This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 640190

EURO-CARES
A PLAN FOR EUROPEAN CURATION OF RETURNED EXTRATERRESTRIAL SAMPLES

Work Package 8

Deliverable 8.10: Promotional Brochure

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Promotional Brochure

Background: Prior to preparing the brochure, the Work Package (WP) team had a strategy meeting to decide (a) the audience for the brochure; (b) the format of the brochure and (c) its content. It was concluded that criteria (b) and (c) could not be determined until (a) had been settled.

(a) Audience: there were several possibilities for the audience:

(i). Opinion formers. The brochure would have to be kept relatively short (at most, four pages in total) and contain quite specific information about costs, timescales and location of the Facility. The WP team decided that since the EURO-CARES project had, very specifically, kept away from these issues, it would be inappropriate to introduce them in a promotional brochure.

(ii). Specialists. This audience would encompass academic and industrial contacts, university students and special interest groups such as astronomy societies. The brochure could be longer and go into a reasonable level of scientific and engineering detail.

(iii). General Public. This audience would include teachers and school students, as well as interested lay people. The brochure would be similar in format to that for specialist audiences, but the content would be more descriptive

The WP8 team decided that option (iii) would be the most appropriate for the promotional brochure, since one of the intended outcomes of the project was to engage the public with EURO-CARES and space exploration missions. However, the brochure would be designed such that it could be circulated to specialists and opinion formers in appropriate circumstances (section (d) below)

(b) Format: to tackle criterion (b), the team looked at a range of brochures and leaflets that they had collected from different sources over the preceding 6 months. The materials included: advertising material from a scientific instrumentation company and from a travel company; a prospectus for university science courses; an information booklet from the UK Space Agency; an information booklet from a Space Research organisation. Also considered was an analogous brochure produced for another Horizon 2020 Program (Asterics). There were three options considered:

(i). A leaflet, in effect a single page of A4 paper folded into 3, giving 6 columns for information. Although there were certain advantages to the format (quick and easy to design, cheap to print in bulk), the team decided that there was insufficient space on the leaflet to get across the message about what EURO-CARES was, and why it was important. However, it was also considered that such a leaflet would be useful in future if EURO-CARES were to have a display stand at a science festival or space conference.

(ii). A wallet containing separate information sheets. The advertising material from the scientific instrumentation company had this format: an A4-sized thin card cover, with a pocket on the inside holding several glossy sheets of paper. The advantage of such

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an arrangement is that it is very easy to update, simply by exchanging one of the sheets. It could be used for different audiences, with separate sets of sheets for specialists, lay people and opinion formers. After some debate, the WP8 team decided against using this format, as its arrangement of loose sheets seemed less professional for the message we were delivering, especially as they would be quite easy to lose.

(iii). A booklet, either bound along the spine or stapled in the centre, depending on the number of pages. This format was by far the most common in the material the team had collected for examination, and it was agreed that it produced the most professional-looking of results. Discussion about the overall appearance (glossy versus matt finish for the pages) and the number of pages (must be divisible by 4 to fit the format) was also agreed.

(c) Content: The content of the brochure would highlight the conclusions and recommendations of the different the work packages, drawing images and charts from the various reports. Each work package would be covered in a double page-spread. There would also be a general introduction, setting the context for EURO-CARES;

Outcomes: The following decisions were taken at the strategy meeting, regarding the promotional brochure:

(a) The audience for the brochure would be the general public;
(b) The brochure would be an A4-sized booklet, with a glossy cover, 16 internal pages, stapled in the middle;
(c) The content would parallel the main work packages, with a double page-spread for each.

Production of the Brochure: Text, images, graphics, etc were prepared by the WP8 team, with input from the other work package teams. The design of the brochure was undertaken, at no cost, by a professional artist with an interest in graphic design, on the understanding that he could include the artwork (with appropriate accreditation) on his website.

A mock-up of several pages from the draft brochure follows; it will not be printed until the content of all the work packages is finalised, enabling the most pertinent findings to be included in the finished product.

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Back cover Front cover

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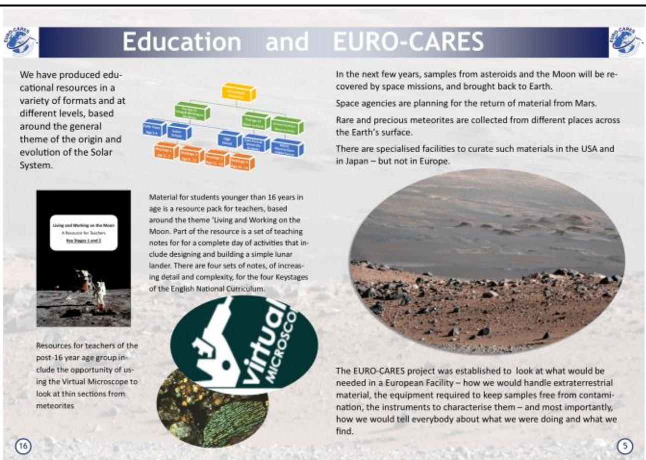

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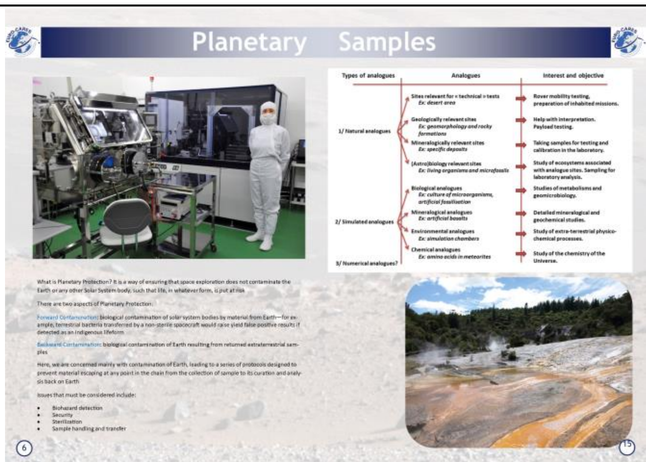

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EURO-CARES

EURO-Curation of Astromaterials Returned from the Exploration of Space

EURO-CARES

Roadmap to a European Sample Curation Facility

Foreword

Welcome to EURO-CARES:

European Curation of Astromaterials Returned from the Exploration of Space

We are an international team of scientists and engineers from 13 European institutions.

We are funded by the European Commission, through its Horizon 2020 Program, to design a roadmap for the steps needed to establish and operate a Curation Facility for samples returned from space exploration missions.

In this brochure, we present a summary of our main findings, with some of the reasons behind how and why we reached our conclusions.

We hope that you find this informative and interesting.

Sara Russell

Caroline Smith

Principal Investigators, The EURO-CARES Consortium

November 2017

European Commission

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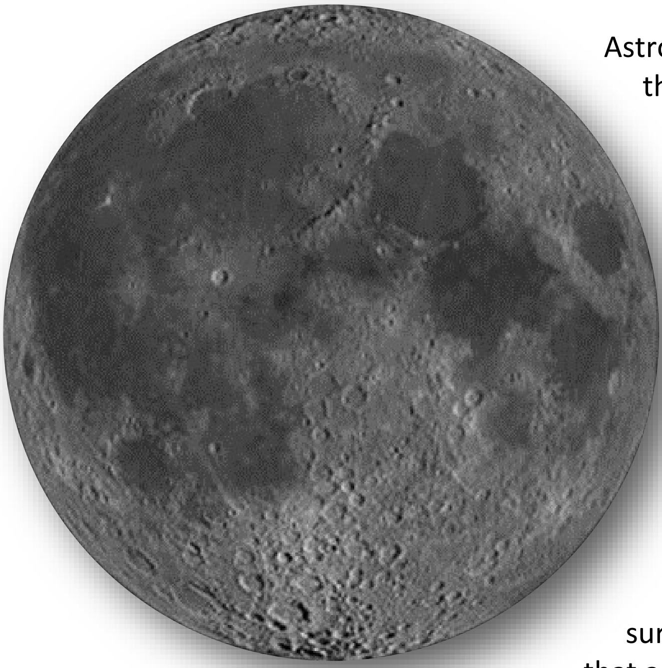
Background

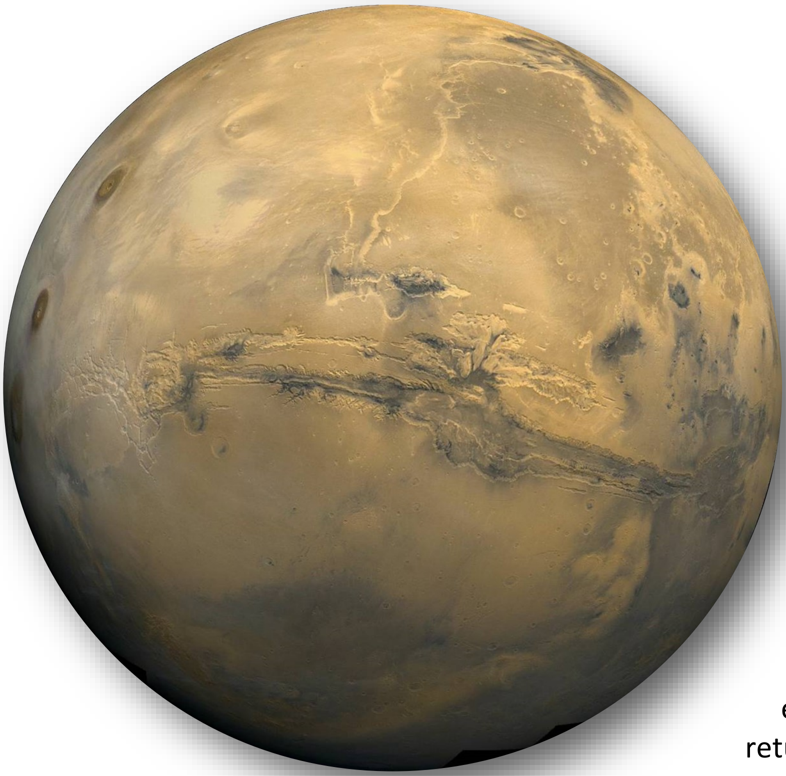


Astromaterials are samples that come from beyond the Earth – from the Moon and Mars, from Asteroids and Comets.

They are precious because they preserve records of materials and processes that we cannot access through analysis of terrestrial specimens, or by observation using telescopes or instruments on spacecraft.

By studying astromaterials, we can learn about the dust from which the planets formed, the fluids that once flowed on Mars, the impact events that modified the Moon's surface and the organic molecules that are the basis for life.

Material brought back from sample return missions must be curated with great care, so that it is not contaminated - and so that it does not contaminate the Earth!



Curation of extraterrestrial materials is a specialised field and requires a breadth of skills, not just in following the requirements of planetary protection, but in understanding of different techniques for sample manipulation, documentation and analysis.

One of the goals of EURO-CARES is that through a programme of education and outreach, it will help develop a new generation of scientists and engineers to curate the first samples returned directly to the Earth from Mars.

In the next few years, samples from asteroids and the Moon will be recovered by space missions, and brought back to Earth. Space agencies are planning for the return of material from Mars.

There are specialised facilities to curate such materials in the USA and in Japan – but not in Europe. EURO-CARES was established to look at how a European Sample Curation Facility (ESCF) could be developed.

EURO-CARES considered restricted and unrestricted samples. Restricted samples are those that will be brought back from places where there is a possibility that life might exist, or have existed, e.g., Mars or Europa. These samples are considered as potential biohazards, and so have to be handled and curated in the same way as a hazardous organisms such as the Ebola virus. Unrestricted samples come from bodies where it is considered unlikely that life existed, e.g., asteroids and the Moon, and so they are curated with care, but not subject to the biohazard protocols of the restricted material.

It considers how we would transport and handle extraterrestrial material, the equipment required to keep samples free from contamination and the instruments needed to characterise them. It also looks at other materials that should be curated at the facility, such as calibration specimens and analogue samples.

The project has also designed resources for a variety of audiences to inform them about extraterrestrial materials and their importance.

Planetary Protection

Planetary Protection is a way of ensuring that space exploration does not contaminate the Earth or any other Solar System body, such that life, in whatever form, is put at risk.

There are two aspects of Planetary Protection:

Forward Contamination: biological contamination of Solar System bodies by material from Earth—for example, terrestrial bacteria transferred by a non-sterile spacecraft would yield false positive results if detected as an indigenous lifeform

Backward Contamination: biological contamination of Earth resulting from returned extraterrestrial samples

EURO-CARES is concerned mainly with **Backward Contamination**, which requires a series of protocols designed to prevent material escaping at any point in the chain from the collection of sample to its curation and analysis back on Earth.

The working hypothesis that EURO-CARES follows in defining the requirements of a European Sample Curation Facility (ESCF) is that samples collected and returned to Earth must be contained and treated as potentially biologically hazardous until they are declared safe.

A sample may only be declared safe after recommended analytical protocols have been applied, including rigorous physical and chemical characterization, life detection analyses and biohazard testing.

There are accepted international definitions of biohazard risk; the highest biological level is Risk Group 4 (RG4): an agent that causes severe human disease and is a serious hazard to workers; it may present a high risk of spreading to the community; there is usually no effective or treatment available.

The assumed technique of handling materials within RG4 is to be fully-suited (upper image); for materials of lower risk, handling within a sealed cabinet is appropriate (lower image). The cabinets, or glove boxes, are at negative pressure to reduce the chance of particle release.

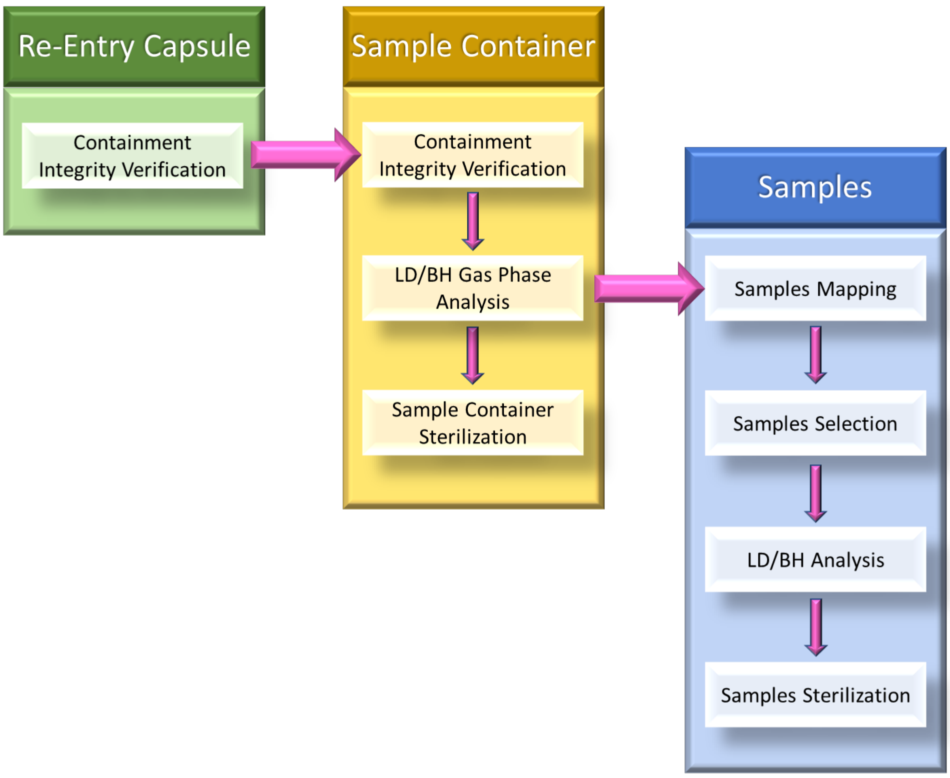
Life Detection (LD) and Biohazard (BH) Assessment Protocols

A biohazard is defined as a hazard that can either replicate by itself or be amplified by a biological system (e.g., viruses). Potential hazards could take one or more forms, including toxic, mutagenic, life cycle altering, hazardous through genetic recombination, disruptive to ecosystems, capable of biasing phenotypes or behaviour.

If a living, self-replicating organism is detected within a sample returned from, e.g., Mars, a biohazard analysis would include:

- Evaluation of the intrinsic hazard characteristics of biochemicals and macromolecules.
- Dose-response evaluation, which involves parameters such as minimal dose for infectivity, pathogenicity, environmental transmission, and distribution in the ecosystem populations.
- Exposure assessment, to determine the potential hazard for staff involved in occupational, clinical, and general environment-related activities.
- Risk characterization, a formalized approach to combine the characteristics of hazard, toxicity, and exposure to derive a measure of risk associated with the biological agent

The work flow for planetary protection would follow a pathway starting with examination of the sample re–entry capsule, then of the sample container and then of the samples themselves.



Sample Transport

Several missions have already returned samples to Earth, and we can learn a great deal from these.

When the "Earth Return Capsule" of a sample return mission lands on Earth it needs to be recovered, handled and transported in a way which preserves the precious sample within.

Before the capsule arrives, considerable preparations for the recovery need to be made. Once the capsule has landed, the recovery proceeds according to these well-rehearsed plans.

Once the sample is packed in a special container, it will be transported to the Curation Facility using a safe and secure method of transport.

For material returned from restricted sites, e.g., from Mars, the need for biocontainment means additional special steps have to be taken.

(1)

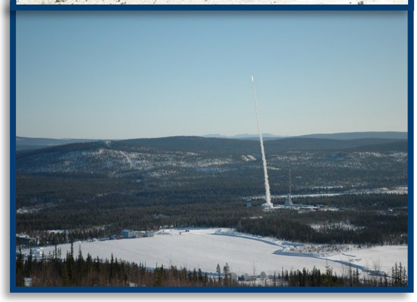
(2)

(3)

(4)

1) Recovery of the Stardust Sample Return Capsule from the Utah Test and Training Range in January 2006, (2) its transport to the Receiving Facility, where (3) it was opened and the sample canister removed and (4) examination of the returned material at the Johnson Space Center in Texas

Landing Site Identification

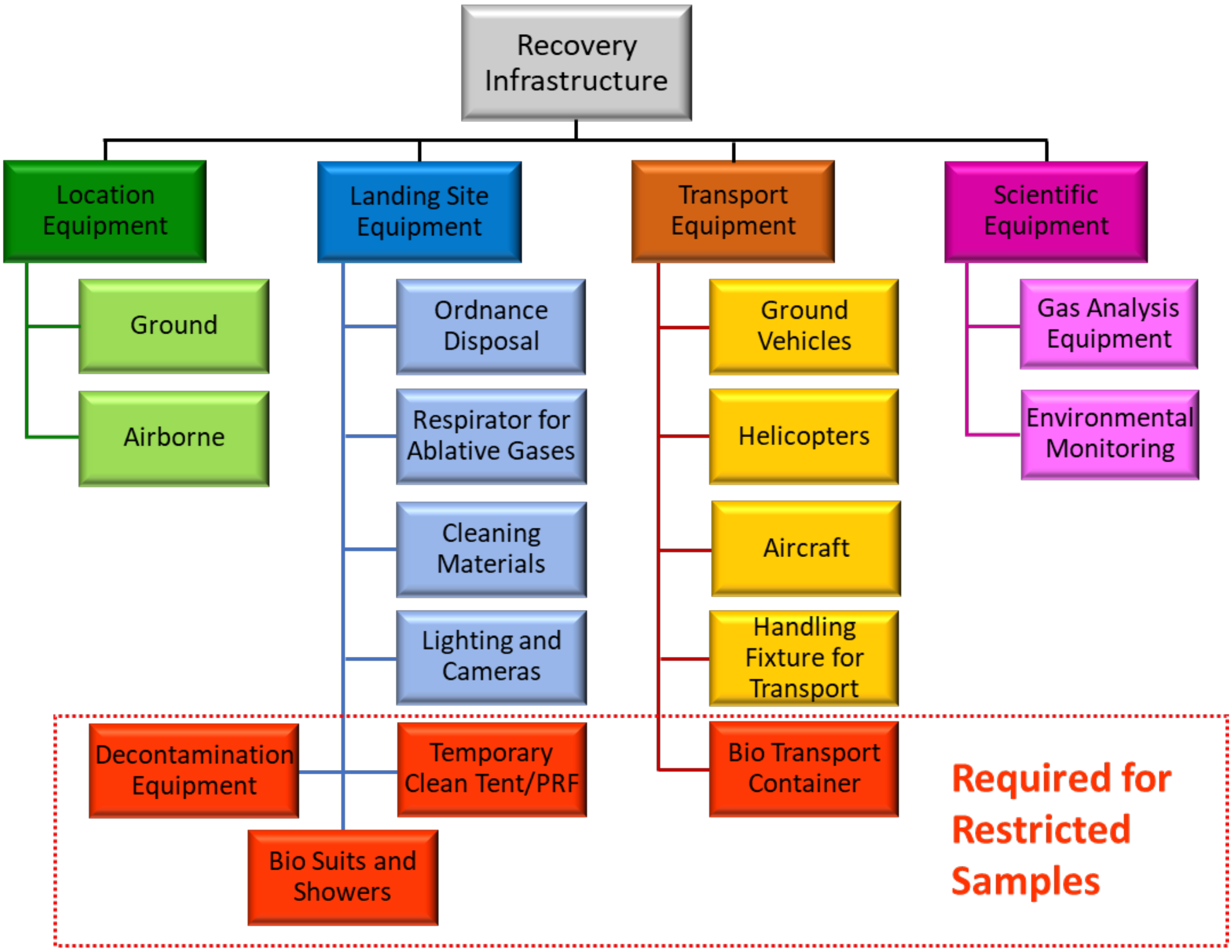


As part of the EURO-CARES project, we evaluated several different possible landing sites, including the Utah Test and Training Range (UTTR) where the ill-fated Genesis mission crash-landed (above) and the Esrange Space Facility in Sweden (below)

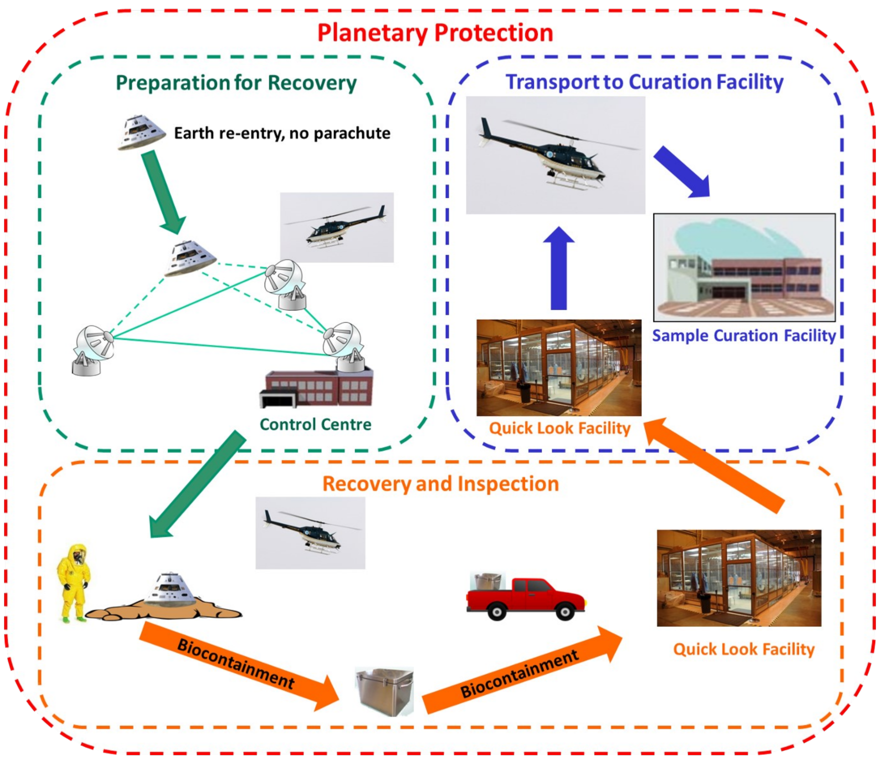
Sites for sample return missions tend to be isolated and remote areas with low population, which often equates to limited infrastructure and the need for specialist access.

Civilian and military test ranges make almost ideal landing sites because of the security and safety provided by the location—though the potential presence of unexploded ordnance can be a hazard.

Infrastructure required at landing site:



Simplified sample recovery procedure:

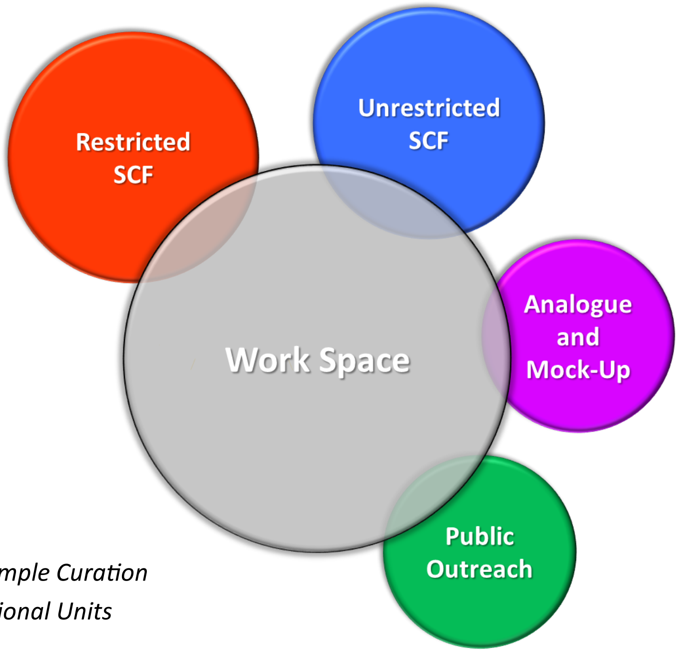


Facilities and Infrastructure

Here we define the facilities required to receive, contain, and curate extra-terrestrial samples whilst guaranteeing terrestrial planetary protection.

Two parallel facilities were considered:

- For unrestricted material that is unlikely to contain indigenous lifeforms (e.g., samples from the Moon or an asteroid)
- For restricted material, where scientific opinion is uncertain whether indigenous lifeforms might be present (e.g., samples from Mars)



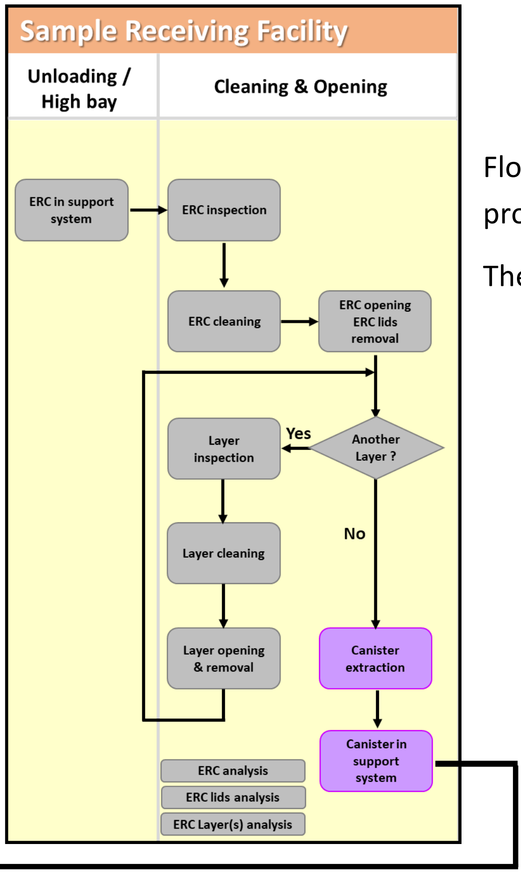
Schematic layout of Sample Curation Facility, showing Functional Units

We looked briefly at the requirements for a Portable Receiving Facility at the landing site, but focussed more specifically on design of the curation Facility itself.

We then considered the different Functional Units (FU) within the Facility, determining which were common to both a restricted and an unrestricted Facility and which additional Functional Units would be required to curate samples from a restricted source.

After identifying the Functional Units, we considered ways in which they could be arranged. The criteria we used to guide the arrangement of the FU were ones of safety and security—of the samples and of the personnel. We looked at the most efficient pathway through the Facility for staff, in terms of progressing from 'dirty' to 'clean' areas, and the provision of services, including air flow, between areas of positive and negative pressure.

Our favoured design was the 'Docking Station' model, in which a central work space formed a hub to which the different FU were connected. Each FU was isolated from the others; the Public Outreach FU was accessible from the outside, whilst the other FU were only accessible through the work space.

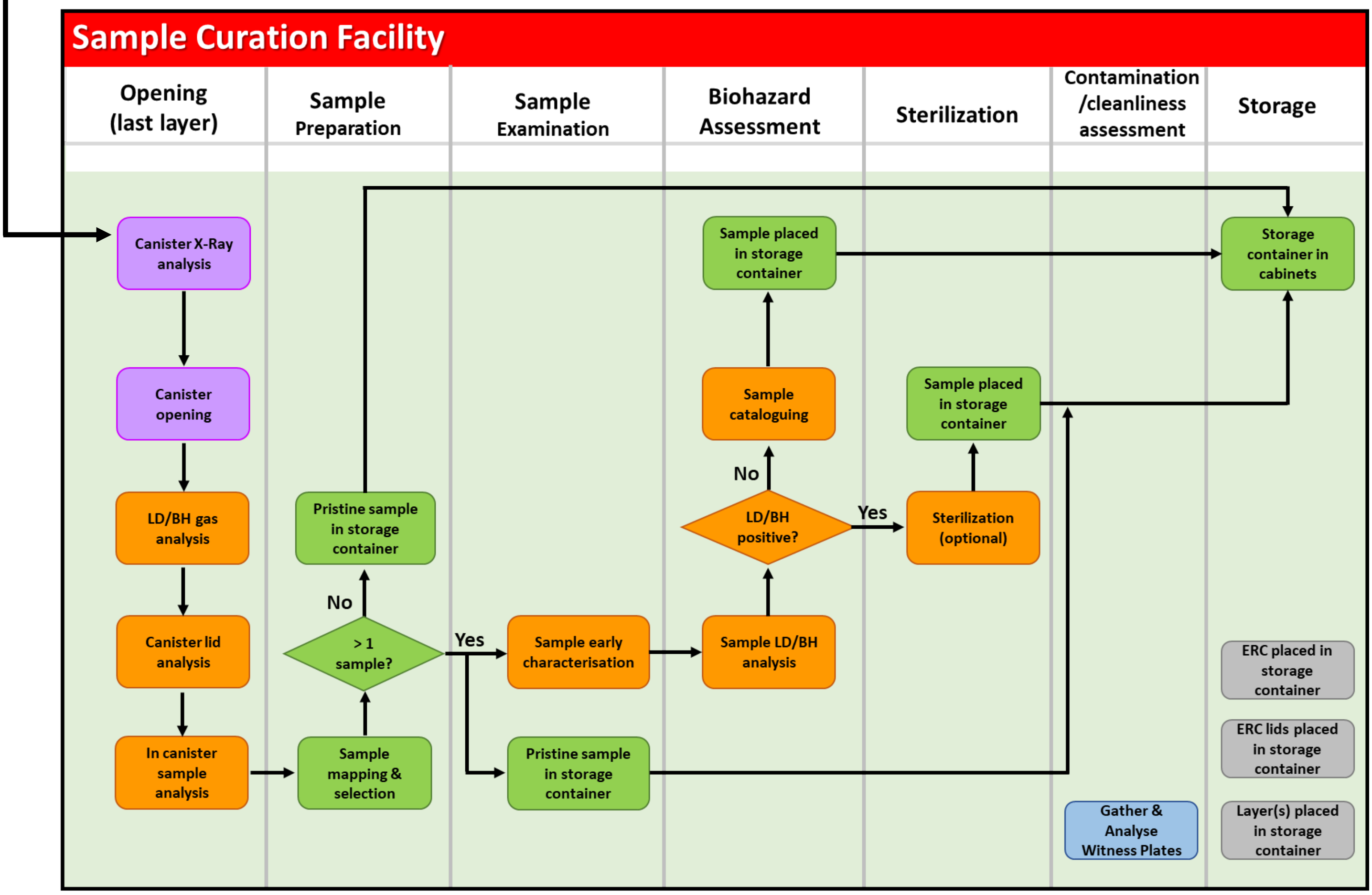


Flow of samples from Receiving to Curation Facility, showing the processes taking place at different stages in the curation process.

The illustration is for samples of restricted material

Legend	
Grey	Earth Return Capsule (ERC), ERC cover and
Mauve	Sample canister manipulation and analysis
Green	Sample manipulation
Orange	Sample and canister analysis
Blue	Witness plates operations

Transport from Receiving to Curation Facility



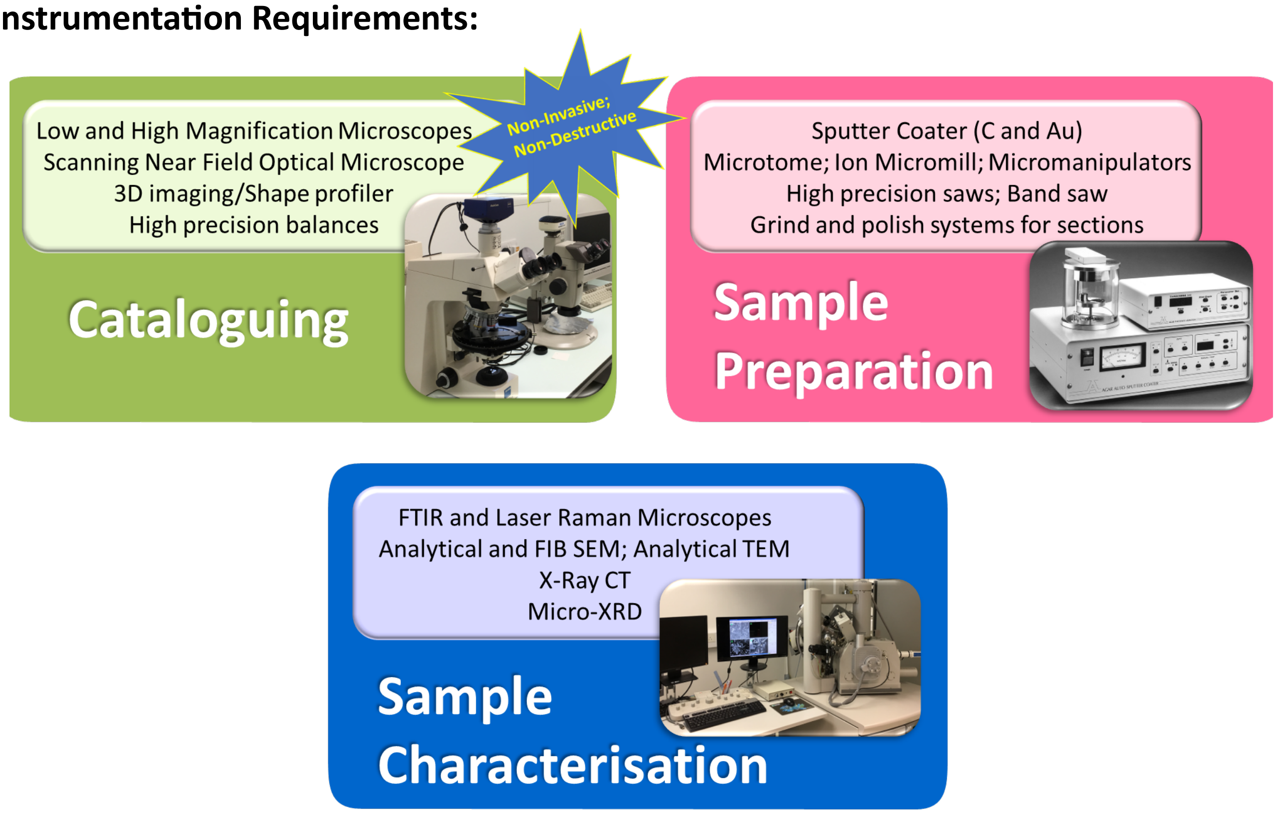
Instrumentation and Methods

A Curation Facility is not simply a place where samples are stored until they are required: it is an active research establishment where specialist staff prepare and investigate the materials, producing the information required to enable other scientists to work on the samples in the most efficient way.

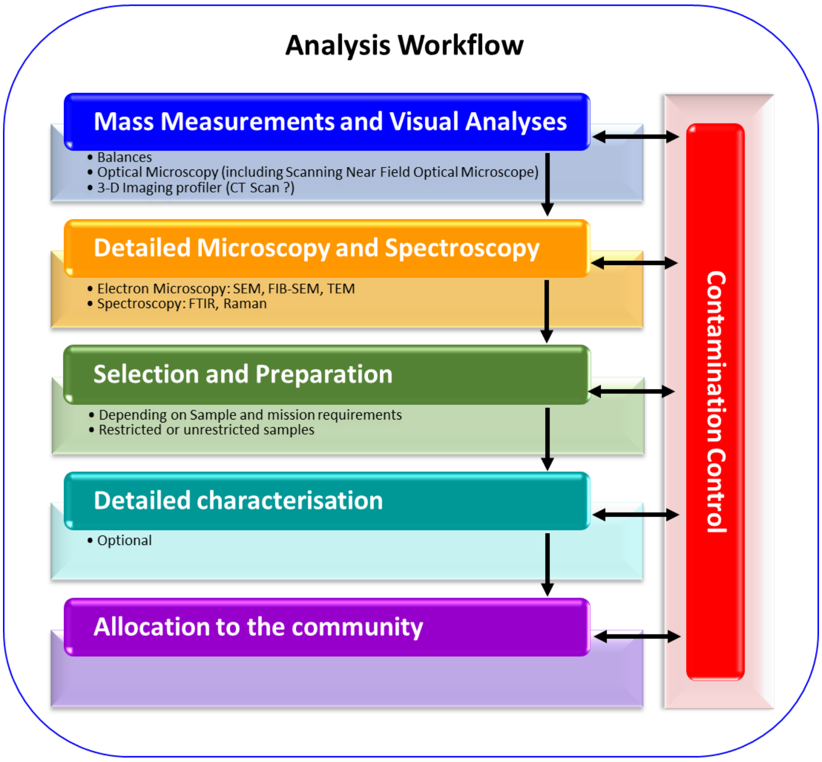
A Curation Facility has to have a suite of instrumentation that will allow characterisation of the specimens. The planetary protection protocols that must be followed after receipt of a returned sample include some of the procedures that are also required for preliminary characterisation of the material for research purposes (page 6).

Assuming then, that the basic procedures of weighing and photographing the material have already taken place, and that the sample has passed its planetary protection tests, we have identified three sets of tasks within the Curation Facility that require specific instruments and tools for preparation and characterisation of material prior to its distribution to the wider scientific community.

Instrumentation Requirements:



Cataloguing the samples sounds fairly straightforward—but it is a continuous process requires painstaking documentation, with images and weights of the material taken before and after each procedure it goes through. Alongside cataloguing is the need for a sample nomenclature system, and a comprehensive databasing tool.



The instruments required in an advanced Curation Facility employ many different approaches, measuring a wide range of physical, spectral and chemical properties. Of prime importance is how the instruments interact with the sample and how that interaction may modify or contaminate the sample. Clearly, as many measurements as possible must be non-destructive – and analyses should be undertaken with the most destructive measurements being the final ones in the analysis chain.

1) Optical methods: for documentation. Methods are non-destructive but may require destructive sample preparation, e.g., polished thin sections. The tools are necessary for documentation and very preliminary characterisation of the samples: size, shape, texture, colour, albedo, etc. Examples: *optical microscopy and imaging; 3D optical shape profiling.*

2) Physical properties: to provide additional information on the physical nature of the samples: mass of grains and fragments, density, grain density and porosity and internal structure at different scales. These techniques are generally non-destructive. Examples*: balances, X-ray CT.*

3) Spectroscopic methods: for characterisation of the mineralogy and chemical composition of the samples; minimal sample handling and preparation and little significant damage to a specimen, but the power of the incident radiation must be controlled. Examples*: FTIR spectroscopy, Raman spectroscopy, VIS-NIR spectroscopy, X-ray diffractometry.*

4) Scanning and electron probe methods: for high-resolution morphological information as well as detailed chemical and structural information. Minimally damaging, the electron beam affects the outer few µm of sample. Contamination can be a major issue, with the potential for electron beam-induced damage as well as the application of graphite or gold coatings to neutralise sample charging. Examples*: Scanning and Transmission Electron Microscopy*

5) Chemical methods and other destructive techniques: for chemical analysis of the samples, including characterisation and monitoring of potential contamination within the Curation Facility. Examples: *Time-of-flight mass spectrometry, liquid and gas chromatography*.

Analogue Samples

Planetary analogues are materials that have similar characteristics to samples that will be collected from various different extraterrestrial bodies. The characteristics in question might be physical or chemical, and the materials might be rocks or minerals, as well as information about specific geological sites.

The purpose behind assembling a collection of planetary analogues that have been formed or modified by similar processes to those on the target object is to provide calibration materials to test systems and instrumentation.

A library of rocks and minerals allows:

- Definition of the protocols necessary for safe handling procedures
- Evaluation of storage conditions during curation and analysis
- Determination of the suites of instruments that would be the most appropriate to analyse returned samples, the order in which the analyses are made, and the amount of material required to get the best scientific return.

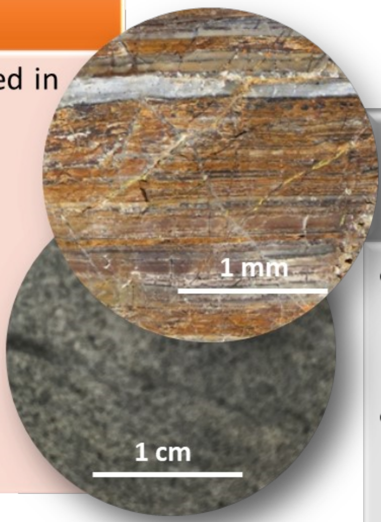
Alongside the analogue materials are other types of material essential for assurance that any findings are from the returned samples, and not a reflection of any terrestrial interferences. Such materials include:

- Calibration standards
- Voucher specimens
- Witness plates

Inclusion of geological sites enables test of sample acquisition and retrieval systems

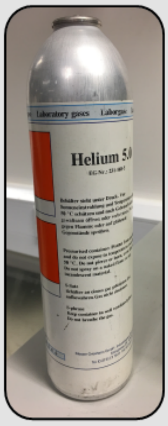
Analogues

- Properties similar to those expected in returned extraterrestrial samples
- Examples:
  - Early Archaean photosynthetic mats
  - Basalt from Theo's Flow, Canada
- Used for:
  - Training
  - Testing of sample transport, handling, preparation and analysis protocols
  - Interpretation of results



Reference Samples

- Well-characterised material used for testing
- Example:
  - helium gas for leak-testing
- Used for:
  - Training
  - Testing of sample transport, handling, preparation and analysis protocols
  - Reference for long-term storage



Standards

- Internationally-recognised, homogeneous material with known physical/chemical properties used for calibration
- Example:
  - Colour target to calibrate a camera
- Used for:
  - Testing and calibration of instruments

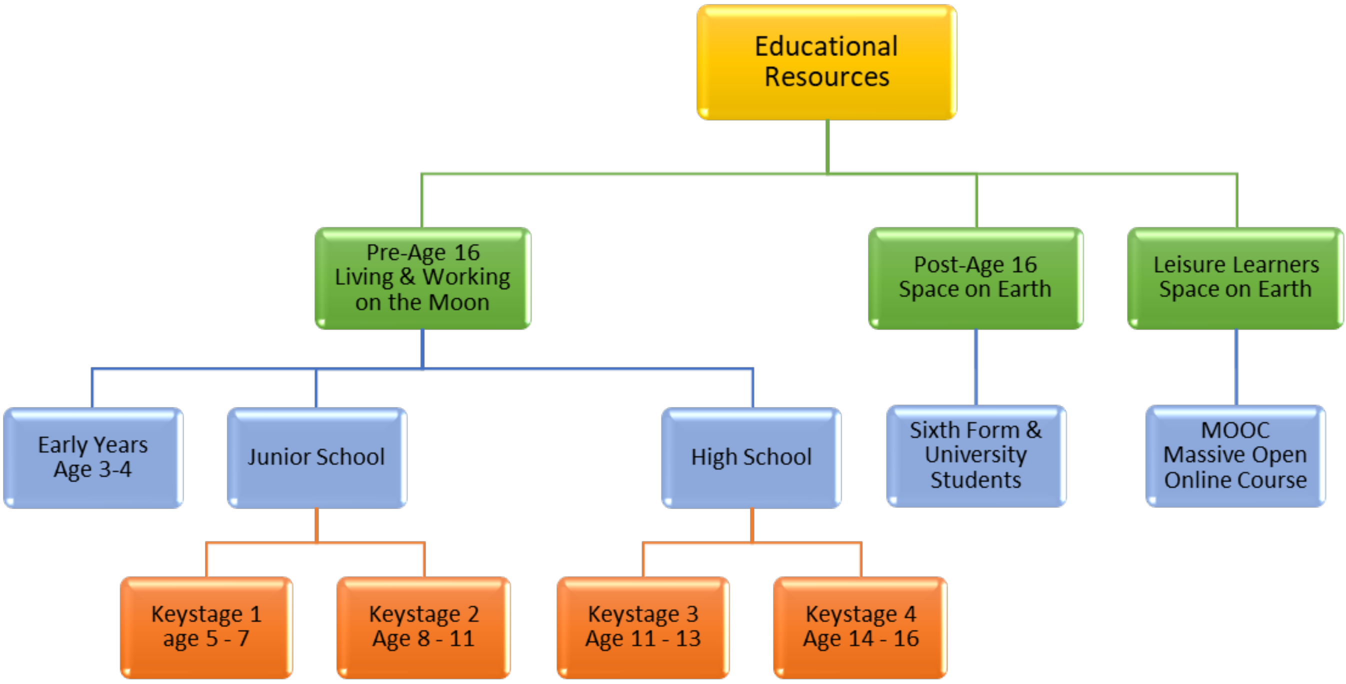
Voucher Specimens

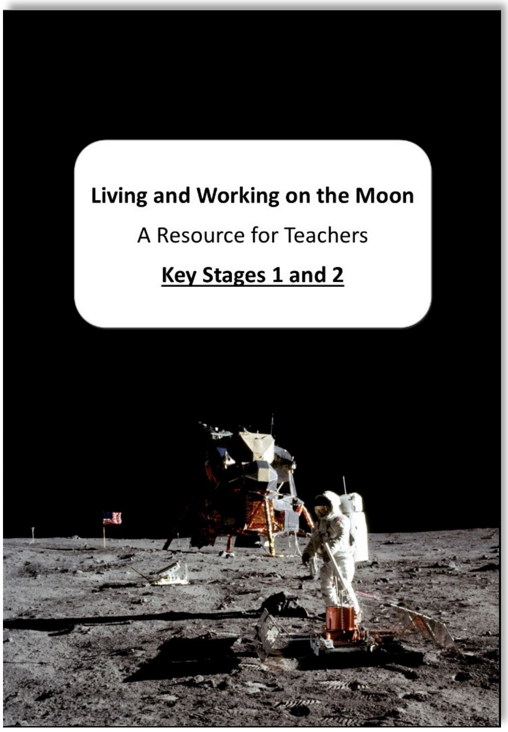
- Duplicate of materials used at any stage
- Examples:
  - Spacecraft materials, lubricants, glues
  - Samples from the terrestrial landing site
- Used for:
  - Detect potential contaminants from the mission

Witness Plates

- Specific material used as a spatial and temporal document of what happens in the work area
- Examples:
  - PTFE surfaces, aluminium foil, packaging, handling tools
- Used for:
  - Detection of potential contaminants from the laboratory
  - Witness for long-term storage

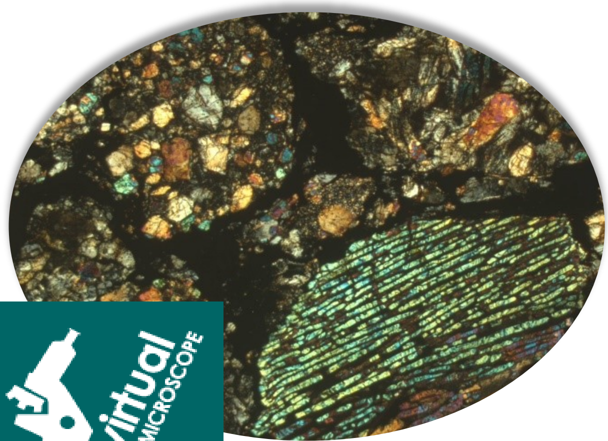
Education and Outreach





We have produced educational resources in a variety of formats and at different levels, based around the general theme of the origin and evolution of the Solar System.

Material for students younger than 16 years in age is a resource pack for teachers, based around the theme ‘Living and Working on the Moon. Part of the resource is a set of teaching notes for a complete day of activities that include designing and building a simple lunar lander. There are sets of notes, of increasing detail and complexity, for the 4 Keystages of the English National Curriculum.



Resources for teachers of the post-16 year age group include the opportunity to use the Virtual Microscope to look at thin sections from meteorites

https://www.virtualmicroscope.org/

For those interested in self-guided study, we have developed a MOOC (a Massive Open On-line Course), which is free to study and lasts 6 weeks (about 3 hours of study per week). Successful completion of the course will be rewarded by a certificate.

The course is designed to take students on a journey of discovery, exploring the Solar System with the latest information from space missions.

Free online course | Duration: 6 weeks | 3 hours pw | Certificates available

FUNDING

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ABOUT THE COURSE

What is the chance of the Earth being hit by a meteorite? Might we all be wiped out, like the dinosaurs? What would cause such a catastrophe?

In this 6 week course, you will find out about the range of materials that falls to Earth, where it all comes from and how it is collected. You will learn how scientists look after this valuable material, and the sort of equipment they use to study it. You will think about why it is interesting and important to study extraterrestrial material – and find the answer to whether you might suffer the same fate as the unlucky dinosaurs

CREATED BY

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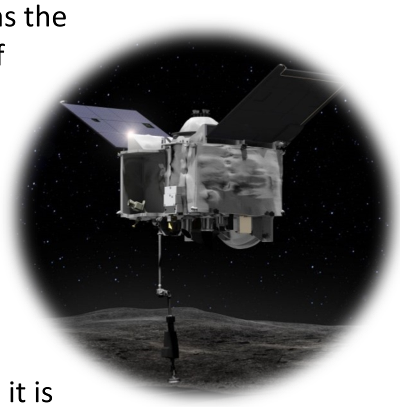
#spaceonearth

The specific topics covered in the 6 weeks are:

1. What is extraterrestrial material?
2. Where does it come from?
3. How do we acquire it?
4. How do we look after it?
5. How do we analyse it?
6. What can we learn from it?

Next Steps



The requirement for a European Sample Curation Facility will grow as the number of proposed sample return missions increases: at the end of 2017, two sample return missions to asteroids were in progress (USA, Japan), two separate lunar sample return missions were at planning stage (ESA-Russia; China) and a USA-led comet nucleus sample return mission was in the selection process. An international Mars Sample Return programme was also in the planning stages, based on material selected and cached by the Mars 2020 mission.

For European scientists to take full advantage of such opportunities, it is essential that a sample curation facility be built in Europe. Information about the ESCF must remain on the political agenda and in the public consciousness.

The next steps that EURO-CARES will take are based on a communication strategy aimed at four communities:

1. Political and Funding bodies

ESFRI

The **European Strategy Forum on Research Infrastructures** (ESFRI; http://www.esfri.eu/) is the EC body advises on development of research infrastructures in Europe. It keeps a forward look – on decadal timescales - at what facilities might be required within Europe, and maintains a roadmap for funding and development of the facilities. **A key next step for EURO-CARES is to submit a proposal for an ESCF for consideration by ESFRI**.

2. The Academic Community

It is important to keep the wider academic community informed about the findings of the EURO-CARES project. This will ensure that our recommendations are incorporated into future discussions and proposals, and are widely disseminated beyond Europe. We have already made presentations about an ESCF at major international conferences. **A key next step for EURO-CARES is to publish its findings in a Special Edition of the peer-reviewed journal *Planetary and Space Sciences***.

3. Students

We will use social media to build up an international network of students enthused by space research and exploration. **A key next step for EURO-CARES is to produce translations of our resources into French, German, Spanish and Italian.** We aim to accomplish this through continued engagement with the Horizon 2020 programme, *via* the EuroPlanet portal.

4. The General Public

Non-specialists are an important audience with whom to engage, because as tax-payers, voters, and consumers and producers of news media, they are significant in influencing opinion formers and funding bodies. **A key next step for EURO-CARES is to use local and national media to publicise the advantages of a European Sample Curation Facility**. We aim to accomplish this through lectures to the general public and articles in non-specialist and special-interest magazines.

Consortium Members

Members of the EURO-CARES consortium would like to acknowledge with gratitude the assistance given to them by international colleagues. Without their generous help, we would not have been able to complete such detailed work, for which this brochure is a summary.

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