Multibody Aerothermodynamics of Space Debris Fragments

Ali Gülhan

Department Head (ali.guelhan@dlr.de)
Supersonic and Hypersonic Flow Technologies Department
Institute of Aerodynamics and Flow Technology
German Aerospace Center (DLR e.V.), Cologne, Germany

Abstract

Due to the increasing space transportation activities and possible entry of Near-Earth-Objects at very high velocities, space debris became an issue of safety for our Earth. The evolution of the demise process and formation of fragments has a big influence on the prediction of the ground impact. The available numerical tools have still significant shortcomings in correct physical modelling of the demise and multibody interaction. While small pieces usually burn up during atmospheric re-entry, larger pieces reach the earth's surface regularly. Typical examples are rocket upper stages and satellites in low orbits that have reached their end of live or are out of control.

One of the key questions is the prediction of aerothermodynamic behaviour of space debris fragments and their interaction with each other. Such objects may have complex non-aerodynamic shapes. Therefore the determination of aerodynamic and thermal behaviour of multi bodies is very challenging and requires an upgrade or development of new experimental and numerical tools. Since the standard aerodynamic measurement technique using high precision six component balances would cause undesired limitations with respect to the multi body motion, new approaches like free flight in the wind tunnel need to be developed. Such data can also improve the modelling of multibody aerodynamics, prediction of aerothermal loads and demise behaviour of fragments. All these elements are used for the flight dynamic analysis and estimation of the ground impact of space debris components. Based on these facts the Supersonic and Hypersonic Technologies Department of DLR has successfully implemented the free flight technique in the hypersonic wind tunnel H2K. This unique technique can perform free flight tests with duration up to 0.3 seconds using high speed tracking method. The accuracy of the experimental data has been improved continuously by further development of the tracking techniques and software package. This expertise in combination with the demise testing capabilities in the arc heated facilities L2K and L3K allowed the Supersonic and Hypersonic Technologies Department becoming one of the worldwide key institutions for experimental work in this field.

This lecture discusses first main challenges of the determination of aerodynamic coefficients and heat flux rate on single- and multi-bodies using well established methods like six components balance measurements, heat flux gauges and infrared thermography. Interaction of a two body configuration in terms of aerothermal loads and aerodynamic coefficients is the core topic of the lecture. Depending on the orientation of two bodies significant differences in the results have been observed. The last part of the lecture is devoted to the multi body interaction and future work.

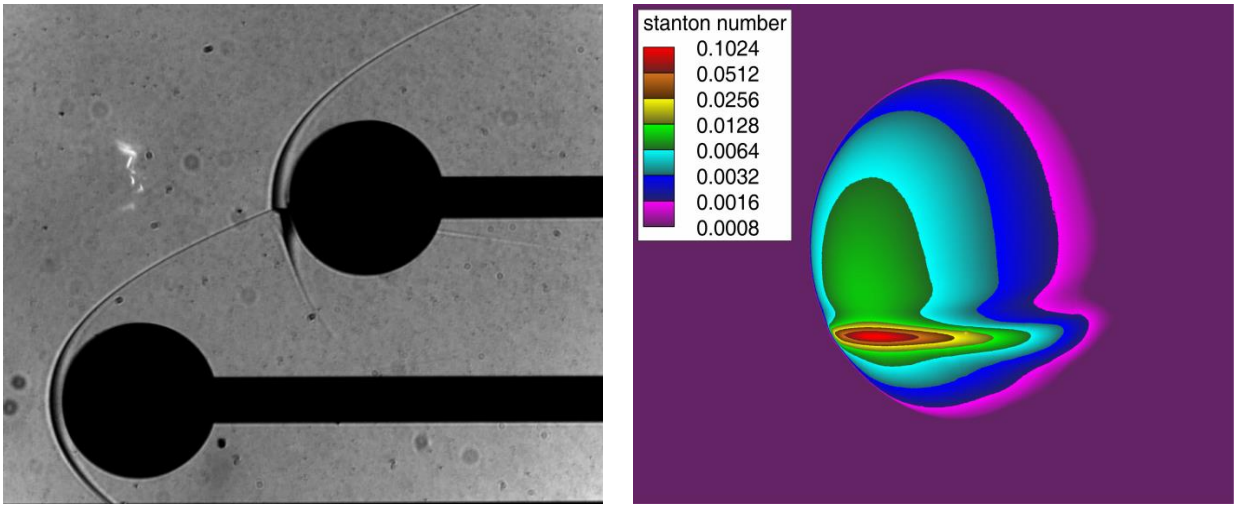

Figure 1: Aerothermodynamics interaction of two spheres at Ma = 7.0.

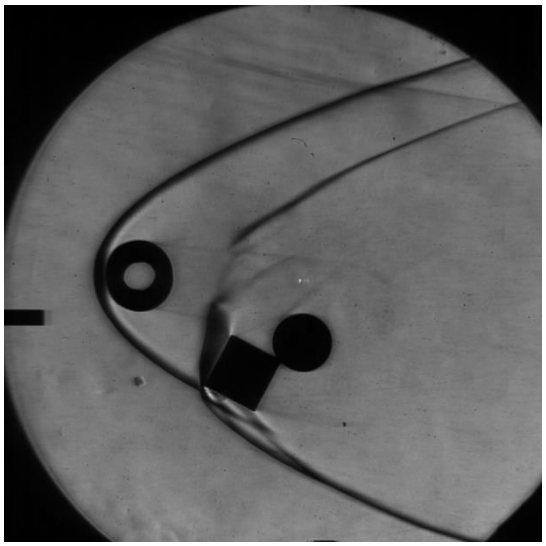

Figure 2: Aerodynamic interaction of three different bodies at Ma = 7.0.

Bio

Prof. Ali Gülhan is head of the DLR Department of Supersonic and Hypersonic Technologies. After receiving his Ph.D. degree at the RWTH Aachen University in 1989 he joined the DLR. Until 2001 he was the team leader of arc heated facilities before he became the head of the former DLR department 'Wind Tunnels'. His main working areas are aerothermodynamics, flight instrumentation, thermal management and ground testing wrt aerothermal qualification. Prof. Gülhan was the PI of the COMARS+ instrumentation package of the EXOMARS 2016 mission and belonged to the EXOMARS 2016 - Schiaparelli Anomaly Inquiry Board. He has been leading several projects of the EU frame programs, ESA TRPs and DLR research program space technologies. Prof. Gülhan has more than 150 publications.