to determine the suitability of modifying existing isolator technology whilst maintaining containment and ultra-cleanliness under representative operational conditions.

References: [1] A detailed design, operation and assessment of technology development required for a Mars Sample Return (MSR) Sample Receiving Facility (SRF), M. Guest et al. 61st IAC, Prague, 2010, [2] Report on the workshop outputs from the Working Group on Scientific Investigations to be conducted in the Mars Sample Receiving Facility, E913-010\Working group report, Draft

Keywords: Mars Sample Return, MSR, Sample Receiving Facility, SRF, Double Walled Isolator, DWI, RTP, Containment, Ultra-Clean, MREP

Remote Manipulation (RM) System for Mars Sample Receiving Facility (MSRF) - Outline of Activities and Early Results of European Space Agency (ESA) Technology Development

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Inside the future Mars Sample Receiving Facility (MSRF) there are several critical systems[1] that are required to perform all the identified operations[2] in the defined environment to the imposed level of safety. One of these critical systems is the Remote Manipulation system which is required to remove the returned sample material from the many layers of spacecraft containment hardware[3][4], then in ultra-clean conditions, prepare the sample material for scientific investigation, conduct scientific investigation on the sample material to ensure no bio-hazard is present and finally to curate the sample material to allow worldwide scientific research.

Within the framework of the European Space Agency (ESA) “Mars Robotic Exploration Preparation” (MREP) Technology Development programme, a Remote Manipulator ‘Breadboard Model’ is being designed to determine the capabilities of this representative technology with required operations in a controlled environment to the defined level of safety. The demonstration testing of the ‘Breadboard’ Remote Manipulator system will especially focus on critical operations which have never been conducted before, these will be performed using a robotic arm with haptic feedback control and interchangeable end-effectors.

References: [1] A detailed design, operation and assessment of technology development required for a Mars Sample Return (MSR) Sample Receiving Facility (SRF), M. Guest et al. 61st IAC, Prague, 2010, [2] Report on the workshop outputs from the Working Group on Scientific Investigations to be conducted in the Mars Sample Receiving Facility, E913-010\Working group report, Draft, [3] “Design, breadboarding and testing of a Bio-Containment system for Mars Sample Return mission”, S. Senese et al. IAC63, Naples, 2012, [4] “Sample Tube Seal Testing for Mars Sample Return” , Paulo Younse, et al., 2014 IEEE Aerospace Conference, Big Sky, April 2014.

Keywords: Mars Sample Return, MSR, Sample Receiving Facility, SRF, Remote Manipulator, Haptic Feedback, Containment, Ultra-Clean, Safety, MREP

Curating NASA's Past, Present, and Future Astromaterial Sample Collections

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The Astromaterials Acquisition and Curation Office at NASA Johnson Space Center (hereafter JSC curation) is responsible for curating all of NASA's extraterrestrial samples. JSC presently curates 9 different astromaterials collections in seven different clean-room suites: (1) Apollo Samples (ISO class 6 + 7); (2) Antarctic Meteorites (ISO 6 + 7); (3) Cosmic Dust Particles (ISO 5); (4) Microparticle Impact Collection (ISO 7; formerly called Space Exposed Hardware); (5) Genesis Solar Wind Atoms (ISO 4); (6) Stardust Comet Particles (ISO 5); (7) Stardust Interstellar Particles (ISO 5); (8) Hayabusa Asteroid Particles (ISO 5); (9) OSIRIS-REx Spacecraft Coupons and Witness Plates (ISO 7). Additional cleanrooms are currently being planned to house samples from two new collections, Hayabusa 2 (2021) and OSIRIS-REx (2023). In addition to the labs that house the samples, we maintain a wide variety of infrastructure facilities required to support the clean rooms: HEPA-filtered air-handling systems, ultrapure dry gaseous nitrogen systems, an ultrapure water system, and cleaning facilities to provide clean tools and equipment for the labs. We also have sample preparation facilities for making thin sections, microtome sections, and even focused ion-beam sections. We routinely monitor the cleanliness of our clean rooms and infrastructure systems, including measurements of inorganic or organic contamination, weekly airborne particle counts, compositional and isotopic monitoring of liquid N_2 deliveries, and daily UPW system monitoring. In addition to the physical maintenance of the samples, we track within our databases the current and ever changing characteristics (weight, location, etc.) of >250,000 individually numbered samples across our various collections, as well as >100,000 images, and countless "analog" records that record the sample processing records of each individual sample. JSC Curation is collocated with JSC's Astromaterials Research Office, which houses a world-class suite of analytical instrumentation and scientists. We leverage these labs and personnel to better curate the samples. Part of the curation process is planning for the future, and we refer to these planning efforts as "advanced curation". Advanced Curation is tasked with developing procedures, technology, and data sets necessary for curating new types of collections as envisioned by NASA exploration goals. We are (and have been) planning for future curation, including cold curation, extended curation of ices and volatiles, curation of samples with special chemical considerations such as perchlorate-rich samples, and curation of organically- and biologically-sensitive samples.

Keywords: Astromaterials Curation, Clean Sample Handling, Apollo, Meteorite, Stardust

Storage and Usage of Analogue Samples in an Extraterrestrial Sample Curation Facility

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One particular challenge concerns the handling of extraterrestrial materials returned to Earth in a curation facility. The facility needs to serve at least three major purposes: (1) initial inspection and characterisation of extraterrestrial materials, (2) preparation and allocation of samples for analysis in internal and external laboratories, and (3) long-term storage of such materials. Each of these points needs special equipment for sample handling, manipulation, analysis and storage. In addition, samples from planets or asteroids will need different kinds of treatment. Analogue samples are important for testing handling protocols and may be crucial in monitoring effects from long-term storage.

We are presently expanding the list of existing analogue samples, based on a review of the literature. The criteria for determining analogue rocks and minerals include characteristics, such as the kinds of physical and chemical properties expected for returned samples from potential target materials. The major focus here clearly lies on non-biological analogue samples.

While, so far, analogue samples are kept outside existing curation facilites, we follow the approach to keep them inside a curation facility for immediate accessibility and for long-term storage. In order to accommodate different returned sample materials, we are considering two distinct handling and storage areas within a curation facility. One "normal" non-sterile area for returned samples without restrictions for planetary protection, and a sterile area for samples returned from Mars that are restricted. Analogue sample collections would ideally be kept separately in both areas. The collection in the non-sterile area could be larger and a small collection of the most essential analogue types could be stored in the sterile area. In addition to the analogues used for testing handling procedures, we recommend keeping a pure, clean sample for monitoring purposes in these areas in order to evaluate any potential forward or cross contamination, e.g., of biological signatures.

The physical requirements on the curation facility for storage conditions of analogue samples are expected to be minimal. In the event of returned samples from Mars, a mirror sterile area that would allow testing protocols with biological analogues without compromising the returned samples should be considered.

Keywords: Sample analogues, Planetary materials, Storage and curation, Handling protocols.

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EURO-Curation of Astromaterials
Returned from the Exploration of Space

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