DLR-ESA Joint Announcement of Opportunity for Parabolic Flight Electro-Magnetic Levitation Experiments (TEMPUS)

AO-TEMPUS-2025

European Space Agency
Agence spatiale européenne

1 INTRODUCTION

German Space Agency

Within the "National Programme for Space and Innovation", the German Space Agency at DLR provides national funding for space research and the development of innovative technologies. This not only drives exploration and scientific knowledge gain, but also provides key contributions to societal challenges like health, climate protection, mobility, communication, or safety.

One of the programme's focus areas, "Research and Exploration", covers biological, human physiological, physical, materials science, and exploration topics. It funds scientific research with a space background and/or realises experiments which utilise specific space conditions for their research objective – like for instance absence of gravity. To provide or simulate space conditions, access to Earth-based space analogues and different microgravity platforms like drop towers, sounding rockets, the International Space Station (ISS), and parabolic flights is offered by the German Space Agency at DLR. Beyond national activities, the German Space Agency at DLR also realises cooperation with other space agencies in this programme. One is the contribution to ESA's Exploration Science programme with dedicated collaborations, as for the Electro-Magnetic Levitation experiments on parabolic flights (TEMPUS) and onboard the International Space Station (EML-ISS).

European Space Agency

ESA's Exploration Science programme includes scientific activities on research platforms such as ground-based space analogues (e.g., bedrest studies, research on Antarctic stations, radiation facilities, drop tower, sounding rockets, parabolic flights), as well as an ambitious research programme onboard the International Space Station. The Exploration Science activities cover science in the domains of human research, biology (including astrobiology), planetary sciences and physical sciences, with an emphasis on scientific excellence, space research- and exploration-relevance, innovation and timely delivery.[1] Its research results will advance Europe's knowledge base, support its economy and help prepare future human and robotic space exploration. In addition to gaining fundamental knowledge, the research carried out within ESA's Exploration Science programme is helping to deliver solutions to problems back on Earth; e.g., developing innovative materials to manufacture products, removing pollutants from water, improving engine efficiency, testing new medical techniques and support equipment for the elderly and disabled.

This Announcement of Opportunity (AO) falls within the domain of **solidification physics**, and more in particular addresses the topic of microstructure formation and materials' properties. The document at hand provides an overview of the research opportunity offered within this announcement and of the sequence of events starting from the submission of the research proposal to the selection, definition and implementation of successful experiments.

[1] Buckley N.; *SciSpacE Strategy*; ESA report ESA-HRE-RS-PL-32 (issue/revision 1.0, 22/10/2022)

2 OBJECTIVE OF THIS OPPORTUNITY

The objective of this call for proposals is the selection of an appropriate number of samples and experiment cycles for the 2025 TEMPUS experiment on the 45th DLR parabolic flight campaign. This campaign includes three flight days with 31 parabolas each and is currently scheduled in the **weeks 43–44** (**October 20–31, 2025**). The contingents of the German Space Agency and the European Space Agency that are the subject of this joint AO comprise of 31 parabolas (experiment cycles) each.

The TEMPUS[2] facility enables containerless processing of metallic and other electrically conductive liquids excluding the effects of gravity and can be used for the study of solidification mechanisms (e.g., crystal nucleation and growth, multiphase growth, and glass formation) and the measurement of thermophysical properties (e.g., specific heat capacity, surface tension and viscosity) amongst others. Extending scientific knowledge in these areas is of pinnacle importance in further advancing the predictive capabilities of numerical modelling approaches for casting and solidification processes, which in turn are key to the manufacturing of almost all (metallic) industrial and consumer goods on Earth.

In addition to scientific investigations, the TEMPUS facility also serves to qualify new materials and alloy compositions for the Electro-Magnetic Levitator onboard the International Space Station (EML-ISS), realised and operated by DLR and ESA as a joint undertaking. Sample selection for EML-ISS is done following dedicated Announcements of Opportunity (for batches of 18 samples). The enduring and enhanced microgravity conditions on the ISS allow for longer experiment durations, experiment repetitions for statistical purposes and parameter studies, as well as enable measurements at unprecedented accuracy.

Specifics of this Announcement of Opportunity are as follows.

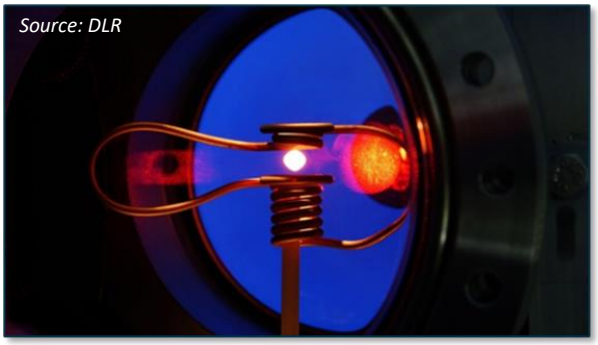
- In addition to established research teams and projects (e.g., DLR or ESA AO projects), scientists that have not worked with TEMPUS before are encouraged to apply. Further, first-time Principal Investigators are encouraged to apply so as to foster a new generation of scientists to conduct research with TEMPUS and EML-ISS.
- Collaboration and sharing of samples between research teams and projects is encouraged so as to make optimal use of resources.
- The proposed samples/experiments are to be novel versus the alloy systems, chemical compositions and investigations that have been undertaken before, as being documented in scientific literature amongst others.

[2] Tiegelfreies Elektromagnetisches Prozessieren unter Schwerelosigkeit (Containerless electromagnetic processing in zero-gravity)

3 THE FACILITY TARGETED WITH THIS OPPORTUNITY

TEMPUS is an electromagnetic levitation facility regularly flying on DLR parabolic flight campaigns. It provides containerless melting and solidification of electrically conductive, spherical samples under ultra-high vacuum or high gas-purity (argon or helium) conditions. As a multi-user facility, TEMPUS performs experiments proposed by the scientific community, supported by the German Space Agency at DLR, the European Space Agency and the DLR Institute of Materials Physics in Space.


Source: DLR


Source: DLR

In TEMPUS, a sample is levitated by an electromagnetic field that is created by an alternating high-frequency current passing through a coil. The induced eddy currents in the sample lead to heating and positioning, and by that enable containerless processing of for instance highly reactive liquid metals. In microgravity (such as during the 0g phase in parabolic flight), no lifting force but only a residual positioning force is needed. This means that the coil current can be strongly reduced after melting, so that stirring of the molten droplet is minimised. Therefore, investigations can be performed under well-defined and reduced convection conditions.

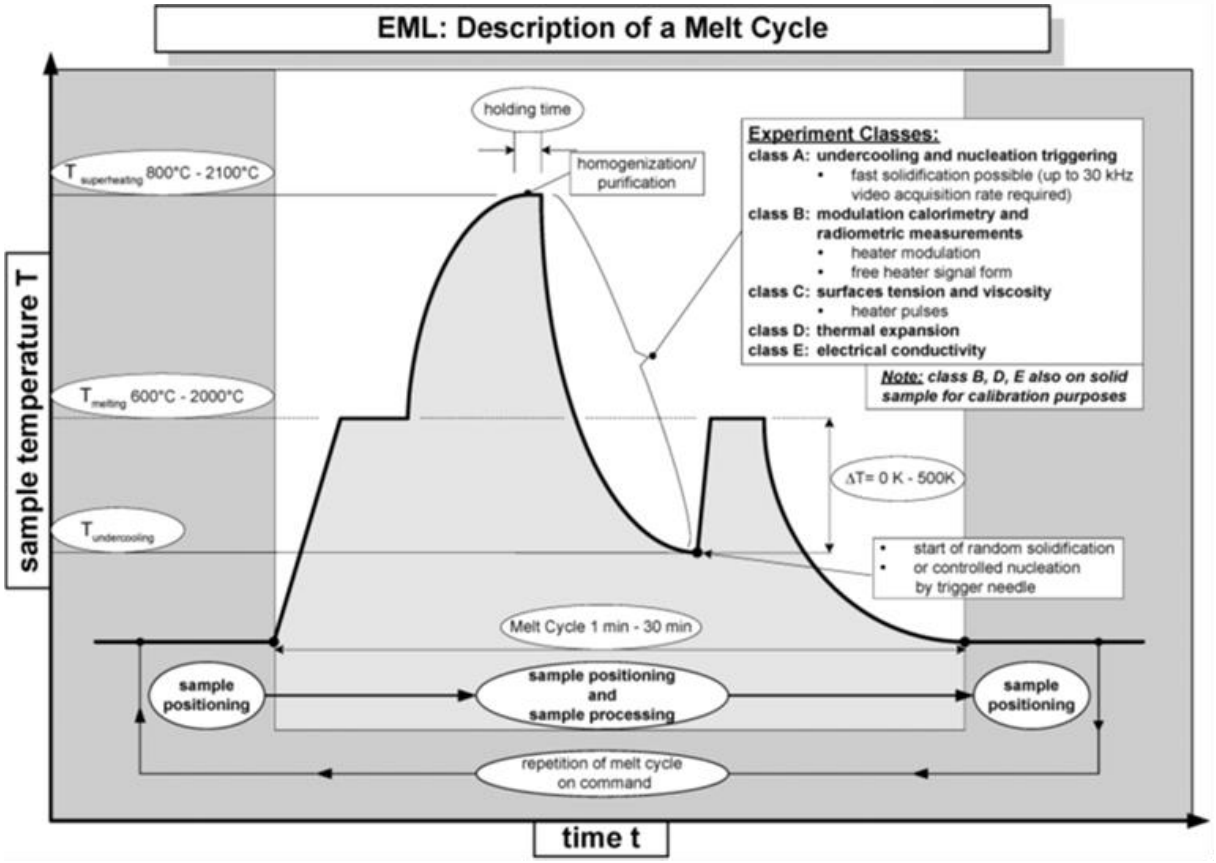
Basic specifications / user data are listed in the table.

	SPECIFICATION	COMMENT(S)
GENERAL		
Temperature range	400–2,100 °C (900–2,000 °C common)	
Sample size	∅6.0–8.0 mm (∅6.5–7.5 mm common)	Compromise between heating time, coupling and containment, among others
Sample holders	Cup (cage)	Cage in exceptional cases
Chill plate	No/Yes	To mimic a chill of the melt (exceptional use, requires specific sample holder, of limited availability)
OPTIONS		
Cooling	Free/convective	Depends on gas atmosphere (convective>helium>argon>vacuum)
Pulses	No/Yes	For oscillating drop method (surface tension, viscosity)
DIAGNOSTICS		
Pyrometer	300–2,100 °C	For temperature measurement

	SPECIFICATION	COMMENT(S)
Radial camera	200–400 Hz (typical), 1 kHz (max. whole cycle), 5 kHz (max. short); 896×800 pixels	For surface tension and viscosity measurements
	40 kHz; 512×512 pixels	For nucleation and solidification front observation
Axial camera	25–150 Hz	For general observation, and additional surface tension and viscosity evaluation (@150 Hz)
Infrared camera	1 kHz; 384×384 pixels	For observation of low melting-point alloy samples (<700 °C)
Sample Coupling Electronics (SCE)	No/Yes (400 Hz)	For electrical conductivity measurement
SAMPLE MATERIALS		
Electrical conductivity	Metallic, semi-conductors	Needed is an adequate inductive coupling with the coil
Surface condition	Free of oxides and other contaminants	Generally beneficial to maximise undercooling potential
Evaporation	Volatility of alloying constituents during processing	Excessive dust generation may disturb levitation stability and sample visibility (mirror contamination)
Other		Not posing a safety hazard to facility, flight and crew (e.g., radioactivity)

The samples are processed one by one with predefined settings, stimuli and diagnostics, and this is being monitored and controlled to some extent by crew onboard. Per flight day a maximum of eight to nine samples can be accommodated. A process cycle consists of the heating and melting of the sample up to the superheating/peak temperature and holding time, followed by cooling while simultaneously gathering science data according to specific cycle types (a generic temperature-time profile is shown in the figure[3]). The next cycle starts with the (p)re-heating of the sample ahead of the subsequent 0g phase. A sample can be used for multiple cycles to achieve the science objectives.

[3] Soellner W., Seidel A., Stenzel C., Dreier W., Glaubitz B.; "EML – Containerless processing facility for materials science research onboard the ISS"; *Journal of the Japan Society of Microgravity Application* 27/4 (2010): 183–189 (DOI 10.15011/jasma.27.4.183)



Process cycle types that can be implemented are the following (T = thermophysical properties, S = solidification, O = other).[4]

- **T1: specific heat**. Not applicable for TEMPUS (time window too short for modulation calorimetry).
- **T2: surface tension, viscosity**. Measurement of surface tension and viscosity by means of the oscillating drop method, implying that the sample is excited by a short-duration pulse of the heater field and then the frequency and damping time of the surface oscillations are recorded.
- **T3: electrical conductivity, density, thermal expansion**. Measurement of electrical conductivity (and its inverse electrical resistivity) and the radius of the liquid droplet by using the Sample Coupling Electronics (SCE). With a known sample mass, density and thermal expansion can be derived from the SCE, but also from the camera recordings. Continuous registrations during cooling deliver these properties in dependence on temperature.
- **T4: emissivity**. Measurement of total hemispherical emissivity from the thermal radiation of the sample. Only for indicative purposes for TEMPUS (time window too short for stepwise cooling).
- **S1: spontaneous nucleation**. Measurement of solidification growth velocity, following spontaneous nucleation upon undercooling of the melt. Successive cycles can be applied to collect statistics and/or to explore different levels of overheating and/or fluid flow (i.e., electromagnetic stirring by varying heater voltage).

[4] Due to the limited duration of microgravity in parabolic flight, the range of cycle types and options is smaller than for the EML-ISS

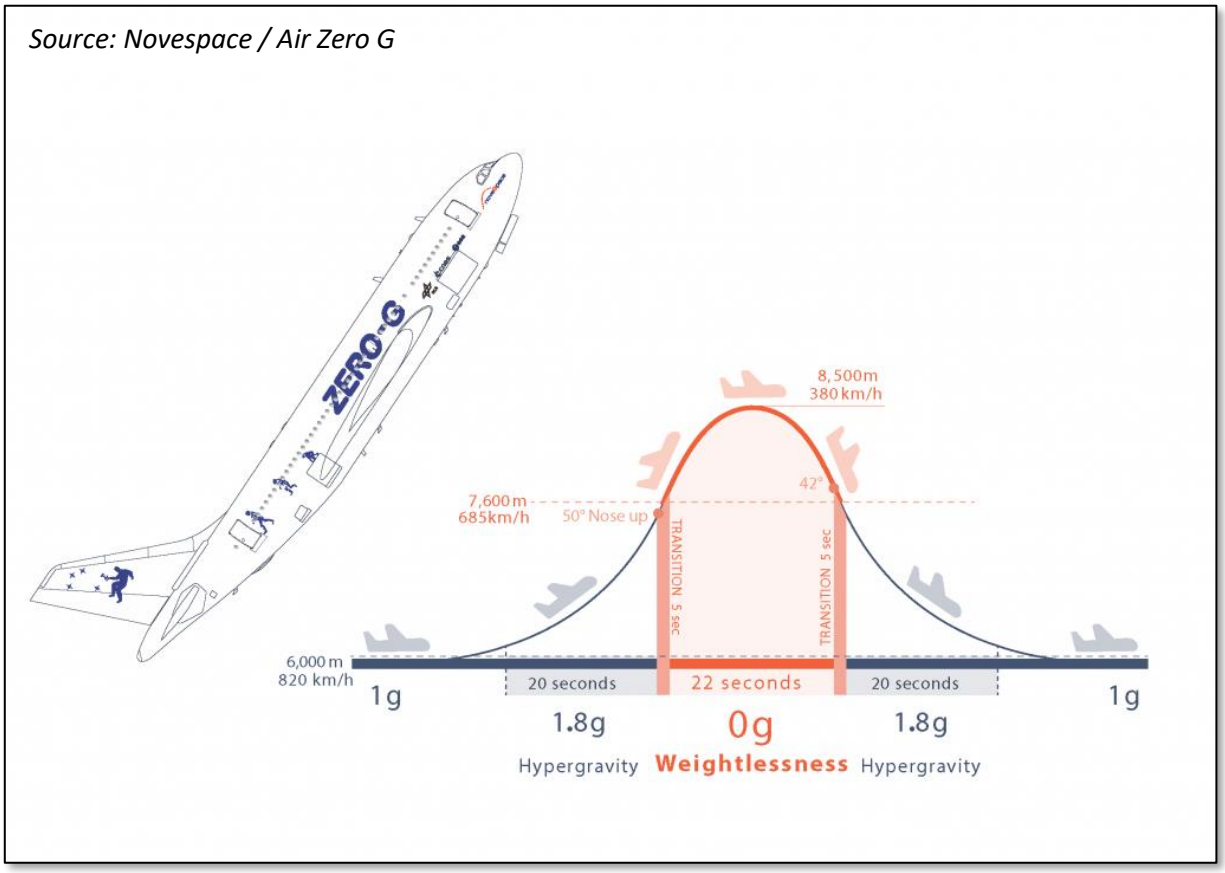
- **S2: forced nucleation**.[5] Measurement of solidification velocity, following forced nucleation at some distinct temperature by the trigger needle. Cooling rate is affected by atmosphere and heater voltage (which also induces stirring). Successive cycles can be applied to explore different solidification trigger temperatures.
- **S3: forced solidification**.[6] Measurement of solidification velocity and evolution of sample shape and dimensions, following forced nucleation and crystal growth at some distinct temperature by the chill-cooling plate. Cooling rate is affected by atmosphere and heater voltage (which also induces stirring). Successive cycles can be applied to explore different chill temperatures.
- **S4: solidification microstructure**. Final solidification of the sample during free cooling for the purpose of post-flight investigations of the solidification microstructure.
- **Ox: other**. Cycle types other than described in the above. Separate specifications with have to be given.

In addition to the various settings, options and diagnostics, also the processing atmosphere (argon or helium) is to be specified. Process cycles are to be elaborated in conjunction with the Microgravity User Support Centre (MUSC; Cologne, Germany) during the ground preparation phase of the experiments. Their implementation is of course within the capabilities and constraints of the TEMPUS facility and the processing envelopes that can be realised.

The 0g phase during a parabola of the used Novespace Airbus A310 Zero G provides about 20 seconds of weightlessness which thereby sets the time window for the investigations and measurements during a single TEMPUS experiment cycle.[7] A flight day consists of 31 parabolas, sub-divided in blocks of five (and one of six). A full parabolic flight campaign includes three or four flight days.

[5] Special case, to be confirmed if this cycle type can still be done on TEMPUS
[6] Special case, requires dedicated sample holder
[7] https://www.airzerog.com/the-airbus-a310-zero-g/

Source: Novespace / Air Zero G



4 APPLICATION PROCESS

4.1 Who can apply

Science teams responding to this Announcement of Opportunity have to comply to the following eligibility conditions, depending on the space agency to which they are submitting their proposal. Science teams that qualify for both can select either but may be subject to rearrangement between DLR and ESA for programmatic reasons.

German Space Agency

The scientific institution of the applicant(s) must be located in Germany. Joint research proposals, led by a German institution, are also eligible.

European Space Agency

The scientific institution for which the coordinator of a proposal is working must be located in one of the ESA member or associated member states that contribute to the Exploration Science programme: Austria, Belgium, Canada, Czech Republic, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway, Poland, Romania, Spain, Sweden, Switzerland, United Kingdom. Scientists from other ESA Member States that do not contribute to the Exploration Science programme and scientists from other European countries having a cooperation agreement with ESA are encouraged to enquire with their national space organisation about the conditions for their participation in proposals to

ESA. Submissions from international investigators that are part of the interagency agreements on collaborative research using the EML facility are also welcome.

4.2 Preparing and submitting the proposal

Please submit your proposal by clicking "Submit Your Idea" and by filling in all sections of the submission form. You can also use this platform to ask questions if needed. Proposals for this Announcement of Opportunity are due by **April 25, 2025; 24:00 CET**.

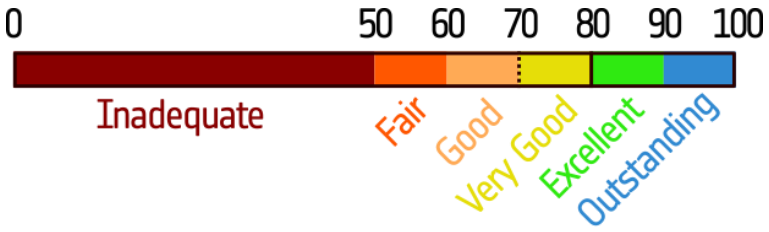
4.3 Evaluation of proposals

ESA will make use of independent experts for the relevance and scientific merit evaluation of proposals. The evaluation criteria that will be applied for evaluation of the proposals are as follows.

Scientific Merit

- **Significance** (50%). Does the proposed study address an important problem or challenge indicated within the AO? Is there a clear, well-grounded and elaborated scientific justification and motivation provided in the proposal? Does the proposed research lead to an advance which is incremental or paradigm shifting?
- **Approach** (35%). Are the conceptual framework, design, methods, and analyses adequately developed, well integrated, and appropriate to the aims of the project? Will the experiment yield statistically robust results and if not, is it justified? Does the applicant acknowledge scientific risks and suggest mitigation? Has a data management plan been provided? Is the requested platform mandatory for the proposed study, or can other (laboratory) means be used before using this platform?
- **Knowledge translation** (15%). Will the results of the research provide a benefit to Earth or for space exploration? Will the results (or other aspects related to the experiment) have a sustained impact on research in the future?
- **Personnel and Environment** (pass/fail). Are there sufficient and appropriate personnel dedicated to the project?

Each proposal will receive an overall scientific merit score between 0 and 100 points, corresponding to the weighted average of the above-mentioned criteria. The proposals will receive one of the following marks.



Only proposals receiving a scientific merit score of Excellent or higher (score of 81 or higher) will be selected for implementation. Furthermore, a minimum score of Very Good or higher (score of 71 or higher) or a pass for pass/fail criteria is needed for each individual criterion. This is to ensure the selection of balanced proposals across the scientific merit criteria.

Additional Evaluation Criteria

- **Relevance** (pass/fail). Can the objectives and protocol be effectively achieved within the capabilities and limitations of the platform? Is there a demonstrated necessity for utilising the chosen research platform? For calls related to the space station, does the proposal justify why the experiment cannot be conducted on the ground? Will the proposed research significantly benefit from the unique conditions offered by the selected platform? Does the proposed research align with ESA's Exploration Science research strategy and address the specific questions outlined in the call for proposals?
- **Programmatic assessment** (pass/fail). To ensure efficient programme implementation within a defined timeline, experiment selection will be balanced with available resources and programme capabilities. ESA will choose experiments from each Announcement of Opportunity (AO) based on existing research pools and work plan. Furthermore, to foster inclusivity and equal opportunities within the Exploration Science programme, ESA encourages the submission of diverse proposals. This includes promoting balanced collaborations among institutions and scientific communities from all ESA Member States, ensuring representation across early-career and senior scientists, as well as gender diversity.
- **Preliminary Technical Feasibility Assessment** (pass/fail). Each proposal will undergo an internal, preliminary pass/fail technical and operational feasibility assessment. This assessment will be done either prior to or in parallel with the peer review process. This assessment aims to determine the proposal's compatibility with the capabilities of the chosen research platform, evaluate the technical, operational, and development complexity of the required hardware and activities, and identify the resources necessary for successful project implementation.

Following approval of the proposed selection, the proposers will be individually informed of the outcome of the review in a confidential letter. This will include the report of the scientific peer review with overall scoring and programmatic assessment. The results of the selection will be final and not open to appeal. A positive selection may still require adjustments to enhance scientific return and optimise feasibility.

5 IMPLEMENTATION OF THE SELECTED PROPOSALS

Proposal coordinators will be informed by DLR and ESA about the outcome of the review shortly (weeks) after the proposal submission deadline. It should be noted that the acceptance of a proposal is not a guarantee for a flight opportunity, but that the successful implementation also depends on the technical feasibility of the science requirements, the acceptability of the samples, as well as on any emerging programmatic (e.g., contractual) constraints. DLR and ESA reserve the right to select only a part of a proposed experiment if this portion is still of high relevance. The applicant will be given the choice to accept or decline such a partial opportunity. If two or more proposals address similar problems and/or adopt similar approaches, it may be requested that the science teams consolidate specific parts of their proposals into a single experiment and work as one team.

Costs of the parabolic flight campaign including its preparation and the science data archiving are covered by DLR/ESA. Science teams have to arrange their own budget for science activities, travel/subsistence and insurance through institutional support and/or through their national space agencies and/or other sponsors.

After proposal acceptance, the sequence and timing of events is as follows.

- **June 13, 2025**. Delivery of ground samples (1 per selected sample composition; spherical, with a radial hole of about ∅1.1 mm to sample centre) to MUSC. These samples will be used to measure sample properties relevant for performing the planned experiments (emissivity, coupling to the electromagnetic field). As a part of ground preparation, also the experiment scripts will be developed by MUSC in conjunction with the science teams.
- **September 26, 2025**. Delivery of flight samples (number of samples depending on science objectives and experiment selection, 1–3 to be decided) to MUSC. Samples that are not sensitive to oxygen exposure will already be pre-integrated into the TEMPUS sample chamber ahead of the actual campaign.
- **October 20, 2025** (to be confirmed). First day of the parabolic flight campaign at Novespace (Bordeaux, France). While the first week will primarily be dedicated to flight preparation (safety briefings, sample integration,…), the second week will include the actual flight days with experiment execution. There is a limited capacity for scientists to fly with their samples for on-board finetuning of the experiments. Ending date of the campaign is **October 31, 2025** (to be confirmed). Processed samples are returned to the science teams for post-flight (metallographical) analysis.
- **November–December 2025**. Science data available from the data repository (HyperTest).
- **March–April 2026**. Meeting between science teams, DLR and ESA to report on the experiment findings. Venue for this meeting will be DLR Space Administration (Bonn, Germany).

The schedule may be adapted, pending any currently unanticipated developments.

6 DATA RIGHTS

German Space Agency

German Space Agency at DLR adheres to the General Data Protection Regulation (GDPR).[8] The scientific institution of the applicant (domiciled in Germany) has to adhere to this regulation as well.

European Space Agency

Please see the Attachment titled “DataRights_PF_final”.

[8] Datenschutz-Grundverordnung (DS-GVO)