Peertechz

Innovations in Aerospace Science and Technology
ENGINEERING GROUP
OPEN ACCESS JOURNAL
DOI: https://dx.doi.org/10.17352/iast

Short Communication

SCAMIX: Small Capsule for Microgravity Experiments

Philippe Reynier*

Engineering and Advanced Systems, France

Received: 04 July, 2025
Accepted: 28 July, 2025
Published: 29 July, 2025

***Corresponding author:** Philippe Reynier, Engineering and Advanced Systems, 16 Chemin de l'Ousteau du haut, 33610 Cestas, France, Tel: +33 5 56479274; E-mail: Philippe.Reynier@isa-space.eu

Keywords: Microgravity; Flight experiment; LEO; Space capsule

Abstract

This contribution focuses on the assessment of the needs for a microgravity platform for performing scientific experiments in LEO. This point is a consequence of the ISS's end of life. To fill this gap, an assessment of the existing microcapsules developed so far is performed. Additionally, first results for paving the way to provide a platform for performing such flight experiments are shown through the first elements of a dedicated aerothermodynamic database.

Abbreviations

DOC: Demise Observation Capsule; ISS: International Space Station; LEO: Low Earth Orbit; REBR: Re-Entry Break-up Recorder

Introduction

Testing microgravity payloads can be performed using different platforms; these platforms, with their characteristics in terms of microgravity level and test duration, are shown in Figure 1. The figure highlights. A lack of European capabilities for testing durations higher than 10 minutes. There are existing capabilities in Europe with drop towers, zero-g aircraft flight, and sounding rockets, but for longer tests, it is necessary to fly the experiments on the ISS or Foton/Bion missions. However, these solutions suffer from some drawbacks:

- Foton/Bion missions are operated by Russia, and like ISS, suffer from a long delay (for a couple of years) for flying experiments in orbit;
- The testing on ISS could be attractive with a crew to operate experiments; however, the delay for accessing is long (and sometimes so long that the payload has to be reconfigured), and the cost is rather high. Additionally, ISS will last until 2030 with a de-orbit in 2031, and no replacement is planned so far.
- There is a lack of European capabilities for testing microgravity experiments for a couple of days; there is no microgravity platform covering this gap.

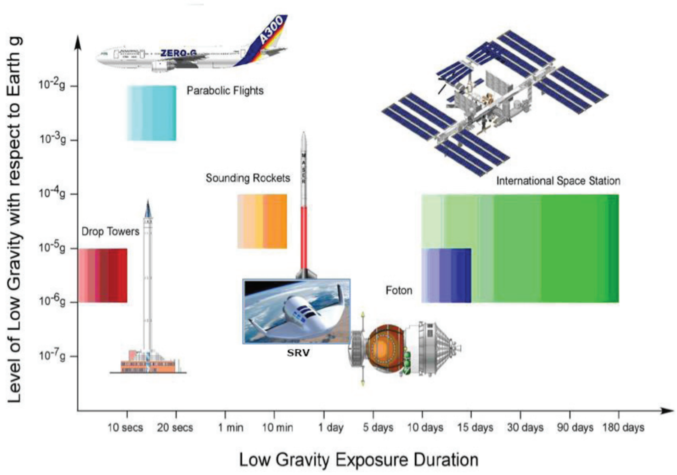

Figure 1: Microgravity platforms (credit: ESA).

Citation: Reynier P. SCAMIX: Small Capsule for Microgravity Experiments. Innova Aerosp Sci Technol. 2025;3(1): 013-015.
Available from: https://dx.doi.org/10.17352/iast.000006

To resume, the end of ISS will induce a strong reduction in the available capabilities for microgravity experiments, and only short-term capabilities will remain in Europe. This will impact European research institutes operating scientific experiments in a microgravity environment, except if a dedicated platform is developed.

Method

For the time being, a commercial alternative for testing payloads in microgravity conditions for long durations (a couple of days) does not exist. To mitigate this issue, there is a need for a platform to fill the gap. This can be performed in low LEO using a small and flexible capsule for testing payloads in a microgravity environment, with shorter delay and lower cost than on ISS. The aim of the SCAMIX (Small Capsule for Microgravity Experiments) project is to provide such an open commercial capability for the testing of payloads in microgravity conditions, with a high level of flexibility, and keeping the cost as low as possible. Compared to the current possibilities to test payload in LEO, SCAMIX will present two main advantages. For the time being, the only way to do microgravity testing for a longer period than 10 minutes is to fly on the ISS. The delay to access it is quite long, more than 5 years, for SCAMIX. The objective is to fly a capsule, once a year, to start the service. Then, the flight occurrence will be increased as a function of the needs and launch opportunities. Concerning the launcher, the baseline will be to launch on Ariane 6; the alternative will be to use SpaceX launchers, depending on their availability. Due to the small size of the capsule, launches on smaller launchers will also be possible.

The mission duration will be limited to a maximum of one week, and the power generation autonomy will be ensured by a battery. Solar panels are not an option since one of the objectives is to have a reusable capsule. Concerning the thermal stability, heating from external sources such as solar heating will be addressed using the thermal protection system of the capsule. If necessary, thermal radiators will be used.

Concerning the cost analysis, the first cost estimates show an exploitation cost lower than the use of ISS. The flight cost for a payload on SCAMIX is estimated to be in the order of 1-2M€, while the same cost for flying on ISS is higher than 5M€.

On the technical aspects, the development of this platform is very challenging; the main point is the reduce mass and size, which is even more constrained when considering a descent system for recovering the capsule. The second point is the power limitation to the selection of the battery alimentation, with for consequence a limitation of the available power for the payload. However, the recent developments for the miniaturisation of subsystems and the progress made for improving battery performance allow us to reduce the risks associated with the project.

This platform would offer the space ecosystem the possibility to test and fly scientific and industrial payloads with more flexibility and lower cost than the current possibilities.

Discussion

The proposed capsule design will draw heavily from experience obtained from previous micro-entry capsule designs and similar re-entry vehicle projects. In particular, the design will be highly influenced by recent advances in "black box"-type destructive re-entry recorder vehicles such as the successfully flown Re-Entry Break-up Recorder (REBR) built by the Aerospace Corporation [1]. A more recent example, to be first deployed in 2018, is the Demise Observation Capsule (DOC) designed by S&T [2].

Even smaller-scale mission concepts exist, such as the QARMAN entry CubeSat reported by Sakraker, et al. [3] and the IRS MIRKA2 capsule project developed by Ehresmann, et al. [4] In the latter case, the outer diameter of 100 mm of the capsule mould line, which constitutes a scaled-down version of the geometry used for the Mars Microprobe mission [5], and was also utilised for REBR, renders it fully compatible with the dimensions of a CubeSat. Thus, MIRKA2 constitutes the smallest entry vehicle designed to date. A precursor mission has succeeded in verifying important operational aspects of MIRKA2, including an efficient, fully functional instrumentation, and a data transfer link based on a strongly miniaturised vehicle bus. Whereas the knowledge obtained about miniaturisation and efficient ground communications will prove valuable in itself for the proposed project, the small size severely limits the use of entry capsules of CubeSat-equivalent proportions for the operation and intact return of scientific payloads, and thus, platform sizes that are similar to those of REBR and DOC are considered a reasonable minimum.

None of the aforementioned micro entry capsules was designed for extended autonomous operations in LEO in independence of a host vehicle, as the respective spacecraft bus configurations are currently incapable of providing sufficient power for extended durations to on-board powered scientific payloads. For typical mission profiles, the capsules are maintained in a dormant operational mode until shortly before re-entry, whereupon they are activated for a short operational lifetime. The proposed design of SCAMIX will accordingly attempt to maintain ties to existing and currently planned micro-entry vehicle designs, attempting to roughly emulate them with regards to sizing, however, further expanding on their degree of subsystem miniaturisation and autonomy to enable the extended autonomous or semi-autonomous operation and/or retrieval of microgravity experiments.

To pave the way to the capsule development, the first step of the project is to select a capsule geometry and to develop its aerothermodynamics database. First efforts [6] have been undertaken, and preliminary results have been obtained by computing the 3D flow-field for atmospheric re-entry conditions using SU2 (https://su2code.github.io/docs/Test-Cases/). Calculations were performed for laminar conditions and accounting for chemical non-equilibrium around a Soyuz-shaped capsule (Figure 2). A 3D mesh was created using GMSH [7], the computational mesh is made with tetrahedra and is completely unstructured with 3,762,824 elements. A hypersonic

Citation: Reynier P. SCAMIX: Small Capsule for Microgravity Experiments. Innova Aerosp Sci Technol. 2025;3(1): 013-015.
Available from: https://dx.doi.org/10.17352/iast.000006

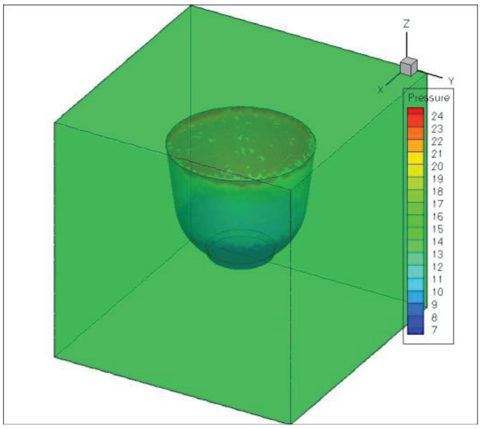

Figure 2: Pressure field computed around a Soyuz-shaped capsule for a hypersonic flow at Mach 18.

flow at Mach 18, typical of re-entry conditions from LEO, has been computed. This effort was performed to assess the tool capabilities for the automatic generation of aerodynamic databases in order to foster future capsule development.

Conclusion

In this contribution, an assessment of the available European capabilities for long-duration microgravity tests has been performed, highlighting the need for a dedicated platform. This last could be developed on the basis of the existing heritage for small capsule accounting for recent progress in space subsystem miniaturisation. Finally, the first elements for future SCAMIX development have been presented, preparing the way for filling the current gap for LEO testing of scientific experiments.

Acknowledgement

This work was for a part financially funded by the PRACE project funded in part by the EU's Horizon 2020 Research and Innovation programme (2014-2020) under grant agreement 823767.

References

1. Ailor W, Weaver M. Reentry Breakup Recorder: An Innovative Device for Collecting Data during Breakup of Reentering Objects. In: Proceedings of the 5th IAASS Conference A Safer Space for Safer World; 2012; Noordwijk, The Netherlands. Available from: https://ui.adsabs.harvard.edu/abs/2012ESASP.699E..68A/abstract

2. Science & Technology Corporation. Demise Observation Capsule (DOC) for re-entry science and safety. Science & Technology Corporation. Available from: http://stcorp.nl/highlights/demise-observation-capsule-doc-re-entry-science-and-safety/

3. Sakraker I, Umit E, Scholz T, Testani P, Baillet G, Van der Haegen V. QARMAN: An Atmospheric Entry Experiment on CubeSat Platform. In: 8th European Conference on Aerothermodynamics for Space Vehicles; 2015; Lisbon, Portugal. Available from: https://www.researchgate.net/publication/277891078_QARMAN_AN_ATMOSPHERIC_ENTRY_EXPERIMENT_ON_CUBESAT_PLATFORM

4. Ehresmann M, Behnke A, Baumann J, Tietz R, Franz J, Galla D, et al. CubeSat-sized Re-entry Capsule MIRKA2. In: 10th IAA Symposium on Small Satellites for Earth Observation; 2015; Berlin, Germany. Available from: https://www.researchgate.net/publication/305807017_CubeSat-sized_Re-entry_Capsule_MIRKA2

5. Mitcheltree RA, DiFulvio M, Horvath TJ, Braun RD. Aerothermal heating predictions for Mars Microprobe. J Spacecr Rockets. 1999;36(3):405–11. Available from: https://doi.org/10.2514/2.3460

6. Reynier P, Dupays I, Léger L. SHAPE Project Space Capsule Aerothermodynamic Database. White Paper 323. Partnership for Advanced Computing in Europe; 2023. Available from: www.prace-ri.eu

7. Geuzaine C, Remacle J-F. Gmsh: a three-dimensional finite element mesh generator with built-in pre- and post-processing facilities. Int J Numer Methods Eng. 2009;79(11):1309–31. Available from: https://doi.org/10.1002/nme.2579

Citation: Reynier P. SCAMIX: Small Capsule for Microgravity Experiments. Innova Aerosp Sci Technol. 2025;3(1): 013-015.
Available from: https://dx.doi.org/10.17352/iast.000006