Debris characterization in the super/hypersonic and rarefied wind tunnel MARHy

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ABSTRACT

With the ever-increasing number of artificial satellites in Earth orbit, the risk of accidental collisions between functional satellites and orbital debris is becoming a major problem. This trend is not expected to be reversed, particularly with the advent of satellite constellations. To overcome this problem, space agencies investigated different de-orbiting solutions. Two solutions are currently practiced, re-entry or removal into a graveyard orbit [1]. None of those two solutions is ideal, but the second solution only postpones the problem of orbital debris. Regarding the first solution, it presents some risk to the population. Indeed, despite that during the re-entry of orbital debris on Earth, a large part is destroyed in the atmosphere; however, 10 to 20% touch the ground.

Therefore, it is essential to be able to determine their trajectory to minimize the risks. Numerical methods are developed to predict satellite's re-entry trajectory and several codes have been developed by different space agencies such as DAS (NASA), ORSAT (NASA), ORSAT-J (JAXA), DRAMA/ SESAM (ESA), Debrisk (CNES), DRAPS (China), SCARAB (ESA-HTG Germany), PAMPERO (CNES) [2]. However, depending on the boundary conditions and on the bridging functions used, the obtained results differ from each other with these different codes. This generally occurs during the transitional regime phase, which is the most problematic and requires test cases [3]. Indeed, the debris pass through four successive flow regimes, cited in the order of descent: the free molecular flow regime, the transitional regime, the slip flow regime and the continuous regime. This successive passage through different flow regimes greatly complicates numerical calculations because they must take into account a number of parameters and applicable models depending on the flow regime properties. In addition, it is necessary to have a good definition of the boundaries of the flow regimes in order to apply the predominant physical phenomena. Currently, there is a lack of experimental data to validate the models used by those codes, in particular in the intermediate regime flow.

Our purpose is to provide experimental test cases that could be used to improve the aerodynamic physical models used to determine the trajectory of space debris. These debris have geometric shape which can be diverse. Nevertheless, many of the debris found on the ground are spherical [4]. As a first approach, we have focused the present work on the experimental study of the aerodynamic properties of spherical debris in Mach 4 supersonic rarefied flows ranging from the transitional to the near continuum regime with slip conditions [5, 6]. For this purpose, two Mach 4 nozzles giving different static pressure, 8 and 71 Pa have been used to test spherical objects with several diameters. The shock shape and the drag forces have been determined for each test condition. A back illuminated camera was used to visualize the flow field, and a pressure probe was used to measure the total pressure fields around the bodies. A two axes force balance measured aerodynamics forces. This experimental study is carried out in the rarefied hypersonic wind tunnel Marhy, one of the three facilities of the platform FAST, belonging at the ICARE laboratory of the CNRS in Orleans, France.

[1] ESA, "Space Environment Report Latest". 2018. Technical Note GEN-DB-LOG-00239-OPS-GR.
[2] Prevereaud, Y., Vérant, J. L., Moschetta, J. M., Sourgen, F., and Blanchard, M. "Debris aerodynamic interactions during uncontrolled atmospheric reentry." AIAA Atmospheric Flight Mechanics Conference. 2012.
[3] Annaloro, J., Galera, S., Karrang, P., Prevereaud, Y., Verant, J. L., Spel, M., Hauwaert, P. V., and Omaly, P. "Space debris atmospheric entry prediction with spacecraft-oriented tools." 7th European Conference on Space Debris, ESA. 2017.
[4] Prevereaud, Y. "Contribution à la modélisation de la rentrée atmosphérique des débris spatiaux. " Diss. Institut Supérieur de l'Aéronautique et de l'Espace (ISAE), 2014.
[5] Coumar, S., and Lago V. "Influence of Mach number and static pressure on plasma flow control of supersonic and rarefied flows around a sharp flat plate." Experiments in Fluids, 58 (6): 74, 2017.
[6] Laurence, S. J., Parziale, N. J., and Deiterding, R. "Dynamical Separation of Spherical Bodies in Supersonic Flow", Journal of Fluid Mechanics, 713:159–82, 2012.