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EURO-CARES: A Plan for European Curation of Returned Extraterrestrial Samples

WP1 Literature Review for WP6: Sample Transport/Portable Receiving Technologies

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1. INTRODUCTION

1.1 Aims and Objectives

Objectives: to propose methods for recovery and transport of Mars Moon or asteroid samples from the landing site to the curatorial facility.

This study consists of a detailed literature review and knowledge capture exercise for Portable Receiving Technologies. The status, mission architecture and science objectives of potential sample return missions to asteroids, the Moon and Mars. A preliminary report will be generated for each theme highlighting the requirements and important information identified during the knowledge capture.

Specific Objectives of the work will be:
• To determine what information and procedures are necessary for preparation for recovery of the sample
• To assess what tasks and facilities are necessary for recovery and initial inspection of the sample
• To determine how the procedures for recovery to be used will differ in the case of i) Mars samples (which contain the risk of biohazard) and ii) Lunar/asteroid samples including ice-bearing ones.
• To provide a concept for the transport of the sample to the curation facility
• To outline needs for innovation, particularly in terms of portable receiving facilities and transport
• Assess legal issues & public concerns associated with the transport of potentially hazardous sample containers.

1.2 WP6 Portable Receiving technologies description

The objective of this work package is to propose methods for the recovery and transport of Mars or Lunar/asteroid samples from the landing site to the permanent curatorial facility. The Earth re-entry capsule from a sample return mission will be targeted at a specific landing ellipse on the Earth, possibly a considerable distance from the curatorial facility. Before the capsule arrives, considerable preparations for the recovery need to be made. Once the capsule has landed, an assessment of the state of the spacecraft will lead to a recommended recovery procedure. The sample will then be transported to a permanent curatorial facility using a safe and secure method. This is covered in Figure 6-1.

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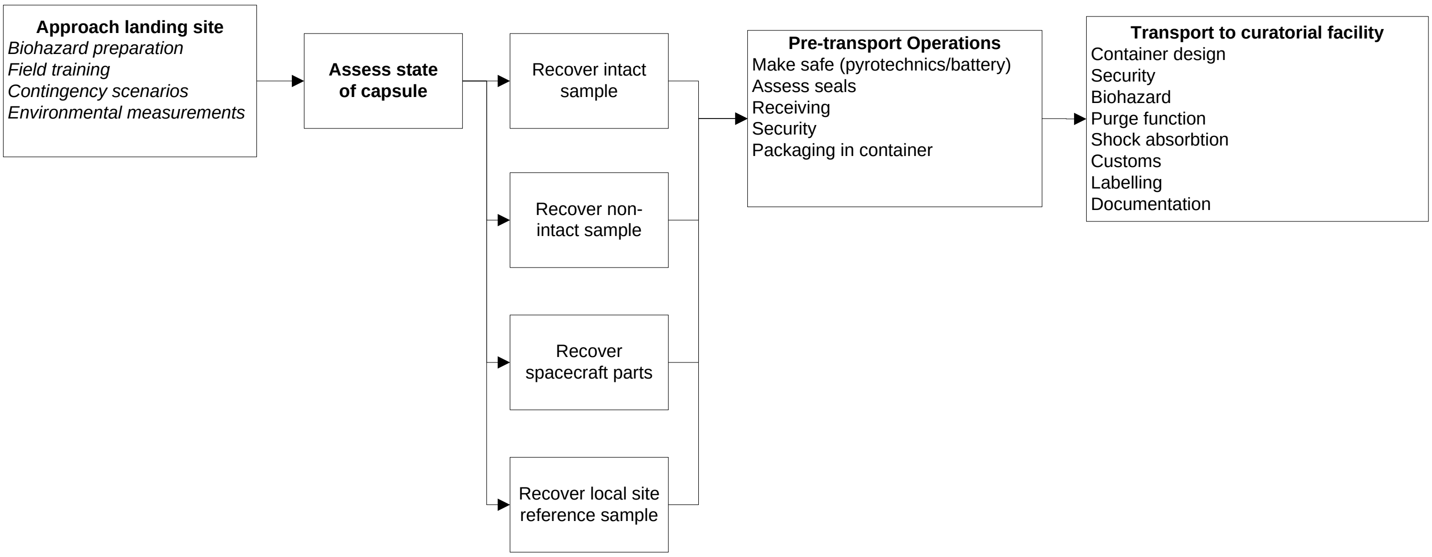

Figure 1-1 Flow diagram to show recovery of sample return capsule to curatorial facility

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2. REVIEW OF PREVIOUS SPACECRAFT SAMPLE RETURN RECOVERIES

2.1 Genesis

The Genesis Return Capsule, bearing the science canister with collected solar wind samples, returned to Earth in 2004. Following a flawless, on-target re-entry the parachutes failed to deploy due to a set of incorrectly oriented deceleration sensors. The spacecraft impacted the landing site – in the Utah Test and Training Range (UTTR) – at a speed above 86 m/s and was badly damaged (Fig. xx). Most of the fragile collectors were fractured and all were contaminated on the surface by debris from the spacecraft and the landing site. A dedicated team of spacecraft engineers and curators immediately went to work to recover the broken spacecraft and move it to a temporary cleanroom at UTTR, where they painstakingly packaged and cataloged thousands of spacecraft parts and collector fragments. These were transported to the Genesis Curation Laboratory at JSC for cleaning, documentation, storage, and allocation. It is believed that all of the collector materials were recovered.

Figure 2-1 : Genesis capsule recovery (Image credit : NASA)

2.2 Stardust

The Stardust Sample Return Capsule (SRC) was released from the mother spacecraft, and parachuted to Earth at UTTR in the early morning hours on January 15, 2006 (Fig. 15). A significant problem during the recovery was that the SRC landed upside down, which severely limited the usefulness of the recovery beacon. Once on the ground, the Stardust SRC was recovered by a team of curators and spacecraft engineers within 2 h, and was moved to a class 10,000 (ISO class 7) modular cleanroom located in a facility close to UTTR for preliminary processing (Zolensky et al 2008). The science canister was removed and secured in a clean transport container in this facility. A significant recovery flaw was that the SRC was placed into a polyethylene bag for several hours, and outgassing from this bag contaminated the aerogel capture media with several organic molecules (Sandford et al., 2006, 2010). Following the preliminary processing, the SRC was placed into a dry nitrogen environment and flown to the

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Stardust Laboratory at JSC in a specially chartered plane. The Stardust Science Team used a class 100 (ISO class 5) cleanroom at JSC for preliminary examination and curation of the returned samples Logistics associated with receiving these samples required careful planning and coordination with JSC Receiving, Security, Safety, Quality Assurance, Photography, and Curation. The samples received a police escort from Houston's Ellington Airport to the curation facility at JSC (Zolensky et al 2008).

Fig. 2-2. Stardust sample return capsule at Utah Test and Training Range recovery site.

2.3 Hayabusa-1

Following a series of propulsion, communication, and control failures, the spacecraft successfully returned to Earth in June 2010. The return capsule was predicted to land in a 20 km by 200 km area in the Woomera Prohibited Area, South Australia (Figure 2-3).. Four ground teams surrounded this area and located the re-entry capsule by optical observation and a radio beacon. Then a team on board a helicopter was dispatched. They located the capsule and recorded its position with GPS. Following ensuring that batteries used with EDL were safe and disconnected, the capsule was placed into a container with a nitrogen atmosphere, for transportation, initially to a temporary facility in South Australia.JAXA built and equipped a main laboratory in Sagamihara, Japan to carry out the external cleaning and de-integration of the recovered spacecraft, sample extraction and preliminary examination, and sample curation for the Hayabusa mission. .This is the first non-NASA or Soviet facility for curation of samples returned from space.

The returned hardware was planned to include one sample of ~100 g, but due to the failure of the sampling system, only ~1500 grains of asteroid material were recovered. These are still immensely valuable scientifically, and were recovered from the sample container on an individual basis. Contingency facility operations were needed where micromanipulation was used to sort genuine asteroid particles from contamination particles.

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Figure 2-3 : Hayabusa sample return capsule after landing in Australia (Left) and Hayabusa sample container prior to opening (right) Image credit : JAXA

2.4 Osiris-REX (NASA)

OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer) is a NASA mission slated for launch in 2016 to encounter and sample Asteroid (101955) 1999 RQ36 and return ~60g back to Earth. The sampling is based on a "Touch-and-go" method that will retrieve sample directly off the surface in a single collector (Figure xx) and return it to Earth in a return capsule similar to that used by the Stardust mission.

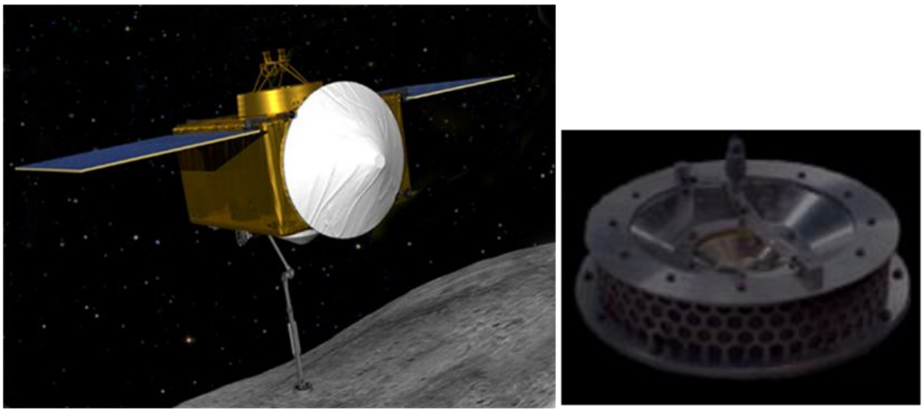

Figure 2-4 : OSIRIS REx spacecraft sampling an Asteroid and TAGSAM sample collector (Credit: NASA/GSFC/UA)

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3. CURRENT DESIGNS FOR MARS SAMPLE RETURN MISSIONS

The current MSR mission scenario has an 'Earth Return Capsule' (ERC) which performs a hard landing at a sparsely occupied location on Earth. Inside the ERC is a biocontainer (BC). Inside the Biocontainer is a Sample Container (SC) and inside this are the Sample Vessels (SV). The exact amount of sample and number of sample vessels is subject to change.

The outside of the hardware down as far as the biocontainer (BC) (see *Figure **3**-**1***) is considered to be Earth contaminated during landing and so high level contamination protection are in theory not needed. However if the ERC is breached or damaged in some way, contingency measures may need to be in place.

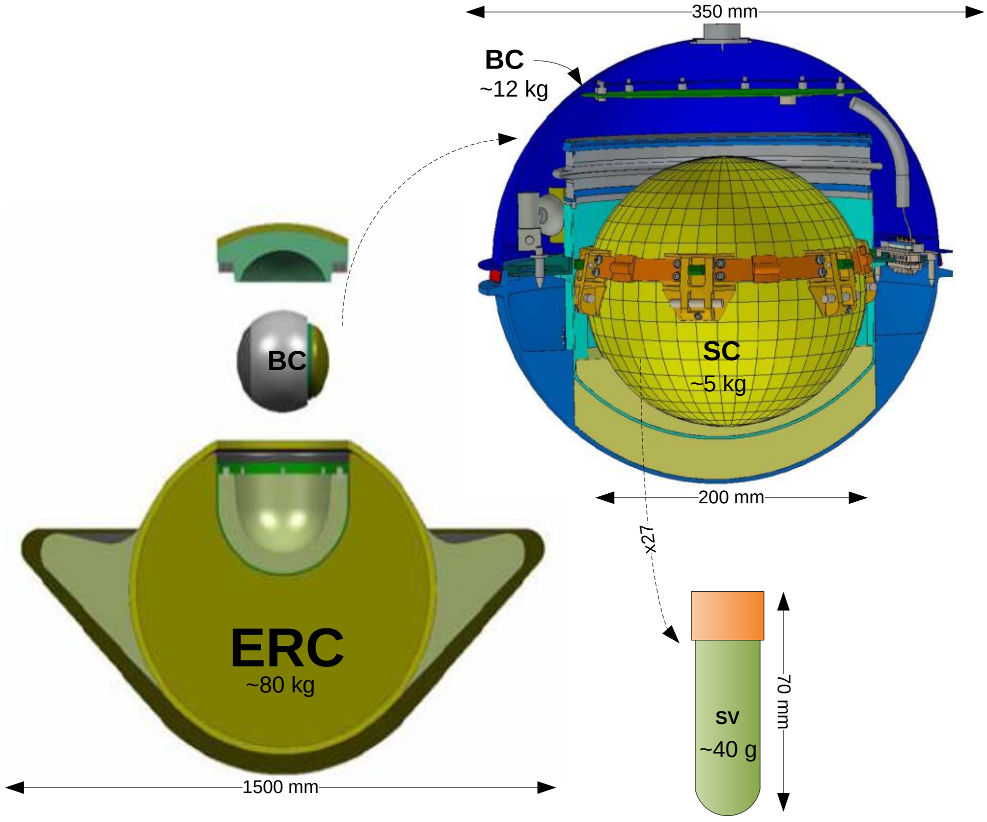

Figure 3-1 : BioSMoS (Bio-Sealing and Monitoring Technologies for Sample Containers) Concept

As a comparison it is useful to look at the Life Marker Chip project sample chamber (SPS). Meeting the PP requirements of category IV missions, the SPS was designed to accept a small sample (approx. 1cm^3) through a 5 mm aperture into a sealed and sterile Ti chamber. The flight representative model in the fig below is not ideal for a MSR sample; however, it serves to illustrate the engineering constraints of such a chamber (Figure 3-2).

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Figure 3-2 : University of Leicester Life Marker Chip Sample Processing Chamber

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4. PREPARATION FOR RECOVERY

4.1 Introduction

A landing site is ultimately dictated by orbital mechanics, spacecraft design and the mission architecture. By comparison with missions like Genesis, Stardust, Hayabusa and Osiris-REX, mass and physical size is likely to be very different. Hayabusa, for example, was designed to return a single sample of approximately 100g, which in turn, dictated the service requirements and hence, volume of the landing component. NASA's Mars2020 mission is currently being designed as the first stage of a MSR mission where a subsequent retrieval lander / spacecraft will collect its cached samples. (Obj C of the Mars2020 SDT Report). For this reason, an estimate of sample size is based on these mission requirements. Section 6.2.3.1 of the SDT defines a total sample mass of 500 g divided over approximately 31 individual samples, which gives a sample mass of between 15 to 16 g each. It is also assumed that a sample may contain rock cores, regolith, ice, brine and gas.

In particular, MSR will represent a considerable investment with each sample having a substantial dollar value per gram of material. Risk management, from the point of view of sample integrity, will therefore influence the design of the sample container sub-system. Additionally, the number of discrete sample containers and the engineering requirements for each sample will ultimately dictate the mass of the Earth landed component. The sample return capsule of Genesis had a total mass of 225 kg and failed to land successfully, due to incorrect operation of accelerometers. This strongly suggests that that for a complex mission, such as MSR, the landed component is unlike any previous return mission and perhaps closer in design to a Soyuz type module.

4.2 Landing site

In terms of a landing site, the final selection will be driven by both the scientific requirements of the samples and the small risk of backward contamination of the immediate area. As discussed above, the return capsule of a MSR mission is likely to be larger than any previous return programme and will limit landing sites. Not considering the energy / orbital constraints of a Mars to Earth return spacecraft, there are two main considerations in terms of a landing site.

Security of the site (inc. contingency for a failed landing)
Accessibility of the site, in particular if specialist recovery vehicles are required

It is conceivable that NASA might use components of its new Orion spacecraft to test capability in the return of samples. This being the case, many of the landing site issues, security, safety and risk in particular will have been resolved.

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4.3 Environmental conditions

Irrespective of the sample environment during the return journey, the ideal conditions to limit the risk, albeit very small, of any pathogen in a failed landing situation, is cold and dry. This will slow any chemical reaction rates with the local environment. From a sample integrity perspective, it will also be important to protect the samples from the local environment in the event that seals are compromised and cold dry desert type areas tend to be relatively sterile.

4.4 Assessment of the state of the capsule

The landing outcome will dictate two distinct management strategies.

- Successful landing
- Failed landing (not managed like an unplanned event)

Except for an obvious failed landing, protocols must assume that at least one seal is compromised until proven otherwise. (These protocols need to be assessed)

Due to the increased size and mass of MSR, it is not possible to simply pick up the module as might have been possible with missions like Hayabusa (mass 18kg). The restrictive nature of working in a BSL4 suite must also be considered as a limiting factor, both in terms of time, cost and capability. Therefore, it is strongly suggested that any return module be fitted with a post landing EGSE connecting interface such that certain parameters (e.g. seal integrity) can be checked and monitored. This facility enables situation management; for example, if seals are all determined to be satisfactory, recovery might continue with reduced bio-safety protocols.

4.4.1 Integrity of Seal

As stated in the 2009 NASA Assessment of Planetary Protection Requirements for Mars Sample Return Missions; "…a critical issue …concerns the means by which those charged with implementing a Mars Sample return mission can demonstrate the integrity of the canister's seal."

Seals largely fall into two main types; static (examples being an O ring or metal gasket) or dynamic (an example being a lip seal). Static seals tend to be used where there is a requirement to provide a physical barrier between relatively non-moving interfaces such that the physical content of each side are kept separate. Interaction may still occur in some circumstances if the respective environmental conditions, a temperature gradient for example, are transmitted through the seal medium; which also has to be a design consideration. Dynamic seals differ in that they provide the same isolating function as a static seal, but are required to permit relative motion between the seal and the sealing surface interface. However, dynamic seals often utilise a lubricating fluid film between the seal elastomer and the sealing surface to reduce friction (typically <0.5µm). Lubricating films cannot be used in a MSR seal.

It seems likely, that the planetary protection requirements of any MSR container will require a combination of both static and dynamic sealing techniques, which in turn, drive the engineering requirements of that container. Of particular concern is the material selection, which is criterial both in terms of compatibility with the sample and the harsh environments of Mars, interplanetary (radiation effects on the seals) transfer and landing (mechanical shock). Hence,

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scientific integrity of the sample and the environmental conditions will drive the design of the seals, which in turn, will have significant implication on the mass, volume and complexity of the sample chamber sub-system.

One study [Younse et al, 2012] discusses four different sealing technologies (Teflon plug, crimp, solder & shape memory alloy) in terms of power, some environmental conditions, tolerance to dust, shock, integrity of the sample, hermeticity, packaging, risk and autonomy. A Teflon plug appears to be the most promising solution. Teflon, also known as polytetrafluoroethylene, PTFE, is the subject of a recent NSTP-2 investigation (University of Leicester) that will consider a different design approach to that given by [Younse et al, 2012]. The use of PTFE to form the seal body is considered for several of its mechanical properties, in particular a low coefficient of friction. Low van der Waals forces make the surface inert, due to the very strong carbon-fluorine bonds and therefore non-reactive to most other compounds. PTFE is also very hydrophobic, which prevents wetting by water and water based chemistry, an advantage if this technology was adopted in a "wet" chemistry application. However, a drawback of PTFE is the phenomena of creep (cold flow) where applied stress (force acting on the material) causes plastic deformation of the material. This must be a design consideration when the seal geometry is considered.

A critical design feature of PTFE tip seals is the surface finish of the sample chamber. An elastomer seal is able to accommodate a "rough" surface by deforming into the surface voids. The elastic properties of PTFE are low and require a high point contact stress to achieve a good seal (force often provided by a spring). In a dry dynamic application, this high contact stress is offset by the low coefficient of friction and benefits from an almost "optical finish" on the sealing surface. This has the added benefit that microbial cleaning is easier to attain.

Scientific integrity of the sample is crucial in that both the sample chamber walls and the seal material must be inert to the sample for the duration of the mission, which could potentially be 10 years. Two materials are often considered for the chamber; titanium (as is used in the LMC [Sims, Cullen and Holt, 2012] sample chamber) and gold, which are required, with the right surface finish, to exhibit either none or low absorption of organics, particularly important if an ice / water / brine based sample is acquired. Gold alloys are common in the electronics industry and there has been considerable investigation of their mechanical applications in high reliability swipe contacts. Pure gold is generally inert to most environments but exhibits relatively poor wear performance, tending to gall under high contact stress conditions. "Hard" gold is an alloy including other elements like 0.7% cobalt or nickel and with appropriate thickness (to overcome porosity) can provide a hard wearing sealing surface when used with a nickel transition layer. L168 aluminium alloy, with its increased strength and hardness, compared to many Al alloys, needs to be compared to stainless steel in terms of forming a sealing surface and considered as the base metal for a gold plated sample chamber.

As part of this study, it will be necessary to conduct an FMECA of the sampling and process of sealing the sample based on a risk analysis of sealing technology and a typical MSR architecture. This will enable weak points in the sampling chain to be identified and recommendations to inform the detailed design, which in turn will influence recovery. For example, many sample chamber designs seem to be based on a process whereby the chamber

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is not fully sealed before the sample is deposited; particularly the carousel type designs where a push type seal is applied after [Backes et al, 2012, Zacny et al, 2011]. As a category V mission with the intention of identifying very low level potential organic biomarkers, it is crucial that the sample chamber is pristine at the point of sample delivery; this was a space agency requirement on ExoMars.

[Guest and Bridges, 2011], identifies explosive welding as a potential high integrity sealing technology to achieve the leak rates that will be required for MSR. Other technologies including brazed and soldered metallic rings might be used in conjunction with the PTFE seal to achieve the high level of hermeticity required.

4.4.2 Other damage

It is a requirement that chamber integrity is monitored during return journey and landing. This could be achieved with a leak detection configuration or pressure sensors in the chamber [6]; either technique would require the chamber to be back filled with an inert gas. If the landed module included an EGSE connector point, it would be possible to verify the seal integrity and potential damage after landing.

4.5 Special measures for biohazards

Any return of material from a mission to a planet thought capable of containing life would be carried out in such a way as to avoid uncontrolled release of a potential biohazard on impact with the earth. This would be a major requirement to protect the scientific purpose of the mission and also to prevent the potential release of extraterrestrial biohazards. Any uncontrolled release would be a low probability but high consequence occurrence. Therefore planning for non nominal returns which may lead to release of Martian material would be warranted and a precautionary approach would be taken

4.6 Planning for Non nominal return

Scenario planning will need to be carried out in order to identify the most effective way of dealing with a non-nominal return. The plans will need to take account of the following drivers

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- Protection of the environment from release of Martian material
- Public perception of an environmental release
- Protection of the science
- Environmental protection from the impact of any remediation exercise
- Safety of the remediation workers
- Financial

These drivers will not work in concert. For example, a potential option to inactivate Martian material may be to generate a high temperature fire in the surrounding area using air dropped incendiaries. This would help to protection the environment from Martian material, allay public concerns and protect workers but would destroy the science and potentially damage the environment

Remediation after incidents involving biohazardous agents can vary from minor use of disinfectants to the removal of material for incineration. The recently published UK Recovery Handbook for Biological Incidents provides a decision making framework for dealing with environment contamination with biohazardous material can be made taking in account various factors (Pottage et al (2014)

An agreed method for decontamination of a Martian life form would need to be agreed before any return. This will inform the response.

4.6.1 Initial Approach to Returned Container

Unless sensors are embedded in the return canister to detect leaks or loss of pressure it will be difficult to assure that the returned container will be undamaged and any biohazard contained. Therefore some other method of identification of non-nominal return will need to be used This may be done using remote observation but if this cannot be done with confidence a robotic system could be used or a person wearing protective equipment could approach the landing site.

4.6.2 Non nominal return

If a non nominal return is reported then an assessment of the required course of action must be taken based on the damage reported The area would need to be secured and entry by unauthorised personnel prevented. The container should be moved into a contained space as soon as possible where it can be more closely observed and cleaned/decontaminated. A HEPA filtered space under negative pressure would be suitable. It would need some means to clean/decontaminate and some system to stor or inactivate any waste

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4.7 Conclusions

Planning of any sample return from a planetary body with potential for life will need to be carried out using worst case scenarios to ensure that preparation can be made for all eventualities to protect both the science and the planet

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5. RECOVERY AND INITIAL INSPECTION

5.1 Introduction

Experience from the recovery of sample return missions to date show the importance of examining the entire sample handling and containment chain, including « landing site characteristics, ground recovery and transport to ground facilities, not just the quarantine or containment laboratory » (NRC, 2009)

In this section, the recovery and initial inspection of the sample will be covered, with recovery of spacecraft parts, portable laboratories, the challenges of handling and the public perception of risk examined subsequently.

5.2 Recovery of an intact sample

Previous missions have used different models of recovery :

Mission	Recovery
Genesis	Transport to temporary cleanroom at UTTR then on to Curation Lab at JSC
Stardust	Transport to class 10000 cleanroom at UTTR then on to JSC in plane
Hayabusa	Woomera and flown to Curation facility at Sagamihara

Both Stardust and Hayabusa-1 were recovered intact – although it is to be noted that even in these recoveries, there were incidents which risked compromising the science return.

After the Hayabusa-1 landing, the capsule was packed into a double layer of plastic bags filled with pure nitrogen gas and then inside an initial/temporary transportation box. The recovery capsule was then transported to the WPA Instrument Building where the recovery team and Quick Look Facility (QLF) were installed. One day was spent safing the explosive devices and the battery in the capsule. The next day was spent on the removal of contaminants adhering to the capsule and the packing the capsule into another clean transportation box for internal transport. The surface cleaning of the capsule and packing operation were both executed in the temporary cleanroom at the QLF installed in the building (Abe et al, 2011). The transportation box has a purge function of pure nitrogen gas, and can ease the shock under transportation. Then the capsule was put inside a cargo container which had air suspension to keep the capsule below 1.5 G shock during transportation [Matsuda, 2015] and then flown to the curation facility in a chartered plane.

Once Stardust touched down, a recovery Team was sent to find and collect the capsule. Depending on ground and weather conditions, the Recovery Team were planning to travel to the SRC landing point by helicopter or by 'MATTRACK' (a pickup with wheels replaced by treads). The recovered SRC was then transported to a cleanroom at the Avery Complex where

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the sample return canister was separated from the heatshield and backshell (Sandford et al, 2006).

To date, no sample return teams have set up a portable facility at the landing site. For a Mars Sample Return mission there may be a public perception that this is necessary in order to contain any potential contaminants if the spacecraft is damaged on reentry/landing.

5.3 Recovery of a non-intact sample

5.3.1 Recovery

The Genesis recovery provides an example of a non-intact recovery as the Genesis capsule broke open on impact, and part of the inner sample capsule was also breached. This experience underscored the value of teamwork and contingency planning, and provides a vital set of "lessons learned" for future sample return missions (Ryschkewitsch, M., 2006).

The Genesis crash underscored the importance of thinking through multiple contingency scenarios and practicing field recovery for these potential circumstances. Having contingency supplies on-hand for all recovery operations was judged to be critical (Zolensky, 2008).

5.3.2 Decontamination of the area

The techniques used to decontaminate the landing area will have to agreed in advance by public health experts. Assumptions will have to be agreed on the potential resistance of biohazards to potential remediation options such as heat. Once a technique has been recommended then planning for its use can be started. The area could either be decontaminated or contaminated material could be removed for off site processing.

5.4 Existing portable laboratories

Truck and container labs are in use for outbreaks, environmental accidents and counter-terrorism. These containers can be loaded onto C-130 cargo planes or similar air transport and airlifted to the main laboratory. Examples are shown in Figure 5-1. A team who set up an on-site portable laboratory for a Marburg virus outbreak in Angola reported that the greatest challenge was the lack of consistent electrical power, this necessitated portable generators and battery backup systems for thermocyclers and the storage of samples at freezing temperatures was not possible. (Grolla and Jones, 2011).

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Figure 5-1 : Germfree Mobile Container laboratories can be loaded on an aircraft, pulled as a trailer and transported by sea or rail. Image: © Germfree.

Another interesting concept used to investigate outbreaks of infectious pathogens up to the highest risk group 4 is a deployable mobile laboratory. This 'European Mobile Laboratory' was developed by the Bundeswehr Institute of Microbiology (InstMikroBioBW) in Munich, Germany, and can be stored and deployed on conventional transport (see Figure 5-2) (Stoecker and Woelfel, 2014).

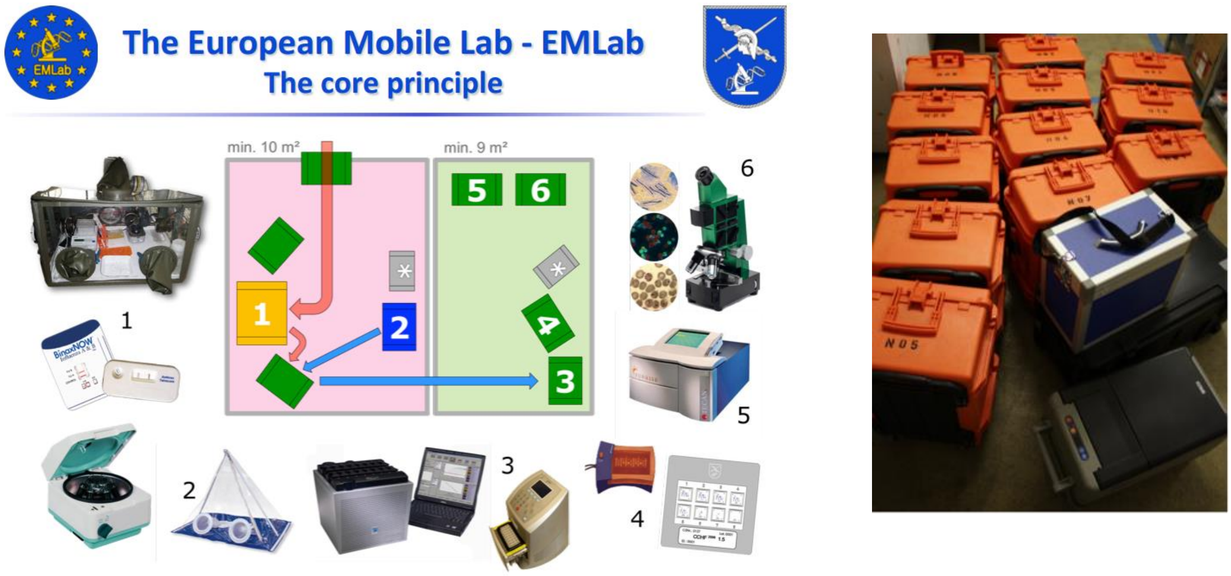

Figure 5-2 : European Mobile Laboratory is packaged in 15 easily transportable containers (Stoecker K. and Woelfel R., 2014).

5.5 Handling

Bridges and Guest, 2011 discuss potential sources of damage to a Mars Return sample once it has landed. These include :

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5.5.1 Vibration and Shocks

The handling of the sample should not introduce vibrations or shocks and these could destroy any structure within the sample.

5.5.2 Electromagnetic Contamination

Any strong electromagnetic fields may compromise the electromagnetic properties of the sample and any static charge induced may allow a dusty sample to cling to surfaces which could make extraction challenging.

5.5.3 Orientation

In order to maintain the structure of the sample (which is useful for sedimentatry rock analysis), it may be advisable to retain the landed orientation during handling.

5.6 Perceived Risk and public perception

The ESF ESSC report (ESF-ESSC Study Group, 2012)discusses perceived risk and public perception of risk. It discusses the hazard vs the risk and the event chain necessary for substantial environmental consequences. In the same report it is suggested that «potential release scenarios are defined and investigated» in order to develop ways to respond.

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6. TRANSPORT TO / FROM CURATION FACILITY

6.1 Introduction

The most important concept of the sample container is to deliver the small samples safely, with prevent them from terrestrial contaminants during its transportation. In order to reach this goal special precautions must be taken into account in the design and procurement of all containers (temporary or permanent) with which the samples will be in contact.
The recovery of the samples will be performed following several steps:

- Operations and packaging of the capsule on the landing site
- Operations in a temporary clean room (cleaning of external surfaces; check of integrity, ecc.)
- Operations at the curation: recovery of the sampling chamber, inspection and storage of the samples.

The delivery of the samples to scientific laboratories needs the definition of the packaging necessary to preserve its integrity during the shipment. In this case containers designed under the responsibility of the curation facility can be used as the standard delivery packaging.
However specific requirements in the samples preparation for analyses, requested, could require the adoption of different packaging. In this last case the responsibility of the package realization and/or procurement is under responsibility of the scientific laboratory requiring the samples.

6.2 Packaging

Packaging is a fundamental process, since it is aimed at minimizing possible sources of permanent damage, e.g. physical shocks, temperature change and humidity.

6.2.1 From landing site to Curation

At the landing point the capsule will be placed into a temporary plastic bag and a stored in a transportation box. The performances both for the temporary plastic bag and the transportation box have to satisfy mainly the following requirements:

- Guarantee a good insulation by the atmosphere
- Guarantee a good insulation from particulate and molecular matter
- Avoid organic contamination
- Preserve integrity of the capsule

A first check of the capsule and/or of the sample container integrity and a cleaning of external surfaces will be at the portable laboratory. After these operations a new transportation box will be used with the same protection capabilities of the previous one. In this case the package must have an improved performances of monitoring and a better sealing capability in order to preserve the samples during the transfer to the curation facility.

Basing on experience of previous sample-return missions, the recovery and transportation of the return capsule has not required extraordinary handling measures or hardware, due to the

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small size and mass of the return capsule, but has been obtaned simply by a specialized handling fixture to cradle the capsule during transport.
In particular, the Hayabusa samples were packaged in a container, sealed with double Viton O-Rings. This was not sufficient to avoid leakage of terrestrial air, which increases with time. Therefore, in order to minimize this effect, the sample container was placed into a ultra pure nitrogen atmosphere (Abe et al. 2011). The scheme of the Hayabusa sample container is given in Figure 6.1 (top).
The Hayabusa-2 sample container will be based on the same design of the Hayabusa one. The improvenet which will be applied will concern :

- Aluminum metallic vacuum sealings, with mechanical latching mechanisms
- Noble gas ventilator at the bottom of the canister
- A larger Canister Volume (48x48x57.5 mm)
- Total mass lower than 500 g.

The scheme of the Hayabusa sample container is given in Figure 6.1 (bottom).

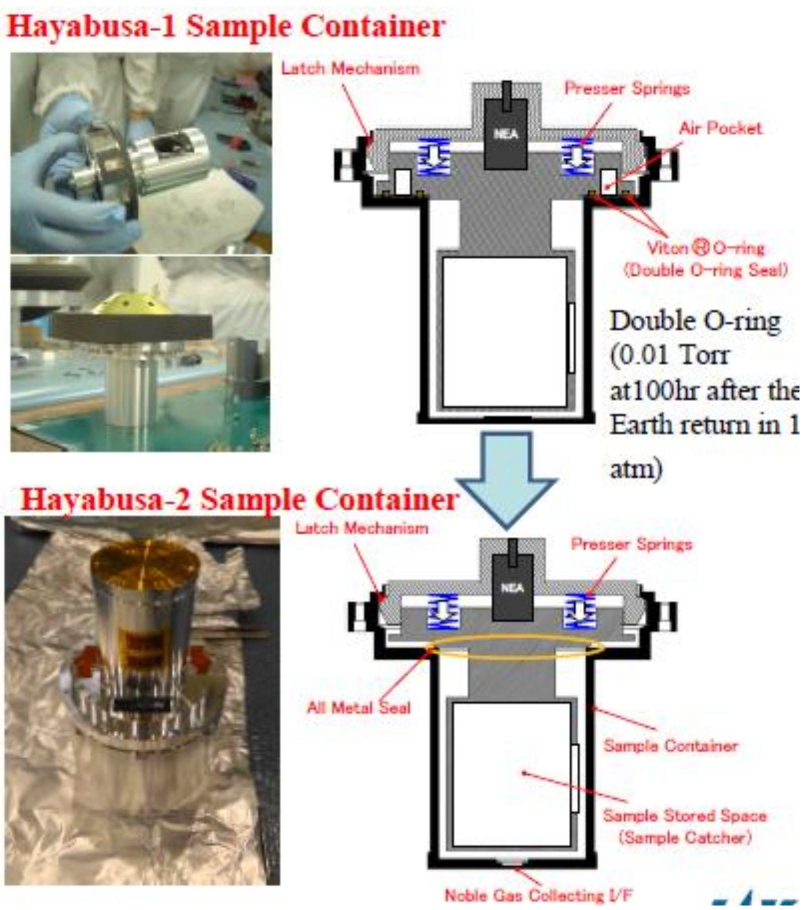

Figure 6.1. Hayabusa (top) and Hayabusa-2 (bottom) sample container.

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6.2.2 From curation to Scientific laboratories

The transport from Curation to laboratories is generally allowed only after approval by the Curator.
Typical size of the sample is less than 100 µm, so handling of the sample is performed with a micro-manipulation system in the clean chamber of the curation facility (see the Stardust and the Hayabusa examples). The sample container for shipment will be able to preserve the sample from the contamination and guarantee the localization of the sample. An example of this kind of container can be the package used for the Itokawa samples collected by Hayabusa-1 mission.
The container consists of a pair of outside flanges and a pair of quartz glass plates. The flanges are made by stainless steel, the same material of the clean chamber. The base flange has been machined to be able to hold a pair of glass plates with clips and screws. A copper gasket coated with gold is set between a cover flange and the base flange. The pair of flange is then enclosed with six screw bolts to seal the pair of glass plate inside. Inside the pair of flanges, the base plate made of quartz glass is set to contain a sample particle. It has three to five dimples whose aperture is about 1mm and depth is less than 0.5mm. The samples are placed in those dimples one by one with the micro manipulator electrostatically controlled in the clean chamber. The metal plate is set under the base glass plate in order to increase the ability of the control the handling of the sample with the micro manipulation system. As the sample is set inside the dimple, a cover plate made of quartz glass is put upon the base plate though which the sample can be observed. The base plate is held with a metal clip and a screw and the cover plate is held with two pairs of a clip and a screw.

6.3 Customs and Regulatory issues

This will depends on the two countries involved ; the country where the landing site is located and the curation facility country. If the US has major involvement in the mission, then it is expected that ITAR restrictions will limit the landing site location to the US. If not, then the strongest candidate for the landing site would be Woomera, Australia. This area needs further investigation. In the case of Hayabusa mission, an agreement between Australia and Japan meant that the sample container was not allowed to be opened for inspection at the airport (Abe et al. 2011).

6.4 Security

The responsible for the security of the samples are the mission Investigators, which maintain the supervision of the samples when these should be analyzed with facilities outside of their laboratories. However, the Investigators should handle these samples in order to maximize the scientific yield of sample analysis (Hayabusa Sample Investigator's Guidebook)

6.5 Labelling and documentation

Marks and label give important information about a sample. Marks are number or codes which identify the specimen, whereas labels provide accessible information. Tha application on mark

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can occur in three stages: 1) after collection ; 2) after entering in the curation ; 3) when the sample is catalogued.
On stage 1 mark could consist of name of the site where the specimen has been sampled and a sequential number. On stage 2, an Entry Number can be assigned to the specimen, accompanied by a label giving information about the sample, e.g. origin, site, preliminary composition. Finally, on stage 3 the specimen Label could allow for recording on addition information with respect to stage 2, e.g. storage location, name of cataloguer, cataloguing date, name of curation, name of institution.
The following techniques are usually used to mark specimens (Brunton, 1984):

- Direct engraving or inscription, but this method is poorly suitable for small samples such as the extraterrestrial ones
- Associating to a paper tag

Labels should be the simplest as possible and should be prepared in order to be written in a permanent medium. Moreover, they should include the « history » of the sample, e.g. subjected processes, donations, exchange, etc.

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7. CONCLUSIONS

Previous mission such as Hayabusa, Genesis and Stardust provide a basis to draw up a protocol for approach to and transport of a returned Mars sample. In particular the Hayabusa mission, being both the most recent, but also a non-US mission, offers much experience. However, the biohazard aspect of the transport and possible decontamination scenarios have only ever been developed by public health teams dealing with eg: high BSL viruses in Africa. In a worst-case scenario, samples from a damaged capsule may be recovered and immediately secured in a specialist container to go to the curation facility. This potentially could be done at the landing site with appropriate support. It will not be possible to use a portable receiving facility to analyse samples in any way. However it might well be used to make the sample safe, assess the seals and package it for transport to the curatorial facility.

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8. ASSUMPTIONS AND DEPENDENCIES

8.1 Assumptions

In order to move to WP6, certain assumptions need to be made about the requirements of the sample capsule and landing, including:

8.1.1 Landing site

All sample return missions have either performed on orbit capture (such as LDEF which was returned via the Shuttle) or landed in a hot sparsely populated desert area such as Utah or Woomera. In Zolensky and Sandford (2011), they state that they found the recovery using Woomera to be more robust than Utah. It is assumed here that the landing site will be on land, in a desert and probably at Woomera.

8.1.2 Temperature of the samples

Consideration needs to be given to the temperature of the capsule during recovery. The capsule will undergo the possible extreme temperatures of reentry (although protected by an ablative heat shield) and then land in a hot desert. It has been assumed here that rather than undergo repeated melt-freeze cycles, it would be preferable scientifically that the samples temperature be kept within room temperature range. If cold storage is required, then a subset of the samples could be sent to the vault storage facility which will have cold storage capacity.

8.1.3 Mass of Sample Return Capsule

The mass of the sample chamber is critical affects size of the Earth return capsule and size of the transport chamber and size of the curatorial facility. NASA's Mars2020 mission is currently being designed as the first stage of a MSR mission where a subsequent retrieval lander / spacecraft will collect its cached samples. (Obj C of the Mars2020 SDT Report). The estimate of sample size will be based on these mission requirements. Section 6.2.3.1 of the SDT defines a total sample mass of 500g divided over approximately 31 individual samples, ie : each one is 15-16g. It is also assumed that a sample may contain rock core, regolith, ice and gas. The argument for mass and size is important in appreciating what services might be deployed at the recovery site. For example, a field-deployable BSL-4 (based on a shipping container) would provide an invaluable facility in terms of assessing samples from the landing area etc. However, such a facility and its protected glove boxes is designed for small items (a culture plate for example).

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8.2 Dependencies

The following questions will be put to the experts involved in the Genesis, Stardust, Hayabusa-1 and Osiris-REX recoveries. The work in WP6 is dependent on receiving answers to these questions.

Questions to be put to experts:

1. What contingency scenarios did you plan for?
2. What field training did you carry out and how long did this take?
3. How is the landing site dependent on size and mass of the capsule?
4. Is current landing technology ie: parachutes suitable for Mars Return capsule?
5. How do we prevent breakup of capsule on arrival?
6. What environmental measurements did you make at the landing site?
7. What procedures were carried out in the temporary cleanroom near the landing site ?
8. With which equipment did you assess the state of the capsule?
9. What security measures did you take to ensure the safety of the capsule?
10. What type of container did you use to transport the capsule to the curatorial facility?

8. How did you ensure no terrestrial contamination during the transport of the capsule?.
9. What customs and regulatory arrangements were necessary for the transport of the capsule?
10. Is there a regulatory specialist contact for the Australian side of the transport for Woomera?
11. How is MSR capture being performed and how is the biohazard chain broken between Earth and Mars?

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