Mars sample return curation, planetary protection, and the science perspective

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/
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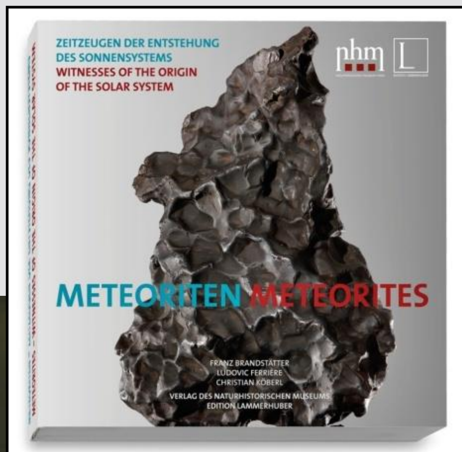
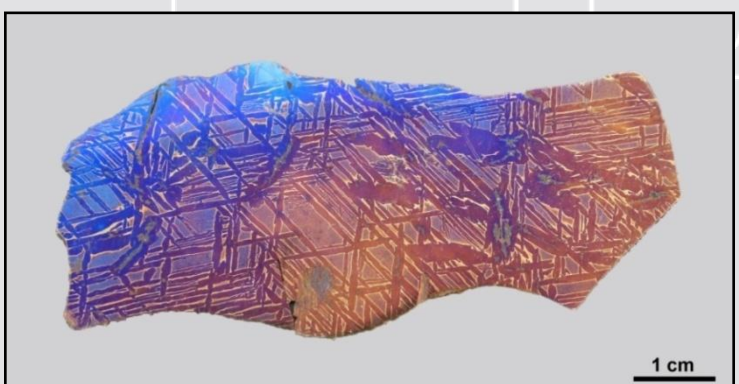


The NHM Vienna Meteorite collection

One of the world's largest meteorite collection
~ 8,500 pieces (~7,000 registered individual specimens)
~ 2,400 locations

Oldest collection in the world
Collection activities started in Vienna (1778) even before the recognition of meteorites as extraterrestrial matter.

Largest meteorite display in the world
Currently, after a thorough renovation and modernization of the hall (in 2012), there are 1,100 meteorites on display, including 650 different meteorites (consisting of 300 falls and 350 finds).



Summary

*__Extraterrestrial samples__ in the form of meteorites have been **curated for almost two and a half centuries**.

*With the **Apollo missions** and the return of precious lunar samples on Earth, **specific facilities have been designed**.

*__Scientists and governments have defined strict rules to prevent cross-contamination__ between Earth and other solar system objects.

*More recently, **new facilities have been designed for the curation of asteroid samples**, however, within the plan of **Mars sample return missions** in the next decades, a **specific facility should be planned and constructed** (to prevent sample contamination and alteration on the one hand, and potential biohazards from the sample on the other hand).

For samples returned from Mars, detection of life is a very important topic:

*"Planetary protection perspective"

These samples are regarded as having the potential of containing life or signatures of life.

*"Science perspective"

To know whether life ever arose on Mars.

→ Specific and appropriate handling and analysis of these samples will be required.

The EURO-CARES project
(www.euro-cares.eu)

EURO-CARES [*European Curation of Astromaterials Returned from Exploration of Space*]:

*A **multinational project** funded under the European Commission's Horizon2020 research programme.

*A **multidisciplinary team of experts** from industry and academia **developing a roadmap for a European Sample Curation Facility** (ESCF) [designed to curate precious samples returned from Solar System exploration missions to extra-terrestrial bodies (including Mars)].

*A **36 months project** focused on six key themes:

- Curation of extraterrestrial materials
- Planetary Protection
- Infrastructure requirements
- Instruments and methods for sample handling, preparation, and analysis
- Analogue samples (proxies for extraterrestrial materials)
- Technologies for sample reception and transport

Some issues and questions?

Designing an ESCF raises a lot of issues and questions:

*What are the best conditions to curate samples from Mars to keep them as pristine as possible?

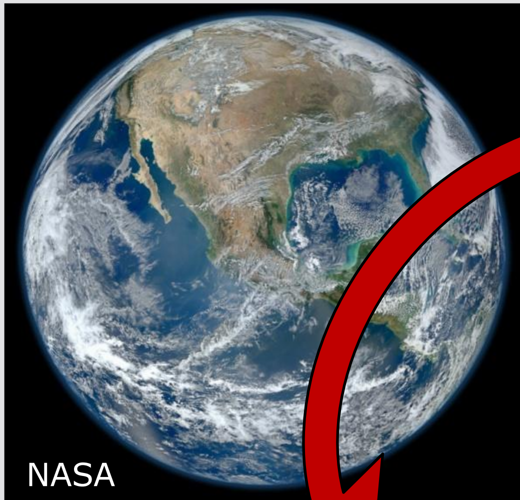
*What kind of tests, destructive or not, have to be conducted to assess the presence of (potentially harmful living) extraterrestrial organisms in the returned samples?

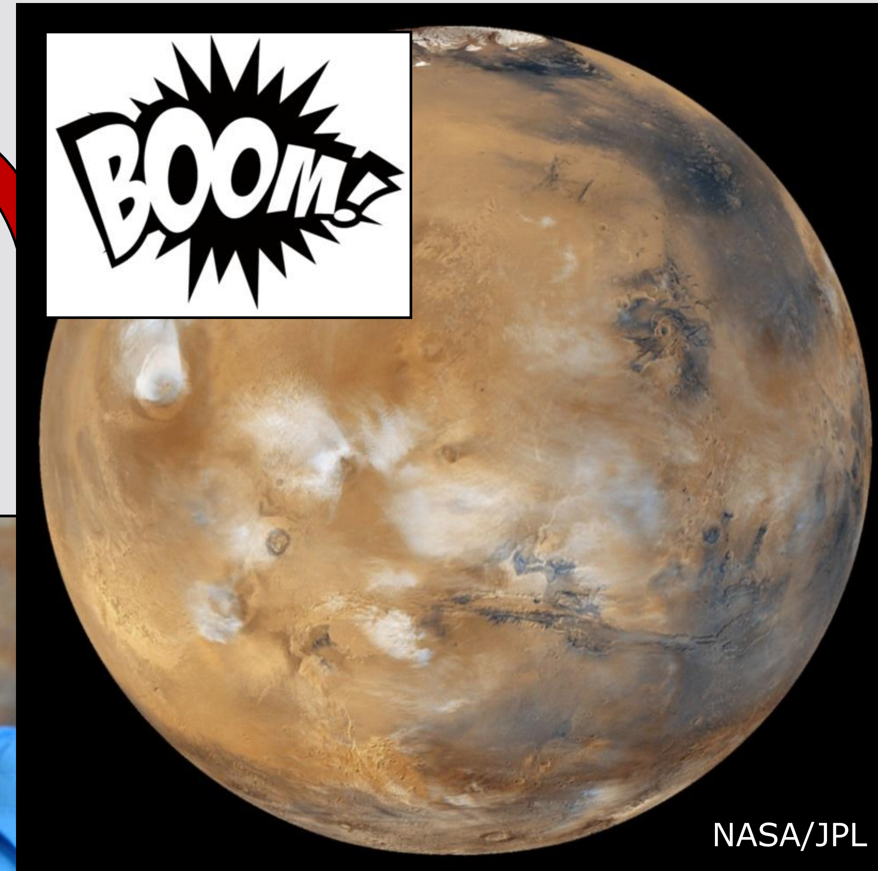
*How much of the limited amount of available samples versus analog materials should be used for these tests to obtain reliable results?

If there is "life" in the samples, should they be sterilized to allow sample distribution to the scientific community, or should (all) the investigations be conducted inside the ESCF?

We are looking forward to the input and expertise of all interested persons!

Martian meteorites





From Mars, ejected by the impact of an asteroid or a comet before to land on Earth…

Martian meteorites

THE METEORITICAL SOCIETY
International Society for Meteoritics and Planetary Science

LUNAR AND PLANETARY INSTITUTE

MetSoc Home | Publications | Search Meteorites

Search the Meteoritical Bulletin Database

Last update: 22 Oct 2015

Search for: Names / Text / Places / Classes

Search type: Contains / Starts with / Exact / Sounds like

Search limits: All countries / Martian meteorites / NonAntarctic / Falls / Has photo

Display: Link to Google Earth / Sort by name / 50 lines/page / Normal table / Limit to approved meteorite names

Publication: All bulls

What's new in the last: (no time limit)

Search text: * | Search! | Reset

157 records found for meteorites (Martian meteorites) with names that contain "*"

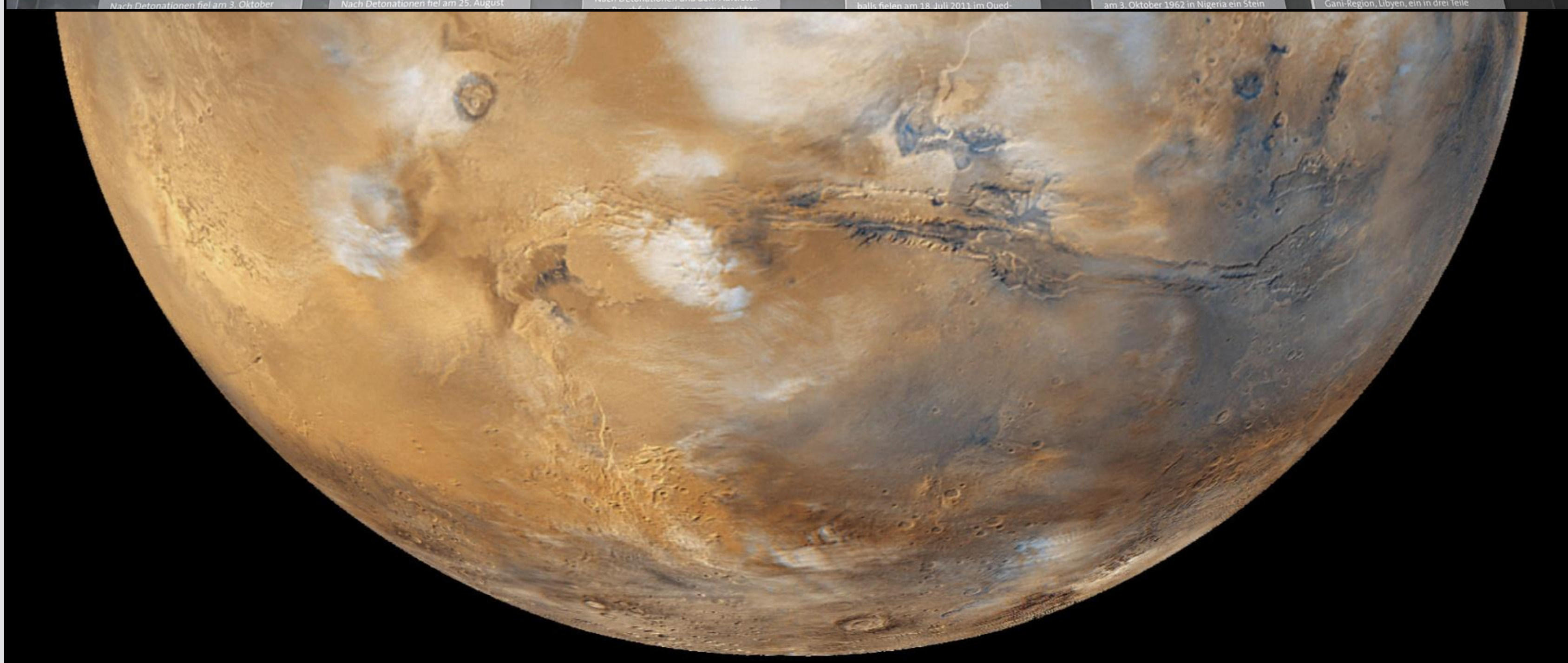
(click on a name for more information; click in header to sort)

Showing data for page 1 of 4: records 1 - 50

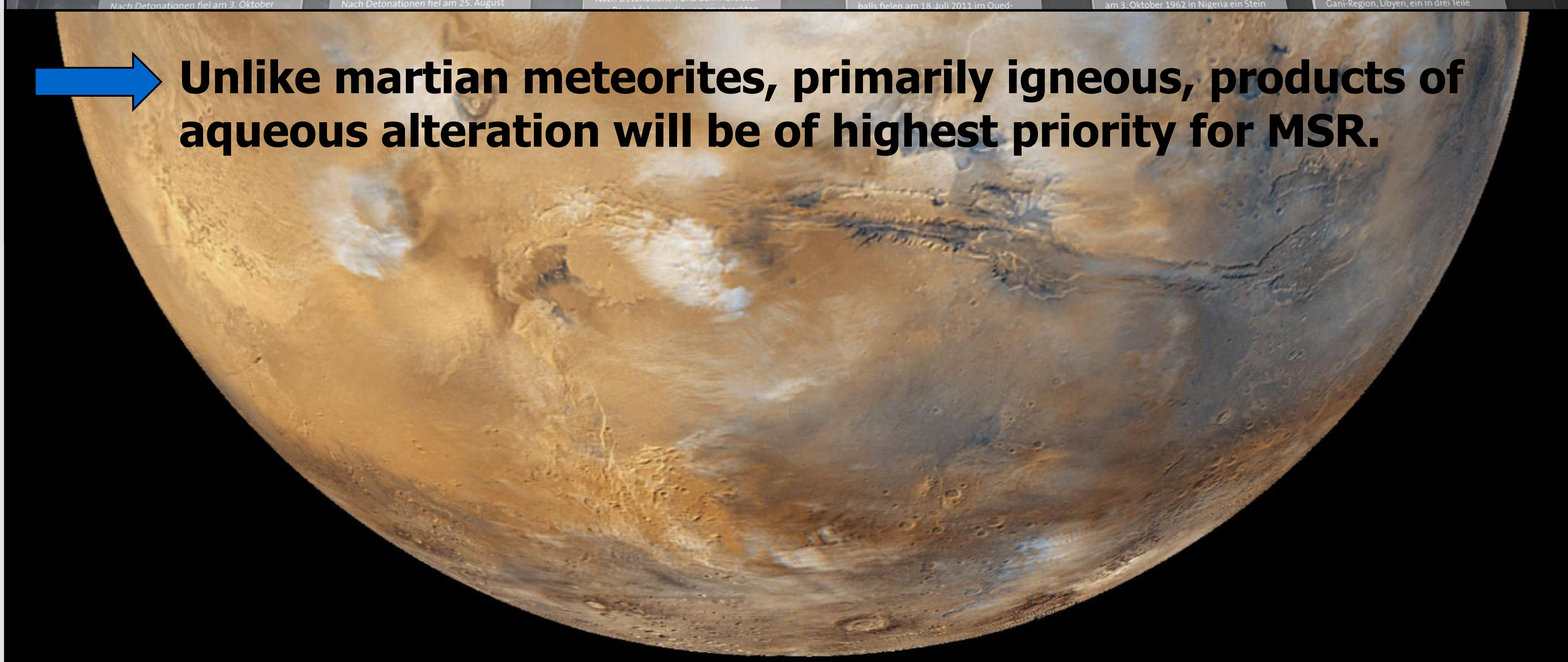
Select page: (1 2 3 4) Next page

Name	Abbrev	Status	Fall	Year	Place	Type	Mass	MetBull	Antarctic
Allan Hills A77005 **	ALHA77005	Official		1977	Antarctica	Martian (shergottite)	483 g	76	4(1) ANS-NIPR
Allan Hills 84001 **	ALH 84001	Official		1984	Antarctica	Martian (OPX)	1931 g	76	16(3) ANSMET
Chassigny		Official	Y	1815	Champagne-Ardenne, France	Martian (chassignite)	4 kg		

Martian meteorites



Martian meteorites



Unlike martian meteorites, primarily igneous, products of aqueous alteration will be of highest priority for MSR.

Previous studies of a Mars sample receiving facility

Townsend (1990)

JSC-24736

MARS SAMPLE RECEIVING FACILITY

Conceptual Design
Initial Processing
Contamination Control and Biological Containment

Prepared by:

JAMES E. TOWNSEND
SOLAR SYSTEM EXPLOR

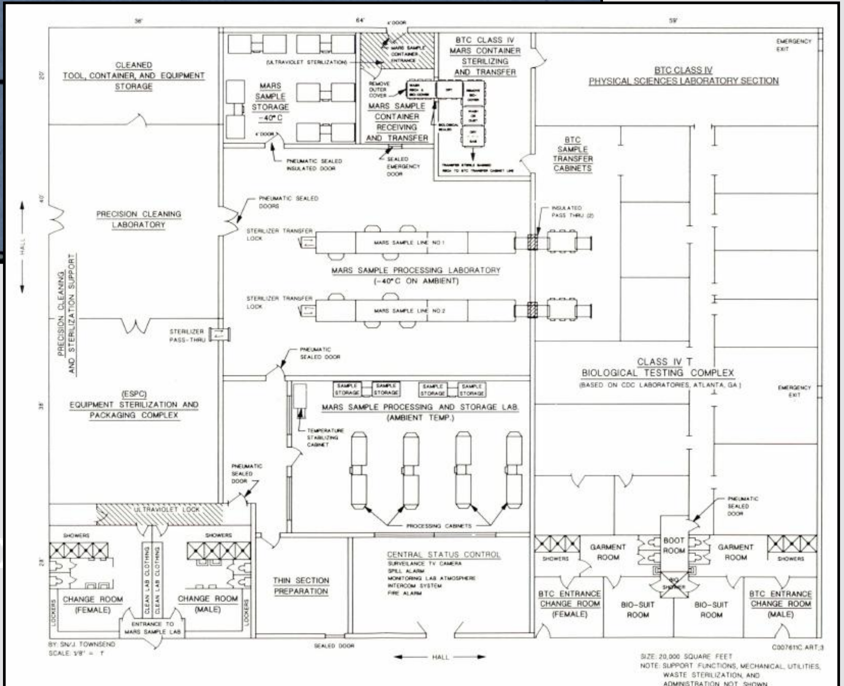


Figure 1 MARS SAMPLE RECEIVING FACILITY CONCEPTUAL DRAWING AND BIOLOGICAL TESTING COMPLEX

esa

Feasibility Study for a
European
Mars Sample Receiving Facility

Dr. Peter Mani

tecr!sk

December 4, 2004

Mani (2004)

Previous studies of a Mars sample receiving facility

Mars sample return curation, planetary protection, and the science perspective
L. Ferrière, NHM Vienna (Austria)

ASTROBIOLOGY
Volume 9, Number 8, 2009

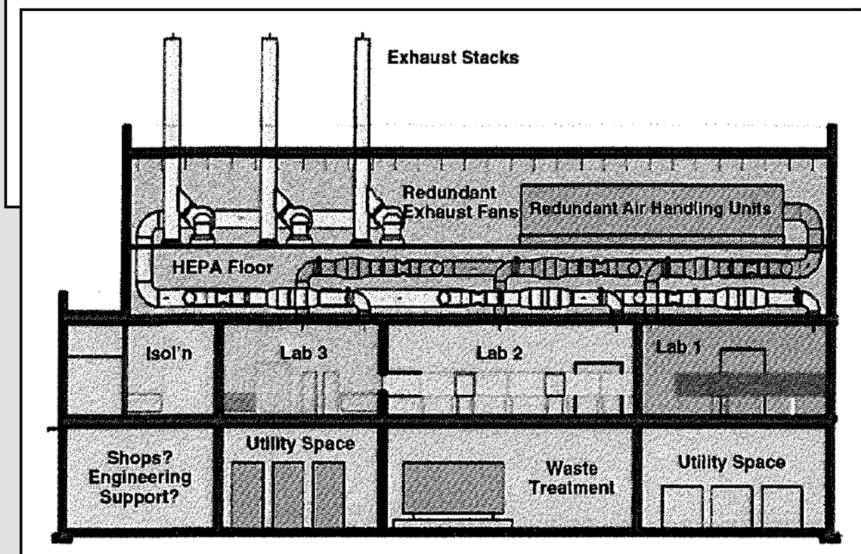
DOI: 10.1089/ast.2009.0339

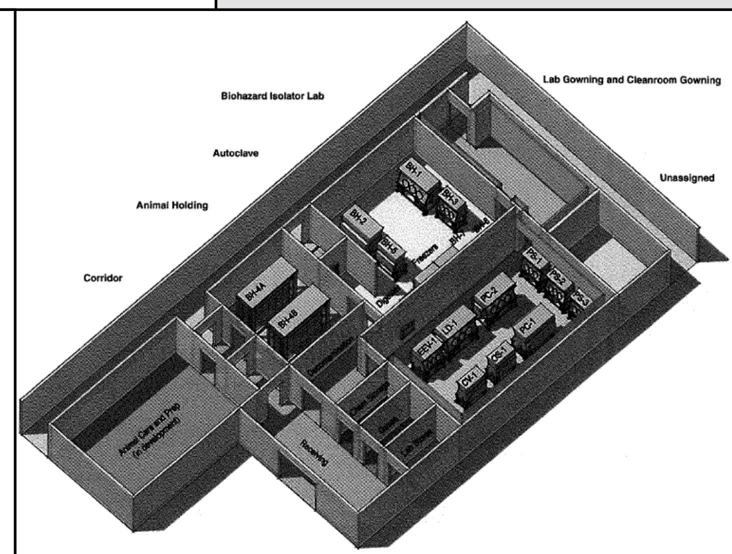
Research Article

Planning Considerations for a Mars Sample Receiving Facility: Summary and Interpretation of Three Design Studies

David W. Beaty,[1] Carlton C. Allen,[2] Deborah S. Bass,[1] Karen L. Buxbaum,[1] James K. Campbell,[1,*] David J. Lindstrom,[3] Sylvia L. Miller,[1,*] and Dimitri A. Papanastassiou[4]

Beaty et al. (2009)





Most of the technology needed to design and construct an MSRF already exists in the biosafety, pharmaceutical, and sample curation communities.

How is EURO-CARES different ?

- **Not country-specific**
- **Not mission-specific**
- **Samples with AND without biohazards**

Contents lists available at ScienceDirect

Chemie der Erde

journal homepage: www.elsevier.de/chemer

Invited review

Curating NASA's extraterrestrial samples—Past, present, and future

Carlton Allen (Astromaterials Curator)*, Judith Allton (Genesis Sample Curator), Gary Lofgren (Lunar Sample Curator), Kevin Righter (Antarctic Meteorite Curator), Michael Zolensky (Cosmic Dust and Stardust Sample Curator)

Astromaterials Research and Exploration Science Directorate, NA

ARTICLE INFO

Article history:
Received 18 August 2010

The Meteoritical Society

Meteoritics & Planetary Science 49, Nr 2, 135–153 (2014)
doi: 10.1111/maps.12027

Hayabusa-returned sample curation in the Planetary Material Sample Curation Facility of JAXA

Toru YADA[1,2*], Akio FUJIMURA[2], Masanao ABE[1,2], Tomoki NAKAMURA[3], Takaaki NOGUCHI[4], Ryuji OKAZAKI[5], Keisuke NAGAO[6], Yukihiro ISHIBASHI[1], Kei SHIRAI[1], Michael E. ZOLENSKY[7], Scott SANDFORD[8], Tatsuaki OKADA[1,2], Masayuki UESUGI[1], Yuzuru KAROUJI[1], Maho OGAWA[9], Shogo YAKAME[9], Munetaka UENO[2], Toshifumi MUKAI[10], Makoto YOSHIKAWA[2,1], and Junichiro KAWAGUCHI[1]

What are the “main/basic” functions of the facility?

*To **receive** the samples

*To **test** and determine whether the samples are hazardous

*To **document and to characterize** the samples (to be conducted by a broadly multidisciplinary science team inside the facility)

*To **prepare and to distribute** the samples (for research works to be conducted outside the facility)

*To **store** the samples (and all information about the samples / database)

*???

Flexibility of the facility is important (with time things can evolve in a way or another…).

Building design of the facility

Infrastructure to be designed and constructed in order to:

1) prevent sample contamination and alteration on one hand

2) prevent potential biohazards from the sample on the other hand

=

A complex facility combining elements of both a clean room and a biohazard containment facility (ISO 4) – something that has never been built!

\+

Long-term (decades…) preservation and protection of the samples.

+

Public outreach

Conceptual design of facility

Several adjacent cleanrooms/laboratories, connected via airlocks:

(1) a receiving laboratory,

(2) a cleaning (and sterilization) room,

(3) an opening laboratory

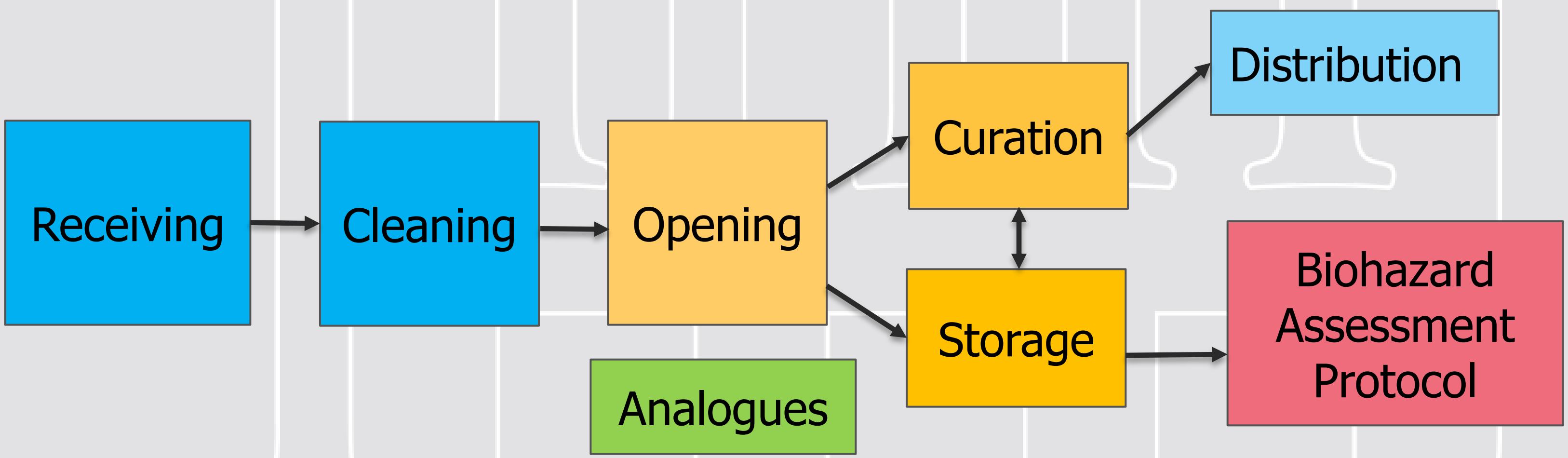
(4) a curation laboratory

(5) a containment lab for BAP assessment

(6) a storage (vault) room (with sealed containers).

+a specific lab for the analogues (preparation, testing, storage, etc.)?

+a specific lab to support instruments development and testing?



Conceptual design of facility

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L. Ferrière, NHM Vienna (Austria)

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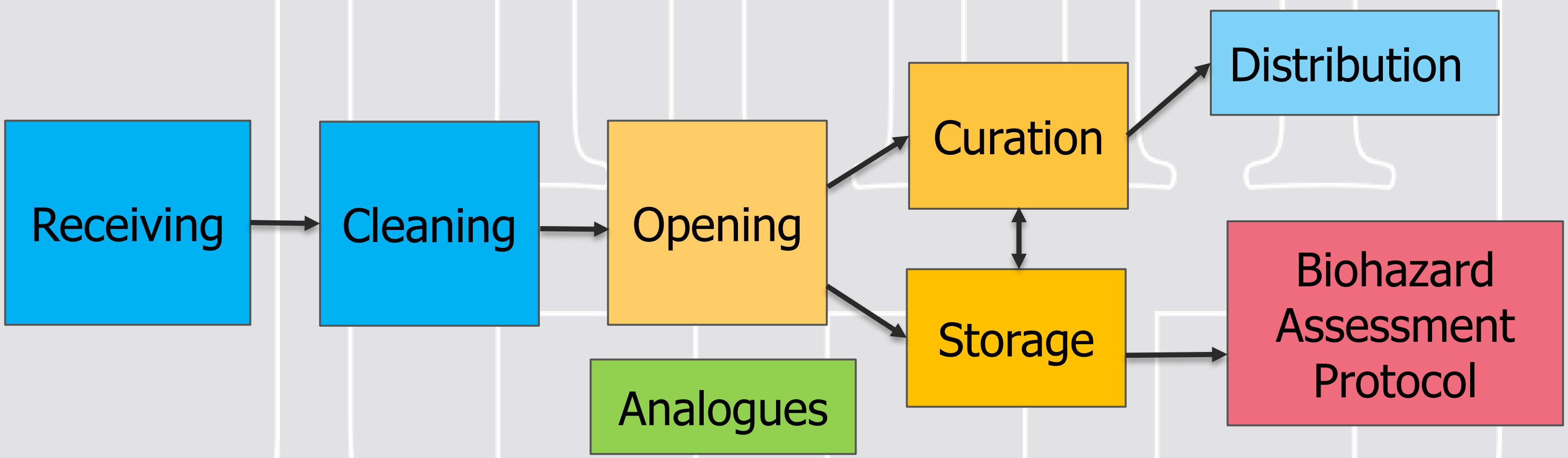
Mandatory for MSR:

Capabilities for life detection / biohazard determinations

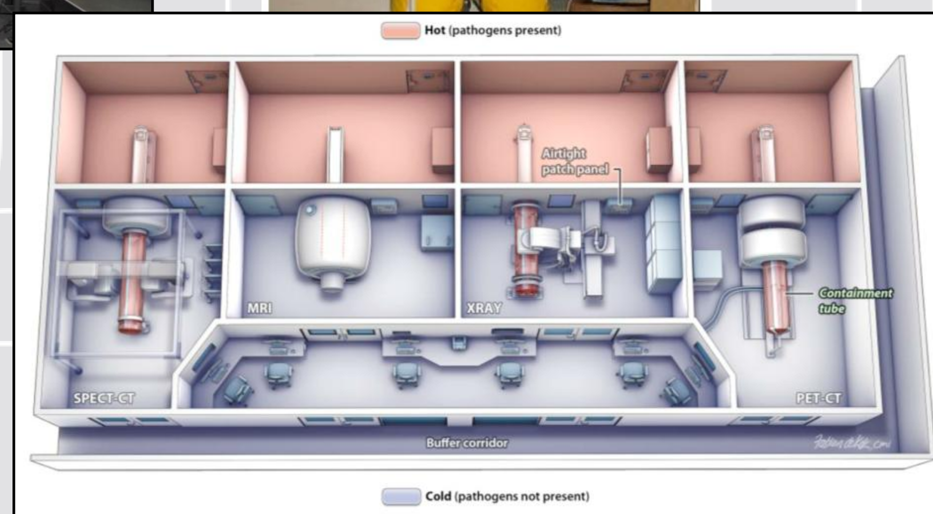


Cleanroom AND BSL-4

Two options:

*__Human handling__ (suit lab or cabinet lab) **and/or**

*__Robotics__ (Remote Manipulation or semi-autonomous robotics)



Requirements and Contamination control

Common requirements:

* HEPA filtrated air (in & out)

* air-handling system(s)

* pure nitrogen (or Ar) supply systems if necessary

* pressure control systems

* anti-static flooring and rounded corners

* Etc.

Contamination Control

* "Passive" control with positive pressure ante-rooms

* Double-walled isolators

Handling of the samples

Sample handling cabinets

*Equipped with air lock(s) to be able to introduce diverse tools, containers, etc. without breaking the environment inside the cabinets.

*Ultraviolet neutralization lamps and/or alpha-ray neutralizer of ^{210}Po radioactive source, to compensate electrostatic charging.

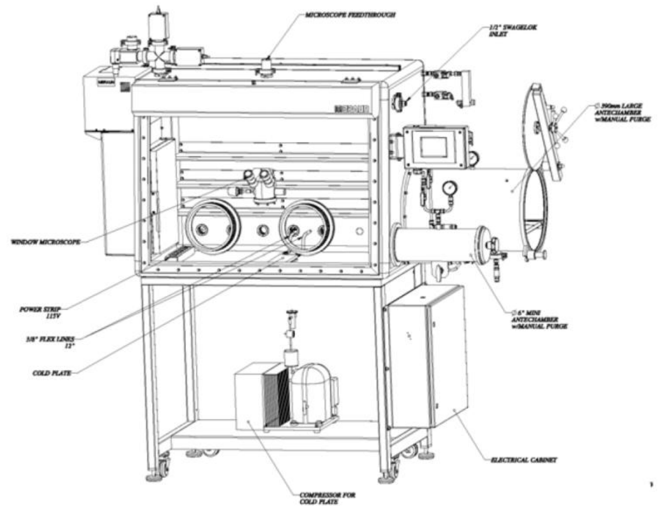


Figure 1: Glovebox design by MBraun, Inc. System includes -35°C freezer, -35°C cold plate, microscope, electrical connections, penetrations for gaseous nitrogen supply and exhaust, spare penetrations for future utilities and monitoring system to display and record nitrogen and temperature parameters.

Double-walled isolators

Materials to be used (or not)

Short list of accepted materials:

*stainless steel (304 and 316)

*pure aluminum and specific aluminum alloy

*quartz glass

*polytetrafluoroethylene (PTFE)

+ Viton (in case of Viton gloves cabinets)

Non accepted/authorized materials or to be avoided:

- Plastic
- Silicones & lubricants (robotics,…)
- Organic compounds (paint,…)

Low potential of contamination (outgassing, dust…) OR simple composition

Safety and Security

Accidents happen in even the best facilities!

All necessary safety measures should be taken to prevent a catastrophe, whether natural or man-made, to protect not only the samples, but also the staff and local population.

To be considered are:

*Fire

*Storm

*Flooding

*Earthquake

*Electricity failure

*Vandalism / Human error

*"Political stability" of the country

A remote storage is necessary (in a distinct country).

Also to be considered…

Timing:

The planning of the facility design needs to start **as early as possible** (i.e. several years before the planned return sample date), ideally to finish the building at very least **two years before any sample return**, to have enough time to properly test the facility on analogue samples, to develop and validate procedures, and to train a dedicated multidisciplinary team.

Other issues to consider:

*Legislation & policy

*Maintenance and operation

*Location of the main facility + remote storage

*Feasibility, cost estimation, and timescales

*…

Storage of the samples

The facility will have to operate at controlled pressure, temperature and atmospheric environment (especially the relative humidity) [all these parameters should be carefully monitored and recorded].

At least three types of sample storages will have to be considered:
(1) "unopened storage", for unprocessed samples,
(2) "working storage", for processed samples (designated for study and loan to other laboratories, etc.),
(3) "readmitted storage", for samples that have been studied in other laboratories and returned to the facility.

Examples of storages

Specific aspects to be considered

*Most appropriate conditions for samples storage

- P, T (cold curation to be considered…), magnetic fields, gas composition,…
- Witness coupons for contamination monitoring and recording

*Different sizes of samples

*Different sample types (rock, soil, ice, gas, etc.)

What are we storing?

What are the constraints?

Curation

<u>Definition</u>: Collection, handling, documentation, preparation, preservation ("into the indefinite future"), and distribution of (a limited amount of) samples for research.

Curator(s) should already be consulted during the mission design:

*__expert of the samples__ to be collected

*to **help in designing the "sampling device(s)"**

*to insure proper **monitoring of the contamination**

The collected and curated **samples have a unique (and distinct) history and come from different environments**.

The samples present **specific and unique challenges for appropriate curation**.

Initial processing and characterization (/documentation) of the samples should be conducted, including:

*naming (a sample ID is given to each sample)

*photographing (such as basic 2D digital photographs and 3D laser scans)

*weighing

*description of the samples (size, color, etc.)

*….

These data are directly entered in a specifically designed **electronic database**.

A large number of additional information will also be stored in the database, including the history of the sample (transfer dates, name of the operator(s), type of manipulation, comments, etc.).

Curation

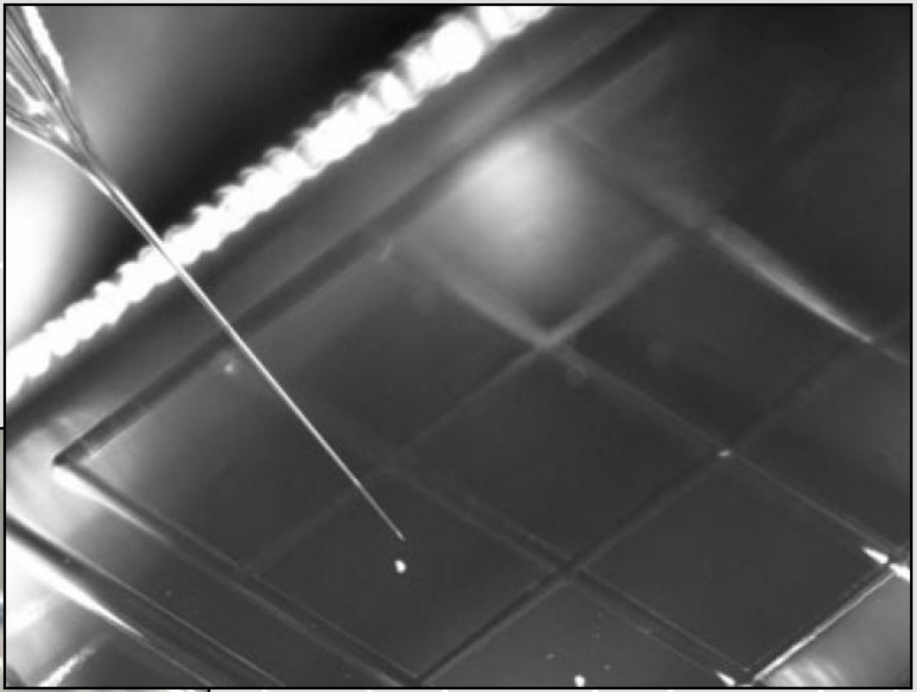
Preliminary examination using different methods such as X-ray microtomography, (field-emission) scanning electron microscopy (SEM; equipped with focused ion beam [FIB]), X-ray fluorescence, microRaman spectroscopy, etc. should be envisaged.

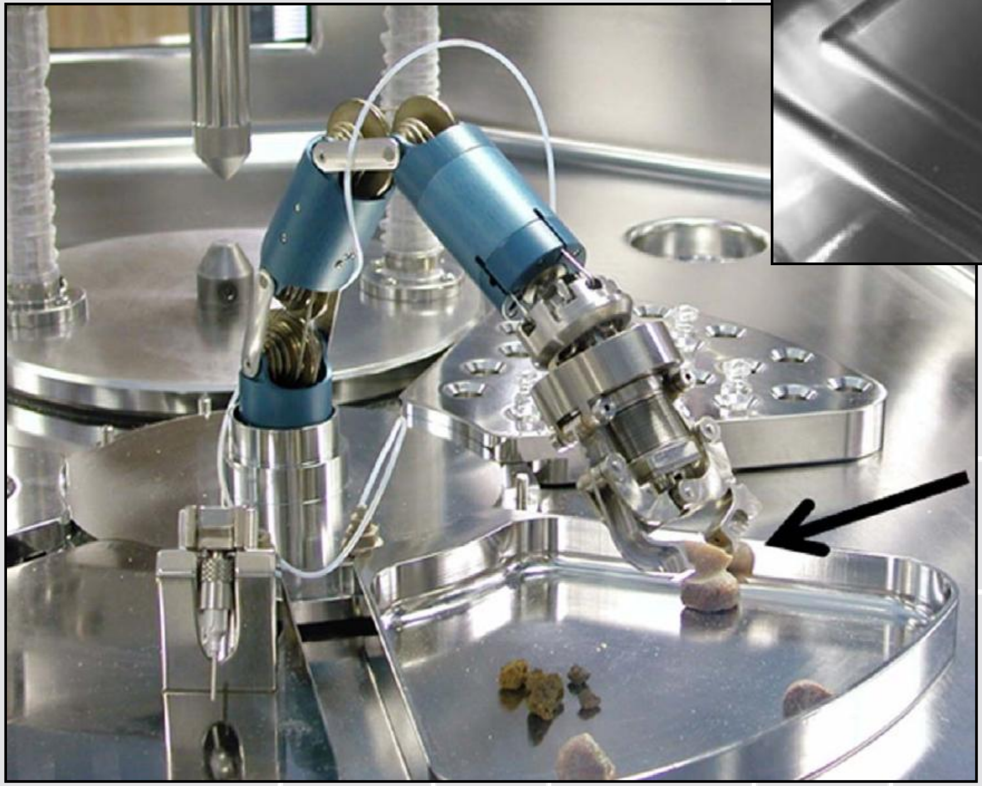
The extent of the preliminary examination (to be completed within the facility) will have to be discussed and defined in accordance with requirements from the scientific community.

Should we locate the facility close to already existing state of the art laboratories?

Manipulation of the samples

Optical tweezers?
(single-beam gradient force trap)





Preparation of the samples:

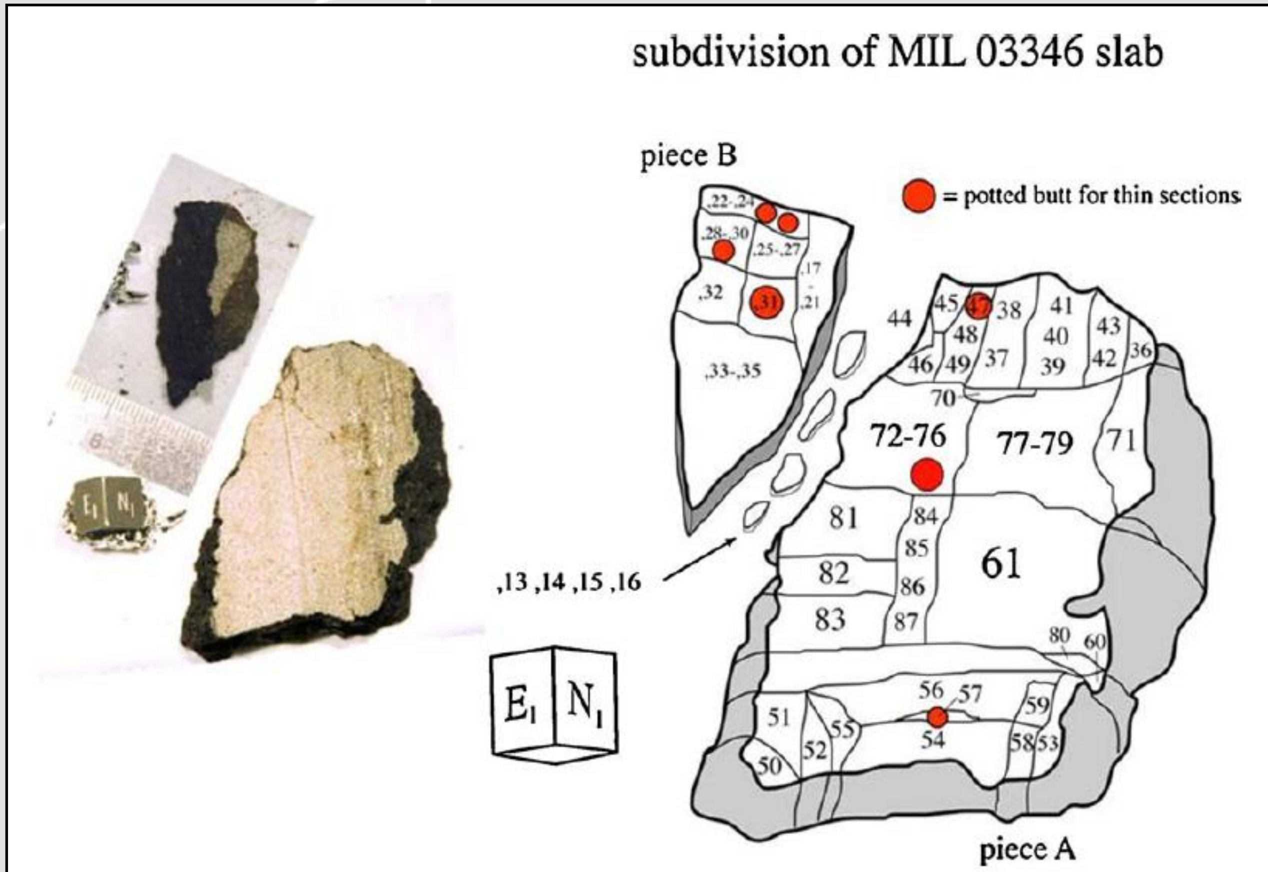
Subdivision of the samples to be done using e.g., precision-cleaned hand tools, ultrathinning techniques, or using a bandsaw (i.e., dry cutting; knowing that in this case the friction and induced increase of temperature will likely affect and, to some extent, alter the sample).

Small particles can be separated either by hand picking with tweezers, micromanipulators, or by dry sieving.

Special sample preparations, such as mounted samples, (thin) sections, FIB foils, etc. will have to be prepared; new techniques of samples preparation will have to be envisaged following requirements from the researchers community.

Documentation of the samples:

New generated (sub-)samples will have to be properly named and documented.



Main issues to be further investigated

Should the facility be based on the principle of a suit lab, or a cabinet lab, or both?

Should the samples be manipulated by humans and/or robots? *In both cases a need of a significant technological advance over the methods currently used is evident.*

What storage environment should be chosen (P, T, and specific atmosphere composition)? *Sampling and especially storing gas and all other adsorbed volatiles, preserving ice and temperature-sensitive mineral phases and dealing with samples that may contain traces of extraterrestrial organic material or prove to be biohazards will be a big challenge.*

New approaches of samples curation and storage will have to be developed…

MSR have strict planetary protection protocols!

Legal basis lies in Article IX of the Outer Space Treaty from 1967.

Martian samples must be contained and treated as potentially biologically hazardous until they are declared safe by applying recommended protocols, including rigorous physical and chemical characterization, life detection analyses, and biohazard testing (National Research Council 2009).

Containment of samples prior to release to the general scientific community may be significantly protracted.

One of the most critical issue is to avoid the “stuck in containment”.

Planetary protection

The probability that a single unsterilized particle of 0,01 µm diameter or greater is released into the Earth's environment shall be less than 10^{-6} (Ammann et al., 2012).

In line with planetary protection baseline, the facility will have to:
*contain areas with different biological safety containment levels
*contain areas with different contamination control levels
*to accommodate not only the samples returned from Mars but also the associated flight hardware.

Should we continue to put so much efforts (and money) into "planetary protection" and continue inhibiting science and new discoveries?

Interface between science desires and planetary protection will need to be carefully managed.

Science perspective

Whether there is or was life on Mars has been one of the most pivotal question since the first telescopic observations of Mars.

Life can be found virtually everywhere on Earth, thus the potential for contaminating the Mars samples and compromising their scientific integrity is not negligible.

How will samples be allocated to scientists?

Which, if any, sub-samples should be sterilized?

What proportion of samples should be left untouched?

…

SAVE THE DATE !

14-15 April, 2016
NHM Vienna

Questions?

Importantly, a waste sterilization system should be planned to be able to sterilize both liquid and solid waste products prior to release them in the environment.