ESA Announcement of Opportunity
soliciting for proposals for “Euro Material Ageing”
on-board the International Space Station

AO-2020-EuroMaterialAgeing

Bartolomeo platform on-board the International Space Station ISS (Airbus)
**Summary of this Opportunity**

The European Space Agency announces an opportunity to test materials on the Bartolomeo platform, the newest external platform to the International Space Station. This is a remarkable opportunity for material scientists, experimenters and engineers to test materials for space applications in the full spectrum of the low Earth orbit environment.

The opportunity is a pilot project primarily aimed at raising awareness of the space environmental effects on materials that are already used or are being developed for space applications, especially amongst new or inexperienced players in the space business. Therefore it is targeted to SME, academia and national institutes.

The Principal Investigator (PI) of the proposal shall be working in one of the ESA member or associated member states that contribute to the SciSpace programme.

Test programmes shall be for peaceful purposes only and the results shall be applicable to ongoing or future ESA space projects.

ESA shall cover the cost of flight and integration (including certain preparatory steps) and routine pre/post sample analysis. Samples must be delivered to ESA at no cost and in a timely manner. All other costs are to be borne by the experimenters.

The test results shall be made freely available to ESA for its own activities, for publication in scientific journals and for inclusion in its materials databases (dissemination to scientific community).

The activities covered by this announcement also provide an opportunity for ESA to broaden awareness of the capabilities of the European space materials community. It is expected to gain information about families of materials for future mission planning and modelling purposes.

Investigators of selected experiments are therefore encouraged to promote and communicate their results to a wider audience (e.g. general public, colleagues, and students).

Submissions shall be made in pdf format using the templates provided to:

**Material_Ageing@esa.int**

Online workshop/Q&A session: 11th June 2020

Proposal deadline: 17th July 2020
Contents

1 INTRODUCTION ......................................................................................................................... 3
2 Objectives of the Announcement of Opportunity ................................................................. 4
3 proposal preparation .................................................................................................................. 4
   3.1 Proposal format and content .............................................................................................. 4
   3.2 Eligibility ............................................................................................................................ 4
   3.3 Submission and Schedule ................................................................................................. 5
   3.4 Selection process ................................................................................................................ 5
4 Implementation ......................................................................................................................... 7
5 data rights ................................................................................................................................ 8
   5.1 General .............................................................................................................................. 8
   5.2 The Erasmus Experiment Archive (EEA) ........................................................................... 8
6 LIABILITY .................................................................................................................................. 8
Annex A Overview of the Facility ............................................................................................... 9
Annex B sample analysis ............................................................................................................ 10
Annex C SAMPLE REQUIREMENTS ........................................................................................... 11
INTRODUCTION

The International Space Station (ISS) is a multi-national scientific platform in low Earth orbit allowing for space-related experiments, both inside and external. The newest addition to the ISS is the Bartolomeo payload hosting platform, attached to the European Columbus Module, allowing for an unobstructed access to the outer space and a number of research opportunities for a wide range of space science applications¹.

This document provides an overview on the research opportunity offered as part of the Euro Material Ageing mission, which is a joint collaboration between the European Space Agency (ESA) and the French Space Agency (CNES).

The Euro Material Ageing mission is an external payload which provides an opportunity for material exposure in the harsh space environment. The material ageing phenomena in space has been studied since the early years of the space age² when it was observed that prolonged exposure in space results in materials degradation - with polymers being the family of materials the most severely affected³. Materials can undergo physical and chemical changes of their properties, such as discoloration, cracking or embrittlement, caused by particle and electro-magnetic (i.e. ultraviolet) radiation. Vacuum leads to problems related to outgassing of volatile matter and consequently contamination of spacecraft sensitive surfaces. Materials can also charge in the space environment that may in the worst case lead to so called ESD’s (Electro-Static Discharge) that may be damaging not only to the material but to a whole spacecraft as well. Changing the spacecraft position from sun to shadow causes extreme thermal cycling, resulting in considerable thermal loads that can affect dimensional stability. Additionally, in the low Earth orbit materials are exposed to atomic oxygen, which is highly reactive and prone to oxidize and erode surfaces.

The Euro Material Ageing facility on-board the ISS offers a unique opportunity to expose materials used e.g. on satellites in the complex space environment. It allows comparing on-orbit to ground experiments, enhancing our models and our knowledge about material ageing in space. However, due to the high cost of in-flight testing, access to the ISS is usually only affordable for the larger industrial primes and national agencies. In many cases, the test results are often considered as proprietary and as such are of limited use to the broader space community. Furthermore, it is not cost effective for an organisation to commission a test for just one or two material samples. This opportunity is a way to overcome such issues.

This document provides an overview on the research opportunity offered within this announcement as well as on the sequence of events starting from submission of the research proposal to selection, definition and implementation of successful material samples. This opportunity is a pilot campaign, with a number of recurring further opportunities to test materials in space.

¹ https://www.airbus.com/space/space-infrastructures/bartolomeo.html
2 OBJECTIVES OF THE ANNOUNCEMENT OF OPPORTUNITY

The overall objective of this opportunity is the selection of 45 passive samples to be accommodated on the Euro Material Ageing facility under ESA responsibility.

The specific aims of the opportunity are as follows:

- to promote awareness of the space environment and its effects on materials, including the requirements driving the selection and test of materials and assemblies, especially amongst new players in the space business
- to promote research and development into new study areas within this field (e.g. sensors, new materials)
- to provide testing opportunities for smaller institutes (e.g. SME, academia), who may not have the knowledge or resources to commission a dedicated space exposure test campaign (collaboration and sharing of samples between research teams and projects are encouraged so as to make optimal use of resources)
- to provide test data which can be accessed by the wider space community, with limited restriction on confidentiality
- to increase efficiency of testing by co-ordinating combined test programmes

Please refer for more information to Annex A Overview of the Facility.

3 PROPOSAL PREPARATION

3.1 Proposal format and content

Proposals shall be prepared using the templates provided.

Detailed information about the materials and processes used for the test items shall be provided. Proprietary information shall be identified. This will not necessarily exclude the proposal, as long as “reasonable” transparency is provided. For example, it would not be necessary to specify in detail the design for a multilayer optical coating, but the constituent materials should be identified.

Collaborative proposals are welcomed.

3.2 Eligibility

The opportunity is targeted to SME, academia and national institutes and the Principal Investigator of the proposal must be working in one of the ESA member or associated member states, that contribute to the SciSpacE programme: Austria, Belgium, Canada, Czech Republic, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, The Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, Switzerland, United Kingdom. Scientists from other ESA Member States that do not contribute to the SciSpacE Programme and scientists from other European countries having a cooperation agreement with ESA are encouraged to enquire with their national space organization about the conditions for their participation in proposals to ESA.
Test programmes shall be for peaceful purposes only and the results shall be applicable to on-going or future ESA space projects (clear evidence shall be provided in the proposal).

Scientists that have not worked with ESA before are also encouraged to apply.

### 3.3 Submission and Schedule

A workshop for this Announcement of Opportunity will be held via teleconference prior to the proposal deadline. Please indicate your interest in participating in this workshop in the Letter of Intent. During the workshop, ESA and CNES will provide general information about this opportunity, in addition to information on the characteristics and constraints of implementing material samples on Euro Material Ageing on-board the ISS. The workshop will also provide an opportunity for scientists to network and potentially start collaborations. Letters of Intent will serve as a preparatory input to the workshop.

The schedule for this Announcement of Opportunity is as follows:

- **Online workshop/Q&A session:** 11th June 2020
- **Proposal deadline:** 17th July 2020

The Letter of Intent and proposal shall be prepared electronically as PDF file using the templates provided and sent to the following dedicated email address:

Material_Ageing@esa.int

An acknowledgement of receipt will be sent to the submitting proposer upon receipt and confirmation of completeness of the proposal.

If funding of the research is not in place yet, ESA strongly advises submitting proposers to contact their national representatives to investigate possible national funding procedures and timelines as well as probability of funding in order to identify alternative funding sources if necessary. As a minimum, it is recommended to submit the proposal to their national bodies in parallel with their application in response to this Announcement of Opportunity, in order to initiate applying for national funding as early as possible.

### 3.4 Selection process

ESA will make use of its own experts for the evaluation of proposals. The criteria that will be applied are:

- **Research Platform Relevance**
  - Is this study appropriate to the proposed research platform, *i.e.* can the objectives and protocol be achieved adequately within the capabilities and constraints of the platform?

- **Material Requirements**
  - **Relevance for space applications:** What is the use of the proposed material in current or future space missions?
Novelty: Is the proposed material a new formulation? What is the foreseen benefit of using this material for space applications?

Space heritage: Is the proposed material currently used for space applications but lacks information about its space resistance, i.e. where does it lack information? Has the material been flown to space? If so, how many times?

Data availability: Has the material been analysed in a laboratory environment for space use? If so, which analytical techniques were used and what is their outcome from a space environment point of view? To what level and with which instruments have post-flight analysis been performed?

Sample availability: Is the material available off-the-shelf? If not, what are the expected lead times or preparation times to procure the material? Are there constraints regarding dimensions, shapes etc? Are there constraints regarding handling and mounting of samples?

Technical feasibility
- The samples shall meet the requirements listed in Annex C Sample Requirements.

Scientific Merit
- Significance: Does this study address an important problem? If the aims of the application are achieved, how will scientific knowledge or technology be advanced? What will be the effect of these studies on the concepts, methods, or products that drive this field?
- Approach: Are the conceptual framework, design, methods, and analyses adequately developed, well integrated, and appropriate to the aims of the project? Does a flight proposal build upon a successful foundation of ground studies? Is the proposed approach likely to yield the desired results? Does the applicant acknowledge potential problem areas and consider alternative tactics?
- Innovation: Does the project employ novel concepts, approaches, or methods? Are the aims original and innovative? Does the project challenge existing paradigms or develop new methodologies or technologies?
- Personnel: Does the scientific team have the appropriate level of experience, are sufficient & appropriate personnel dedicated to the project. Is there evidence of the science team’s satisfactory productivity?
- Scientific environment: Does the scientific environment in which the work will be performed contribute to the probability of success? Do the proposed experiments take advantage of the scientific environment or employ useful collaborative arrangements? Is there evidence of institutional support?

In the review, each proposal will receive a score between 0 and 100 points, as follows:

- Outstanding 100 - 91 points
- Excellent 90 - 81 points
- Very Good 80 - 71 points
- Good 70 - 61
- Fair 60 - 46
- Unacceptable 45 - 0 points

The highest scoring proposals will be given priority for the first flight opportunity. Lower scoring proposals may still be accepted as back-up for the first opportunity, or given priority
for a potential follow-on flight opportunity. Unacceptable proposals will be rejected. All proposers will be individually informed of the outcome of the review in a confidential letter. This will include a report with overall scoring, technical review summary and programmatic assessment.

Selected experiments and back-up for the first flight opportunity will then enter a detailed technical feasibility review phase.

The objectives of this phase are the following:

- Assess the compatibility of the proposed samples with the Euro Material Ageing facility
- Identify and rank the areas of technical risk or uncertainty
- Assess the feasibility of the timely delivery of the samples for integration with Euro Material Ageing facility
- Assess the level of compliance with safety requirements

Experimenter may be requested to provide clarifications during this phase. It should be noted that there may be cases where proposals are subsequently rejected if they are considered unfeasible from the technical or resource requirement standpoint. In these cases, the rationale for not selecting these proposals will be clearly identified. The decision of the ESA selection board is final and there is no right of appeal.

4 IMPLEMENTATION

The following preliminary sequence of events is foreseen for implementation of the flight experiments. This is subject to change.

1. Proposal selection
2. Technical feasibility review
3. Finalisation of Euro Material Ageing payload design and sample interfaces
4. Manufacture, test and delivery of flight samples to ESA / ESTEC
5. Pre-flight sample analysis at ESTEC
6. Delivery of samples to payload integrator
7. Flight acceptance review, including safety review
8. Payload launch and in-flight exposure
9. Sample retrieval from ISS and return to Earth
10. Return of samples to payload integrator
11. De-integration and return of samples to ESA / ESTEC
12. Post-flight sample analysis at ESTEC
13. Return of samples to experimenters
5 DATA RIGHTS

5.1 General

The general data policies of ESA's Directorate for Human and Robotic Exploration Programmes will apply to all data resulting from the experiments in the context of this Research Announcement.

Final results of the study shall be made available by the scientific teams to the scientific community through publication in appropriate journals or other established channels as soon as practicable and consistent with good scientific practice. In the event such reports or publications are copyrighted, ESA shall have a royalty-free right under the copyright to reproduce, distribute, and use such copyrighted work for their purposes. Joint publications with ESA and CNES are encouraged when use is made of their reference data and/or sample analysis results. ESA has the right to publish internally and externally the pre/post analysis performed at ESA. If there are any sensitive information it needs to be discussed during the selection process.

Experimenters are also encouraged to provide relevant engineering data and technology results from their experiments for inclusion in ESA/CNES materials and environmental effects databases. This data could be of benefit to space industries involved in the manufacture of future satellite systems.

5.2 The Erasmus Experiment Archive (EEA)

The EEA covers both physical and life sciences, and can be found at the following URL: http://eea.spaceflight.esa.int

The EEA is an ESA service to the international scientific community. Abstracts, from all ESA microgravity experiments performed to date are collected in this database. Experimenters sponsored by ESA have the obligation to provide these abstracts themselves. Special emphasis is placed on the completeness of the list of references of articles where the experiment results can be found.

Scientists in Europe who have performed experiments, either in orbiting or ground-based facilities are encouraged to either provide an abstract on each of their experiments, or to provide information enabling the updating of their existing abstracts, in particular the list of articles published.

6 LIABILITY

ESA will not be liable for any damage to the items furnished by the experimenter, unless caused by gross negligence or wilful misconduct on the part of ESA.
Annex A Overview of the Facility

Euro Material Ageing is a multi-user exposure facility developed by CNES, which will be amounted externally on the International Space Station (ISS) to age materials.

- Euro Material Ageing accommodates active and passive samples. Only the **45 passive samples** are offered in this Announcement.
- The environment data will not be actively monitored on the passive samples. Two atomic oxygen sensors and a quartz crystal microbalance are accommodated on Euro Material Ageing facility. These sensors and balance are not continuously turned-on during the mission. Data will be made available for scientific reasons.
- General housekeeping data from the ISS (e.g. orbital parameters) will also be made available.
- The planned exposure duration in space is expected to be between **6 to 12 months**.
- The samples will be clamped between two aluminium plates, where a surface of **20 mm** in diameter will be exposed to space.

The Euro Material Ageing facility will be amounted in the RAM face of the Bartolomeo platform on ISS. In this configuration samples are facing the velocity vector of the ISS, where atomic oxygen shows the greatest impact.

The preliminary design of the facility and the sample holder is shown in the following figures. **It should be noted that this design is not final and subject to change during subsequent design reviews.** Therefore experimenters should consider some flexibility in their sample design during the proposal phase.
ANNEX B SAMPLE ANALYSIS

ESA plans to conduct a routine analysis on all received samples. Analysis will be performed by qualified personnel, in accordance with applicable standards and procedures. ESA offers the experimenters a number of material characterization techniques. It shall be stated in the proposal what type of additional analysis is required.

B1 Routine analysis

The following routine sample analysis is planned on the received samples before and after the space exposure test:

- Mass loss measurements using microbalance
- Thermo-optical measurement using spectrophotometer
- Visual inspection using digital camera and optical microscope (low resolution only)

B2 Additional analysis

The following analytical equipment is also available in the ESA laboratories for potential additional analysis of the exposed samples:

- SEM/EDX
- Raman spectroscopy
- AFM with several special measurement modes
- XPS
- TOF-SIMS
- Laser confocal microscopy
- Surface conductivity
- FTIR
- High resolution optical microscopy
ANNEX C SAMPLE REQUIREMENTS

Samples should meet the requirements listed in the table below.

The dimension of the samples should be approx. 24.8 mm² (rounded edges) with a thickness of approx. 1-3 mm. The exposed surface will be a diameter of 20 mm. It should be noted that this design is not final and subject to change during subsequent design reviews.

Material samples should be delivered for integration after notification letter sent by ESA.

Detailed requirements for materials which will be supplied as passive samples on the Euro Material Ageing experiment are described in the table below. The methods of verification for the different requirements are defined using the following abbreviations.

A: Analysis
I: Inspection
RoD: Review of Design
T: Test

Table: Requirements for passive samples and methods of verification

<table>
<thead>
<tr>
<th>CNES requirements for samples supply</th>
<th>Description</th>
<th>Methods of verification</th>
</tr>
</thead>
</table>
| Dimensions and geometry              | Passive samples dimensions shall comply with the following dimensions: 
- 24.8 +/ 0.1 mm length, width 
- 1 +/ -0.1 mm, thickness |
|                                      | Design is not yet frozen and some dimensions as thickness may evolve upper then 1 mm. |
|                                      | Passive samples exposed surfaces shall be free of burrs. |
| 1                                    | ROD, I      |
3 Sharp edges and protrusions shall meet the criteria provided in table 2-1.

Table 2-1 Edge and in-plane corner radii

<table>
<thead>
<tr>
<th>Application</th>
<th>Outer Radius</th>
<th>Inner Radius</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Openings, panels, covers</td>
<td>6.4 mm</td>
<td>3 mm</td>
<td>Preferred</td>
</tr>
<tr>
<td>Corner radii in plane of panel</td>
<td>3 mm</td>
<td>1.5 mm</td>
<td>Minimum</td>
</tr>
<tr>
<td>Exposed corners</td>
<td>13 mm</td>
<td>N/A</td>
<td>Minimum</td>
</tr>
<tr>
<td>Exposed edges:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 2 mm tick or greater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 0.5 to 2 mm tick</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Less than 0.5 mm thick</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposed edges:</td>
<td>1 mm</td>
<td>N/A</td>
<td>Minimum</td>
</tr>
<tr>
<td>Small protrusions less than 4.8 mm on manipulative devices</td>
<td>1 mm</td>
<td>N/A</td>
<td>Absolute minimum unless protruding corner &gt; 120</td>
</tr>
</tbody>
</table>

Technical criteria for material selection

4 Materials selection
Passive material samples selection shall be made following the guidelines of ECSS-Q-70-71.

5 Offgassing and toxicity
All samples considered for use in the crew compartment of manned spacecraft shall be evaluated for offgassing and odour contaminants in accordance with ECSS-Q-ST-70-29 (or NASA-STD-6001).

6 Offgassing and toxicity
Usage of passive material samples which produce toxic levels of offgassing products shall be avoided.

7 Flammability
Passive samples shall be evaluated for flammability according ECSS-Q-ST-70-21 or NASA-STD-6001, respectively the ESA and NASA requirements for flammability testing. They are considered as equivalent.

8 Stress corrosion material
Passive material samples shall be selected in accordance with ECSS-Q-ST-70-36

9 Outgassing
Passive samples shall be evaluated for outgassing in accordance with ECSS-Q-ST-70-02, and shall be compliant with the requirement RML<1%, CVM<0.1%. Minor deviations may be accepted but the decision of the ESA selection board is final.

10 Corrosion
Passive samples shall meet requirements of 5.1.9 of ECSS-Q-ST-70 regarding corrosion.

11 Galvanic compatibility
Passive samples shall meet requirements of 5.1.12 of ECSS-Q-ST-70 regarding galvanic compatibility.

12 Sensibility to humidity
Sensibility to moisture absorption and desorption of passive samples shall be identified and specific integration and storage conditions proposed by samples supplier.
| **13 Bacterial and fungus growth** | Passive samples shall meet requirements of 5.1.18 of ECSS-Q-ST-70 regarding bacterial and fungus growth. | A, T |
| **14 Effect of environment** | The effect of the Euro Material Ageing environment on chosen passive material samples shall be reviewed and assessed on a case by case basis. | A, T |
| **15 REACh** | The chosen passive material samples shall not contain substances included in REACh regulation Annex XIV. | RoD |
| **16 Forbidden Materials** | The following materials constitute a safety hazard and are prohibited from being used:  
- beryllium (for structures)  
- beryllium oxide  
- mercury  
- cadmium  
- zinc  
- polyvinyl chloride (PVC)  
- radioactive materials  
- lithium  
- magnesium  
- polyamide insulated cables  
- pure tin | RoD, A |
<p>| <strong>17 Fluids</strong> | Fluids and chemicals require specific constraints (including hazardous chemicals) and shall not be selected for this experiment | RoD |
| <strong>18 Pyrotechnic material</strong> | Pyrotechnic material shall not be selected | RoD |
| <strong>19 Biological material</strong> | Biological material shall not be selected for this experiment | RoD |
| <strong>20 Frangible material</strong> | Frangible materials shall be avoided or the material supplier shall propose containment or protection to control the hazard of the release or generation of FOD for all mission phases. | RoD, A, T (TBC) |
| <strong>21 Shatterable materials</strong> | Shatterable materials shall be identified and contained such that 50 micron or larger particles are not emitted in the cabin. | RoD |
| <strong>22 Evaluation</strong> | The selection of passive material samples for which limited or no test data are available shall be justified or submitted to an evaluation program. | RoD, A, T |
| <strong>23 Evaluation</strong> | The evaluation program shall be submitted, reviewed and accepted by CNES. It will include the following analysis and tests as minimum: flammability, offgassing and toxic analysis, stress corrosion and outgassing. | A |
| <strong>24 Identification</strong> | Passive samples shall be identified by a unique reference number, code or a lot number to provide traceability. A material identification card shall be provided. | I |
| <strong>25 Procurement</strong> | Passive samples shall be procured with inhouse receipt inspection or specification which defines and guarantees the materials properties | A |</p>
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>26 Long lead items</td>
<td>Passive samples with long lead times or long procurement delays, versus the project schedule, shall be identified. Backup plans shall be prepared and initiated whenever there is evidence of delays or technical problems.</td>
</tr>
<tr>
<td>27 Storage</td>
<td>The supplier of passive samples shall define provisions for packaging, storage and removal from storage for materials.</td>
</tr>
<tr>
<td>28</td>
<td>Measurements and inspections used to guarantee the material integrity and monitoring during storage and removal from storage shall be identified.</td>
</tr>
<tr>
<td>29 Material safety datasheet</td>
<td>Material safety datasheet or equivalent shall be available for passive material samples.</td>
</tr>
<tr>
<td>30 Volatile Organic Compound</td>
<td>The release of the following water-soluble volatile organic compounds into the ISS habitable environment is prohibited: - methanol - ethanol - isopropyl alcohol - n-propyl alcohol - n-butyl alcohol - acetone - ethylene glycol - propylene glycol. This requirement may not apply in the following cases: a) The release of these compounds by normal materials offgassing. b) The water-soluble volatile organic compound is properly contained and released to the habitable environment only as a result of a single barrier failure (redundant containment not required). A Volatile Organic Compound Usage Agreement (VUA), as defined in the applicable DRD, shall be submitted to ESA for requesting usage approval of hardware containing the above forbidden volatile organic compounds.</td>
</tr>
<tr>
<td>31 Cleanliness</td>
<td>Samples provided for the Euro Material Ageing experiment shall comply, unless otherwise specified, with the cleanliness requirement Visibly Clean Standard, i.e. the absence of all particulate and non–particulate to the normal unaided eye (except corrected vision), when examined under oblique white light of more than 540 lux and from a distance of 150 to 300 cm. Provide a certificate of cleanliness upon samples delivery.</td>
</tr>
<tr>
<td>32 Number of samples</td>
<td>Samples shall be provided in triplicate for the need of exposure on the Euro Material Ageing facility, reference and spare. Additional samples as spare and on-ground reference should be provided. These samples would follow the flight samples during on-ground processing but would then be kept on ground for later comparison.</td>
</tr>
<tr>
<td>33 Mechanical qualifications</td>
<td>Passive samples have to be compliant with the following mechanical tests based on AD 8 on the 3 axis X,Y,Z - Sinus environment Table 2-2: sinus environment conditions</td>
</tr>
</tbody>
</table>
### Axis/mass unit

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Acceleration qualification (g²/Hz)</th>
<th>Frequency (Hz)</th>
<th>Acceleration qualification (g²/Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perpendicular Axis</td>
<td>Parallel plan axis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 21-100  | 25g               | 21-100  | 25g               |
| Duration  | 120s/axis            | Duration  | 120s/axis            |

#### Random environment

**Table 2-3: random environment conditions**

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Acceleration qualification (g²/Hz)</th>
<th>Frequency (Hz)</th>
<th>Acceleration qualification (g²/Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perpendicular Axis</td>
<td>Parallel plan axis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 20-100  | +/-3 db/oct                | 20-100  | +/-3 db/oct                |
| 100-300 | 1.5g²/Hz                  | 100-300 | 0.25                  |
| 300-2000 | -5dB/Oct                  | 300-2000 |                                    |
| -       | 29.3gRMS                  | -       | 12 grms (1sigma)               |
| Duration  | 120s/axis                | Duration  | 120s/axis                |

ESA reserves the right to perform additional screening in order to validate the requirements. Experimenters should also note that the final decision on flight safety will be made by the relevant safety review panel.