



Proposal to invite Doctor Lionel Marraffa as Distinguished Visiting Professor of the Department of Physics, Instituto Superior Técnico (September 2020 – September 2021)

1. Introduction

The scientific area of [Plasmas, Lasers and Nuclear Fusion](#) (PLFN), with the Department of Physics (DF) of [Instituto Superior Técnico](#) (IST), is composed by 13 faculty members, 3 researchers and 2 invited professors, actively engaged in education, research and outreach programs in a wide range of topics, both from a fundamental perspective and from a technological / engineering perspective.

The breadth and scope of research in the scientific area of PLFN, is well illustrated in the report of the National Academy of Sciences of the USA Plasma Science: [Advancing Knowledge in the National Interest](#). Our research, developed in the [Institute for Plasmas and Nuclear Fusion](#) (IPFN) of IST, covers all areas of Plasma Science and Engineering: Low Temperature Plasma Science and Engineering, Basic Plasma Science, The Plasma Science of Magnetic Fusion, Plasma Physics at High Energy Density, Space and Astrophysical Plasmas, with a broad methodological approach ranging from theory and simulations to experiments, from fundamental science to engineering.

An important component of our activity involves the characterization of *non-equilibrium atmospheric entry plasmas*, created by strong shock waves upstream of spacecrafts, when they enter the upper layers of a planetary atmosphere at velocities of several km/s. These high-temperature plasmas strongly heat the thermal protections of spacecrafts through convective and radiative heating, and their study is key to support planetary exploration missions. The research is conducted mainly at the [Hypersonic Plasmas Laboratory](#) (HPL), a research facility of IPFN hosting the [European Shock-Tube for High Enthalpy Research](#) (ESTHER). The ESTHER shock-tube is part of the [Research Infrastructures Roadmap](#) of the Fundação para a Ciência e a Tecnologia, and is being developed in the scope of three contracts, with total budget of more than 3M€, awarded by the [European Space Agency](#) (ESA) to an international consortium led by IST/IPFN.

The research infrastructure ESTHER is the sole Portuguese Space facility for the planning of planetary exploration missions, where it is possible to attain shock speeds in excess of 12km/s. The engineering approach for the design of entry spacecrafts starts by defining the representative conditions of a mission entry profile (velocity, altitude and gas composition), performing representative shots in the shock-tube facility. The experimentally measured plasma parameters are used first to validate simplified 0D/1D shock-tube flows and later to simulate a real 2D/3D entry flow surrounding a spacecraft, allowing to properly sizing its thermal protections. The HPL also hosts strong modelling capabilities, through the development and maintenance of the 0D/1D/2D Computational Fluid Dynamics (CFD) code *SPARK* and the Line-by-Line radiative-transfer code *SPARK Line-by-Line*. These have been deployed in support of past European planetary entries (Huygens' Titan entry in 2005 and ExoMars' Mars entry in 2016) and will be deployed in support of the shock-tube operation, as well as future European exploration efforts.



2. Proposal to invite Doctor Lionel Marraffa

Since 1990, Lionel Marraffa was staff at the European Space Research and Technology Center (ESTEC) of ESA in Noordwijk, the Netherlands. His domains of investigation included physical gas dynamics for plasmas and multiphase flows, entry vehicles and ground testing facilities.

His activity involved research, teaching, coordination of scientific activities at European level, technical management of technological and scientific programs, but also project work. In particular, he was involved in various Concurrent Design Facility studies as aerothermodynamics and entry specialist, then as support to specialists, technical expert and study manager.

Lionel Marraffa teaching experience was acquired mainly at Ecole Centrale de Paris, Ecole Polytechnique Féminine, Penn State University, UT Austin, Orleans University and Strasbourg University, where he taught thermodynamics, fluid mechanics and experimental techniques at undergraduate, graduate and post-graduate levels. He supervised and trained 9 grant holders (mostly PhD and post-doctoral researchers), 21 MSc students, 7 BSc students, and 2 NASDA (JP) engineers.

Lionel Marraffa was deeply involved in the commissioning of ESTHER, for which he was initiator and Project Manager for ESA. Following his numerous activities in cooperation with IST and IPFN (e.g. the organization, at IST-Alameda in 2004, of the first International Workshop on Radiation of High Temperature Gases in Atmospheric Entry), he was an invited speaker in the 2019 edition of Técnico's PhD Open Days.

Approximately one year ago, Doctor Lionel Marraffa expressed his intention of joining IST for a limited period of 12 months at 50% ETI, to develop a work plan with two main components:

- a) support to ESTHER, in the development of the infrastructure and the associated research activities, the implementation of its business plan, and the consolidation of its international networking;
- b) involvement in the responsibility for, or the support to the development of a Concurrent Design Facility (CDF) at IST, within the Department of Physics.

A CDF provides the environment and tools allowing concurrent engineering, a new approach for the design of complex systems, with a parallel progress in all the domains involved. A CDF, once achieved, will constitute: on the one hand, a valuable teaching instrument for undergraduate students in their third year of Bachelor or for graduate students, perfectly aligned with the current goals of IST in terms of teaching techniques and pedagogical practices; on the other hand, a facility providing a rapid conceptual or preliminary design, to be used in support and advise of IST and partners, industry and agencies. CDF facilities are being routinely used in reference universities such as EPFL and University of Rome La Sapienza.



Considering that

- the goals proposed in the workplan of Doctor Lionel Marraffa fit perfectly the current endeavours in R&D and teaching of IPFN, the Department of Physics and IST;
- project ESTHER will secure the funding for paying the salary of Doctor Marraffa during three (3) full months (or, equivalently, six (6) months at 50% ETI);
- the Distinguishing Visiting Professor Programme with the Department of Physics of IST usually hosts visitors, at full professor level, during approximately three (3) to four (4) months;

the co-signers of this proposal fully endorse inviting Doctor Marraffa as Distinguished Visiting Professor of Department of Physics, Instituto Superior Técnico, during a period of three (3) months, between September 2020 and September 2021, with the activity plan sketched above.

Lisbon and IST, 28 January 2020

Luís Lemos Alves
(Professor DF/IST)

Luís Oliveira e Silva
(Professor DF/IST)