**EURO-CARES**

**A PLAN FOR EUROPEAN CURATION OF RETURNED EXTRATERRESTRIAL MATERIALS**

# WORK PACKAGE 4

# WORKSHOP REPORT

# (DELIVERABLE D4.3)

J. Aléon,, M. Gounelle, I. A. Franchi, S.S. Russell, Y. Marrocchi, J. Brucato,

A. Meneghin, V. Debaille, A. Longobardo

## 1. Workshop program

The Work Package 4 (WP4) dedicated on "Instrumentation and Methods" held its workshop on October 13th and 14th 2016 at the Muséum National d'Histoire Naturelle (MNHN) in Paris. The finalized full program is available in Annex 1.

The workshop was organized in 5 short topical sessions:

(i) a EURO-CARES dedicated session, where the work package 4 presented an update of its activities since the Panel Review Meeting in February. This session included dedicated talks about the status of the deliverables and work done on the instrumentation list as well as about the curation facility visits at JAXA and NASA. Following these talks, WP 2, 3, 5, 6 and 8 presented a short update on their activities, with an emphasis on those related to WP4.

(ii) The second, open, part of the meeting was dedicated to sample curation. After a short presentation of the EURO-CARES program by P.I. Sara Russell for a wide audience, four invited presentations introduced different curation facilities and procedures for extraterrestrial samples. M. Zolensky (NASA, Houston, USA) gave an enlightening presentation about the organization of the preliminary examination period for different NASA sample return missions. C. Herd (University of Alberta, Canada) presented the subzero curation facility at Univ. Alberta and underlined the benefit of cold-curation under controlled atmosphere. K. Righter (NASA, Houston, USA), P.I. for the curation of samples returned by the OSIRIS-REX asteroidal sample return mission, gave an update on the curation plans for this mission. Finally, J. Duprat (CNRS, Orsay, France) presented the collection and curatorial practices developed in Orsay (France) for the micrometeorite collection from the CONCORDIA base in Central Antarctica.

(iii) In the third, open, part of the meeting, four invited speakers presented several analytical techniques that WP4 is seriously considering as techniques of major interest for the initial sample characterization. J. Gattacceca (CNRS, Aix-Marseille, France) presented the interest and caveats of the magnetic characterization of extra-terrestrial samples from Apollo samples to meteorites. R. Brunetto (CNRS, Orsay, France) presented recent developments for the spectroscopic characterization of interplanetary dust particles, meteorites and Hayabusa samples with an emphasis on up-to-date Fourier Transform Infra-Red (FTIR) but mentioning Raman and Visible-Near-Infrared (VIS-NIR) spectroscopies as well. N. Almeida (NHM, London, UK) presented a broad overview of the possibilities and difficulties of X-ray Computed Tomography (X-ray CT) of meteorites. Finally, L. Thirkell (CNRS, Orléans, France) presented the Time-Of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS) as a technique of choice to monitor surface contamination after a quick overview of the TOF-SIMS instrument COSIMA on board Rosetta for the characterization of dust particles from Comet 67P/Churyumov-Gerasimenko.

(iv)The fourth session was dedicated to instruments and methods presentations by invited manufacturers. One manufacturer, Agilent, was invited to present the recent development of Focal Plane Array (FPA) detectors for FTIR, however they turned out not to be available shortly before the meeting. G. Mercier and O. Pigni from Leica presented their most recent sample handling instruments and digital (including 3D) optical microscopes, respectively. Finally, M. Andrew from Zeiss gave a presentation focusing on X-ray microscopy products on one hand and on correlated microscopy tools for the multiscale characterization of geological samples from the cm scale down to the nm-scale, on the other hand.

(v) After these sessions, a general round table was organized. It was open to all participants in order to benefit from the experience of our invited speakers, as well from fresh ideas from people not necessarily involved in sample characterization and curation. The major topic discussed in this round table was the extent of initial sample characterization to be done inside the SRCF in relationship with Preliminary Examination (PE). Topics also discussed were (i) the need for automation, (ii) the need for a synchrotron light source in the vicinity of the facility, (iii) the importance to define precisely to which extent an analytical technique is non-destructive. A few other points were raised during the discussion.

The WP4 workshop was also the opportunity to hold the EURO-CARES monthly WP leaders meeting face to face instead of a telecom. A group dinner was organized on Thursday 13th evening, where the American speakers were invited.

## 2. Attendance

The workshop was organized in two parts: (i) a EURO-CARES restricted part (session 1 above) where 15 EURO-CARES members were present and (ii) the rest of the meeting open to the sample analysis and planetary science community. Advertising of the meeting was done on the EURO-CARES website (http://www.euro-cares.eu/wp4_paris_home). Additional announcements were circulated ahead of the meeting, first at MNHN, Paris and second in the whole French cosmochemistry community. The meeting was aimed at being not too large in order to facilitate discussions between EURO-CARES members and invited specialists and to maximize the meeting outcome. Still, a total of 38 attendees were present instead of the 32 officially registered in advance. The full list of attendees and contact information for the invited speakers is given in Annex 2.

The 38 attendees included 15 EURO-CARES members, 11 invited speakers and 12 other participants. Altogether, 16 institutions were represented plus two manufacturing companies. Attendees have been involved in at least 6 different space missions, including past and future sample return missions as well as *in-situ* missions at solar system bodies of interest for EURO-CARES: (1) the Stardust mission to short period comet Wild 2, (2) the Hayabusa mission to S-type asteroid Itokawa, (3) the OSIRIS-REX mission to carbonaceous asteroid Bennu, launched from Cape Canaveral on September the 8th, 2016, (4) the COSIMA instrument on board the Rosetta spacecraft at short period comet 67P/C-G, (5) the ChemCam instrument on board the Curiosity rover on Mars and (6) the SuperCam instrument selected for the next rover to be flown as part of the Mars2020 mission. With about one third external participants, the meeting had a significant impact on the French planetary science community. Either among the invited speakers or among the other registered participants, many non-EURO-CARES participants indicated a strong interest in EURO-CARES activities. Local participants from IMPMC-MNHN were from three different teams: cosmochemistry, mineralogy of planetary interiors and geobiology and included two engineers from the electron microscopy platform and from the meteorite collection. With two post-docs and two PhD students present, the meeting also achieved an educational goal for the next generation of scientists. Finally, the meeting will also have a broad outreach with the presence of J. Borg, a former planetary scientist with experience on lunar samples and interplanetary dust particles, now chief-editor of the French wide-audience magazine "L'Astronomie". A short report of the meeting will be given in the News section of the next issue of L'Astronomie (issue 100) and an in-depth article about EURO-CARES and the importance of sample return missions will be prepared for publication in a later issue of L'Astronomie.

## 3. Lessons learned from the presentations

### *Curation facilities*

Several curation facilities have been built at the Johnson Space Center since the return of lunar samples from the first Apollo missions. In addition to the lunar curation facility, they include facilities for the Stardust, Genesis and Hayabusa sample return missions as well as facilities for the curation of meteorites from Antarctica and interplanetary dust particles collected in the stratosphere. Apart from the Apollo sample facility, which was planned before the mission and for which a new building was built, all other facilities were retrofitted from spaces initially dedicated to other uses such as office spaces. Two more facilities are programmed for the OSIRIS-REX and Hayabusa 2 samples to be returned to the Earth within the next 10 years. Again they will be constructed from retrofitted space at minimal cost. The cold curation facility was also built from unused space at the University of Alberta. The Hayabusa curation facility at JAXA has been conveniently built at the site of the mission operation center, which allowed continuous contamination monitoring, however 10% of the sample were allocated to NASA and sent to JSC for remote site storage (and allocation). A similar approach has been chosen for the Hayabusa 2 mission. Using retrofitted space at NASA usually allowed to keep costs in the $100,000 range compared to the $10,000,000 cost of the Hayabusa facility. Ultra-clean collection of micrometeorites has been developed in central Antarctica by the CSNSM since 2000. Thousands of particles have been collected and are now kept in Orsay. The new collection technique designed by Jean Duprat minimizes the duration of micrometeorite interaction with liquid water, and mechanical damage leading to a collection of unprecedented cleanliness and rich in friable particles. Most micrometeorites have preserved their liquid-soluble phases such as sulfides and sulfates. The last expedition in 2016 brought back more than 5000 particles after processing 50 cubic meters of snow. To preserve this unique collection, a 100 $m^2$ clean room ISO8 – ISO7 has been developed with a total cost of 350 keuros. It is now fully operating with a running cost 30 keuros/yr. In that clean room, micrometeorites are kept and catalogued. They are also fragmented and a selected piece is used for preliminary analysis. In the near future a SEM and an IR microscope will be introduced in the clean room to improve characterization activities.

***Preliminary examination conditions***

The functioning of Preliminary Examination (PE) was in fact very different from one mission to another. Different types of PE have been presented and discussed.

For the Long Duration Exposure Facility experiment, samples were recovered from the spacecraft extremely rapidly by a very small team working hard during 5 months during the dismantlement of the spacecraft and were pre-characterized on a volunteering basis at minimal cost. Only a few binocular microscopes were bought at the time. Up to 40,000 impact craters were documented and are still stored in a class 100 clean room and are available for request.

For the Stardust mission, the PE team initially consisted of only the Science team of the mission. However during the 1 year PE period that followed the sample return to the Earth, the PE team was open to all scientists volunteering from all over the world. Most analyses were performed outside the curation facility. In the end, it included ~260 people. This resulted in a maximized scientific outcome, as well as development of sample handling techniques outside the facility that would not have been possible otherwise. Sample handling tools and characterization methods installed in the facility were also kept minimal.

The crash of the Genesis sample return capsule resulted in a complete change of the PE plans and required installation of a portable clean room near the landing site, where the sample remained for a long period during which cleaning procedures were developed to recover as many of the targets as possible and to allow cataloguing of the target fragments that were mixed during the crash. After this period, the PE included only the Science team. Contrary to the Stardust mission, extended costs were included in the mission budget, which allowed the development of Genesis dedicated instruments such as the Mega-SIMS at University of California Los Angeles, a combined SIMS - tandem accelerator. This instrument ensured the successful measurement of the O isotopic composition of the solar wind, the primary science goal of the mission.

For the Hayabusa mission, two extended PE teams were defined and brought in competition. Both teams were finally selected and conducted the PE but it was restricted to Japan with many analyses done during this period. Although, the facility was equipped with a lot of instrumentation including FTIR, SEM, Raman, TEM, and contamination monitoring instruments, many remained unused.

The OSIRIS-REX PE will initially consist of the mission Science team, before release to a broader community. A two year curation period is planned after the sample recovery, expected in 2023. A catalog of samples including (1) bulk samples, (2) contact pads (collectors built like velcro that will directly touch the surface of the asteroid regolith), (3) samples from the return capsule and (4) a collection of witness samples will be released 6 months after return (March 2024).

Finally, although the Stardust PE was very successful with PE sub-teams having smooth interactions, experience gained from the Apollo and Hayabusa missions indicate that having several independent PE teams does not ease interactions and can create difficulties due to some competition between the teams.

***Contamination control***

Different approaches to the monitoring and control of contamination were presented and discussed. For the OSIRIS-REX mission multiple witness plates (Si wafers and Al foils) were placed at various locations during the spacecraft assembly and within the spacecraft to provide a record of possible pre-flight contamination. 4 plates were collected every month between March 2015 and

September 2016. More than 200 materials involved in the mission preparation were collected and archived for future reference.

Contamination control of the micrometeorites collection is first done in the field through visual inspection of filters. During storage, contamination is kept at a low level using specially designed glass to keep individual micrometeorites. All processing work is done in the clean room especially designed for that purpose – see above.

With a total carbon content of 6 wt%, half of it being organic matter, the Tagish Lake meteorite, collected and stored at low temperatures since its fall, can be used as a curation example for the preservation and contamination control of volatile-rich samples from icy bodies (e.g. B-type asteroid Bennu, the target of OSIRIS-REX, Cg-type asteroid Ryugu, the target of Hayabusa 2 or potential icy samples from the lunar poles or from comets). A specific curation facility was designed and built for this purpose at University of Alberta. Tagish Lake samples were handled at temperatures between -15 and -30°C under inert Ar atmosphere and analyzed for their content in volatile organic compounds. The cold curation was found to allow preservation of highly volatile compounds such as formic acid and to reduce contamination by outgassing materials from the facility (e.g. phtalates and oleamides from ziploc bags were found). Recommended temperatures of operation are -80°C for storage and-15°C for handling. At the latter temperature handling cannot exceed 15 minutes as the fingers and feet of the operators becomes cold even with insulated equipment. A strong constraint of the cold curation is to use materials that meet the low temperature requirements in the glovebox (e.g. gloves that do not freeze; a heater and a chiller were required to heat and refresh Ar before and after the Ar purification system, respectively, since the latter works at 10°C). As an inert atmosphere, Ar was preferred to $N_2$ since the latter can form compounds under specific conditions.

Finally, Time-Of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS) appears to be a method of choice for the characterization of surface contamination. With its large mass range, it is widely used for monitoring contamination in industrial processes and allows detection of most elements from the periodic table as well as large organic molecules that can be identified from their fragmentation patterns. Its sensitivity allows detection of contaminants with concentration down to the ppm range. Sputtering with primary cluster or molecular ions such as $C_{60}$ or Bi metal clusters results in desorption of almost intact adsorbed molecules and reduced sample damage. COSIMA is a reduced-size TOF-SIMS instrument (1m, 20 kg) flown on Rosetta. It was used to study the dust particles from comet 67P/C-G, revealed that cometary organics are mostly similar to the insoluble organic matter of chondrites and allowed a characterization of contamination. Contamination identified with the flight model and the ground model in Orléans, France, includes silicon oil (the embedding medium for collection of the dust particles), PDMS, In, Au and Ag from the collection plates, phtalates, teflon, and volatile elements such as Na, K, O, S... It also demonstrated that heating a sample to remove contamination results in diffusion of organics on the surface, which become ubiquitous although in lower concentration.

***Instrumentation***

A full deliverable is dedicated to instrumentation in the ESCF. Only aspects concerning recent and on-going developments as well as user experience discussed during the meeting are covered here.

Magnetic measurements are multifarious. The most important aspect of magnetic properties are that they can help to quantify the amount of metallic minerals. They can therefore help provide a preliminary classification of the samples. Determination of the anisotropic susceptibility can reveal the degree of shock compaction or the stratigraphy of asteroids. Commercial devices such as KLY2 /MFK (AGICO instrument) are available. Instruments can also specifically be built relatively easily. In the context of a sample return facility, this would be the best option.

Fourier Transform Infra-Red spectroscopy (FTIR) is a technique of choice for pre-characterization of samples as it is entirely non destructive. A recent development in detector technology is the release of Focal Plane Array detectors (FPA). These 2D arrays of individual detectors allow acquisition of one spectrum for each pixel and result in highly sensitive and laterally resolved analysis. Lateral resolution with FPA detectors reaches 0.7 µm. Even with conventional light source, analyses can be very rapid (images of the Paris meteorite were acquired in 20 min without synchrotron light with a better resolution than the same images acquired in 2 hours with synchrotron light). FTIR has the advantage of possible coupling with Raman and Visible Near-Infrared spectroscopies if necessary. 3D IR tomography is currently under development but still requires the use of a synchrotron light source. As a result, it is still far from being a pre-characterization tool but it may become of easier use within the next 10 years.

X-ray Computed Tomography (CT-scan) is a non-destructive technique allowing access to many 3D properties of materials in a non-destructive way. The developments presented on meteorites emphasized some difficulties. Techniques of data processing adapted to extraterrestrial samples are still under development and some analytical artifacts appeared that require consideration (for instance due to highly contrasted phases in close vicinity or to phases with similar contrast such as dark low density phases vs porosity). Although the method is mostly non-destructive, it must be kept in mind that the sample is irradiated with X-rays and that its initial X-ray irradiation record is obliterated.

Up-to-date and recently developed instrumentation presented by Leica that are of interest for an ESCF include high precision cutters with mm precision, ion milling possibly in cryo-mode and a cold stage at -180°C that can be installed on commercial instruments. Leica also developed a system under vacuum to transfer samples from one glovebox to another. With close interactions with Leica most instrumentation can be adapted to other other instruments (e.g. Leica cryostages and vacuum coating systems have been adapted to CAMECA electron probes) and to automation chains. Digital microscopes are now available that allow 3D optical microscopy, high repeatability of illumination conditions and some degree of automation. Some microscopes now have a range of magnification comparable to stereomicroscopes and high-resolution microscopes can determine sample roughness down to 1 nm.

Zeiss presented products including CT-scan but other microscopes as well and emphasised correlated microscopy. Several microscopes including optical, electron and X-Ray microscopes can be combined together by using a common geometrically located coordinate system, which allows one to process analytical data in a single database and combine different 3D information. For instance, high resolution - small volume information can be extrapolated to a low resolution - large volume dataset. Another example is the propagation of 2D chemical and mineralogical information for instance on a sample surface to 3D for the whole volume. An interesting possibility with this system is the combination with a high resolution X-ray nanoscope (using hard incident X-rays) to achieve nm-size resolution in geometrically located areas.

Finally, the instrumentation for NASA curation facilities is described elsewhere but interesting new information is the instrumentation planned for the curation of OSIRIS-REX samples: optical, SEM and X-ray CT microscopes, as well as FTIR, UV fluorescence, and XRF spectroscopies. Samples will be handled using tweezers, ionized needles and micromanipulators depending on size. Thin section preparation equipment, microtome and FIB are anticipated for sub-division of different size samples. The whole size range from µm-sized dust particles up to cm-sized pebbles is expected from pre-flight tests, which all collected more than 100 g of material. Handling of particles smaller than 100 µm benefits from previous experience from IDPs and Stardust samples and particles larger than 1 mm are easily manipulated. However, it is still not clear how to sub-divide particles in the 100 µm - 1 mm size range. A high-resolution camera on-board the spacecraft will be used to determine what to expect upon collection.

## 4. Outcome of discussions

A large part of the discussions that followed the presentations focused on the extent and organization of preliminary examination (PE) and initial sample characterization, to which the definition of instrumentation inside the facility is directly related.

The PE of the Stardust mission appeared to be a reference case with a very low cost curation facility, a rapid distribution to the best experts in the world and a high scientific output. It notably allowed NASA to outsource the aerogel handling problem. Analyses of Hayabusa samples and micrometeorites have shown that some samples can be highly reactive, so that quick analyses can be crucial. For instance irradiation damages are surface signatures, which quickly disappear even in a controlled atmosphere. A PE with a rapid wide distribution of samples is inapplicable to restricted samples with biosafety issues. It may be decided that the release of such samples can only be done upon complete sterilization even in the absence of an answer to whether they are biohazardous or not.

However it should not prevent the study and characterization of these samples. A distinction between two extreme cases may thus be required: (1) unrestricted samples with rapid dissemination and limited characterization inside the facility and (2) restricted samples for which a lot of highly specific instrumentation may be required within containment inside the facility. It was pointed out that a Stardust-like organization may be the best approach for a European curation even from a political point of view as many countries will be involved and will likely request a participation to PE with rapid dissemination of samples. This highlights the distinction that needs to be made between the sample early characterization (SEC) necessarily done inside the facility and the PE, which, strictly speaking, is the scientific activity that can be done inside or outside the facility. The choice of instrumentation and methods to be applied within the facility depends on the extent of SEC, which itself depends on the mode of PE. Therefore, decisions require a downstream approach and the full process from sample reception to the functioning of PE must be evaluated before instruments can be chosen for the facility. A final point is that the extent of work done inside the ESCF depends on the nature of the samples: what was possible for Stardust because the dust sample community is limited in size is probably not possible for rocks or pebbles, as the whole geoscience community may want to apply for such samples.

Beside PE, it was emphasized that it is necessary to evaluate the whole chain of contamination including spacecraft building, spacecraft cruise, sample collection, sample handling in the facility and sample delivery to outside labs ahead of the mission. Keeping a record of each material is probably an efficient way to monitor contamination. In the case of samples rapidly delivered to an outside community it is necessary to define rules, to which users have to abide. For instance, the Hayabusa samples were distributed only if scientist agreed to handle them only in vacuum or $N_2$ and specifically in the absence of water.

Discussions also indicate a general agreement that using synchrotron light is useless for SEC especially if the latter is kept minimal for unrestricted samples. Even for restricted samples, if specific analyses are required (for instance for identification of traces of life), current synchrotron facilities can handle biological samples under containment (BS3 samples). There is thus no need for coupling the curation facility with a synchrotron facility.

Automation is also an important point for efficiency, repeatability and contamination control. It enables staffing to be kept to a minimum, and thus reduces costs as the most important cost in a facility is the staff salaries. The usual procedure is to increase the staff at sample return and during PE and to decrease it otherwise. Automation can be very efficient but strongly depends on sample type and sample size. It is all the more efficient than the samples are homogeneous. In that respect, sample size is a critical issue: different analytical and handling techniques are required depending on sample size, which in turn require different skills and thus different training of the curation facility staff.

The result of these considerations is that, because so many differences are expected from one mission to one another (sample type, science goals, biosafety issues), it is important to prepare a short list of instruments for minimum sample characterization and a larger one in case of extended characterization.

Finally, a key issue systematically considered in the choice of an instrument is to which extent it damages the sample. However the definition of a "destructive analysis" is quite subjective and there is almost no entirely non-destructive method. To minimize sample damage it will be necessary to consider instrumentation chains, with priority techniques depending on the mission. Definition of such instrumentation chains will require to take reference sample and to submit it back and forth to different analytical techniques. Such a study will benefit from interactions with JAXA, as it has been done to some extent with several meteorites for the preparation of Hayabusa. Considering the effects on biological samples is also important to prepare the return of potentially biologically loaded samples.

## 5. Conclusions

By all aspects, the workshop was successful. The audience was larger than expected but the meeting remained at a reasonable size so that discussions and interactions between participants were promoted. The workshop turned out to be very efficient and a lot of progress has been made in a very limited amount of time. Organizing the workshop was also the opportunity to take contact with industrial manufacturers that could become future partners. A general comment is that there are not so many alternatives for sample characterization. Unless the returned samples are gases, liquids or ices, all extra-terrestrial samples consist of rocks, and these are the most probable sample return material. Most variations in sample types (breccia vs homogeneous, dust vs rock, biohazardous vs non biohazardous, volatile-rich vs volatile-poor…) were covered by the meeting and, in the case of non-biohazardous samples, have been discussed above (sample size, non destructive volumic techniques for heterogeneity, cold curation for volatiles and contamination, etc.).

As a whole the EURO-CARES program strongly benefited from the presence of curation experts and notably from the NASA experts having experience of different types of PE and curation processes for different types of samples. A first set of general recommendations can be drawn from the meeting and discussions:

(1) monitor possible contamination by keeping a record of materials and conditions during pre-flight spacecraft assembly and in curation facility

(2) having a quick and efficient preliminary examination involving many groups outside the facility is cost-efficient, to solve possible handling problems and to maximize scientific output. At the same time, care must be taken to keep track of sample handling conditions, which could be difficult in these conditions. Rules for handling conditions must be given

(3) a portable clean room installed at the landing site of the sample capsule allows the management of the unexpected in good conditions

(4) instrumentation and methods must be adapted to individual missions depending on the science goals and sample type (including size)

(5) the extent of sample damage induced by different characterization methods including those usually considered to be "non-destructive" requires detailed cross-studies.

**Annex 1 Final program**

**Thursday 13/10**

Morning: closed meeting (10 min talks + 5 min questions)
10:00 J. Aleon - introduction and status of WP4
10:15 I. Franchi - deliverable 4.2 : instrument lists
10:30 Y. Marrochi - report on JAXA visit
10:45 A. Hutzler - report on NASA visit

11:00 coffee break

11:10 A. Meneghin - WP2 status
11:25 A. Hutzler - WP3 status
11:40 F. Fouchet - WP5 status
11:55 M. Grady - WP8 status
12:15 A. Longobardo - WP6 status

12:30 -2:15 pm lunch

Afternoon (open meeting, invited talks : 20 min + 10 min questions)

2:15 J. Aleon / M. Gounelle - General introduction
2:30 S. Russell - EURO-CARES presentation and status
3:00 M. Zolensky (NASA JSC) - Diversity of PE for space missions at NASA
3:30 C. Herd (Univ Alberta) - The subzero facility at University of Alberta

4:00 coffee break (20')

4:20 K. Righter (NASA JSC) - Curation plans for Osiris Rex
4:50 J. Duprat (CSNSM Orsay) - Curation of the Concordia micrometeorites

5:20 end of day 1

**Friday 14/10**

open meeting all day (20'+10')

9:00 J. Gattacceca (CEREGE Aix-Marseille) - Non-destructive, non invasive magnetic characterization of extraterrestrial samples
9:30 R. Brunetto (IAS Orsay) - IR, from Hayabusa to asteroid surfaces
10:00 N. Almeida (NHM London) - X-ray CT scan of meteorites
10:30 L. Thirkell (LPC2E Orleans) - TOF-SIMS, contamination and COSIMA

11:00 am : coffee break

11:15 G. Mercier and O. Pigni (Leica) - Sample preparation and digital optical microscopy products
11:45 M. Andrew (Zeiss) - Correlated microscopic techniques including X-ray computed tomography

12:15-2 pm lunch

2:00 round tables
3:00 Gounelle et Aleon wrap up & conclusions

3:30 end of workshop

**Annex 2** Participants

| Participant | Institution | email |
|---|---|---|
| *Speakers* | | |
| J. Aleon | Euro-Cares | jaleon@mnhn.fr |
| M. Gounelle | Euro-Cares | gounelle@mnhn.fr |
| S. Russell | Euro-Cares | sara.russell@nhm.ac.uk |
| I. Franchi | Euro-Cares | ian.franchi@open.ac.uk |
| Y. Marrochi | Euro-Cares | yvesm@crpg.cnrs-nancy.fr |
| A. Hutzler | Euro-Cares | aurore.hutzler@ens-lyon.org |
| A. Meneghin | Euro-Cares | meneghin@arcetri.astro.it |
| J. Brucato | Euro-Cares | jbrucato@arcetri.astro.it |
| M. Zolensky | NASA JSC | michael.e.zolensky@nasa.gov |
| C. Herd | Univ. Alberta | herd@ualberta.ca |
| K. Righter | NASA JSC | kevin.righter-1@nasa.gov |
| J. Duprat | CSNSM - Orsay | jean.duprat@csnsm.in2p3.fr |
| J. Gattacceca | CEREGE - Aix | gattacceca@cerege.fr |
| R. Brunetto | IAS - Orsay | rosario.brunetto@ias.u-psud.fr |
| N. Almeida | NHM London (PhD) | n.almeida@nhm.ac.uk |
| L. Thirkell | LPC2E - Orléans | laurent.thirkell@cnrs-orleans.fr |
| G. Mercier | Leica | Gregoire.Mercier@leica-microsystems.com |
| O. Pigni | Leica | Olivier.Pigny@leica-microsystems.com |
| M. Andrew | Zeiss | matthew.andrew@zeiss.com |
| | | |
| *Other participants* | | |
| V. Debaille | Euro-Cares | vdebaill@ulb.ac.be |
| M. Grady | Euro-Cares | monica.grady@open.ac.uk |
| C. Smith | Euro-Cares | caroline.smith@nhm.ac.uk |
| P. Rettberg | Euro-Cares | Petra.Rettberg@dlr.de |
| O. Bacon | Euro-Cares | o.bacon@nhm.ac.uk |
| F. Fouchet | Euro-Cares | frederic.foucher@cnrs-orleans.fr |
| A. Longobardo | Euro-Cares | andrea.longobardo@iaps.inaf.it |
| E. Jacquet | IMPMC | emmanuel.jacquet@mnhn.fr |
| K. Benzerara | IMPMC | karim.benzerara@upmc.fr |
| O. Beyssac | IMPMC | Olivier.Beyssac@impmc.upmc.fr |
| S. Bernard | IMPMC | sbernard@mnhn.fr |
| V. Sautter | IMPMC | vsautter@mnhn.fr |
| B. Doisneau | IMPMC | beatrice.doisneau@impmc.upmc.fr |
| I. Estève | IMPMC | Imene.Esteve@impmc.upmc.fr |
| V. Vinogradoff | IMPMC (post-doc) | vassilissa.vinogradoff@impmc.upmc.fr |
| P.-M. Zanetta | IMPMC (PhD) | |
| E. Charon | CSNSM - Orsay (post-doc) | Emeline.Charon@csnsm.in2p3.fr |
| G. Slodzian | CSNSM - Orsay | georges.slodzian@csnsm.in2p3.fr |
| J. Borg | L'Astronomie/SAF | borgjanet@gmail.com |

**Annex 2** Photographs

Attentive audience during the presentations. First row from left to right : Petra Rettberg (EURO-CARES), Sara Russell (EURO-CARES), Kevin Righter (NASA), Mike Zolensky (NASA). The workshop took place in the historical room where Marie Curie gave classes.

Round table discussions. Mike Zolensky (NASA) speaking.