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UNREAL Project: Unveiling nucleation mechanism in aircraft engine exhaust and its link with fuel composition

Ismael K. Ortega¹, Cristian Focsa², Jean François Doussin³, Véronique Riffault⁴, Sylvain Picaud⁵, Alexandre Albinet⁶, Valerie Gros⁷, Topi Rönkkö⁸ and Victor Archilla⁹

¹Multi-physics for Energetics Department, ONERA Université Paris Saclay, F-91123, Palaiseau, France

²PhLAM – Physique des Lasers, Atomes et Molécules, CERLA – Centre d’Etudes et de Recherches Lasers et Applications, Lille University, CNRS, UMR 8523, F-59000 Lille, France

³LISA, UMR CNRS 7583, Université Paris Est Créteil et Université Paris Diderot, Institut Pierre-Simon Laplace, 94000 Créteil, France

⁴IMT Lille Douai, Univ. Lille, SAGE-Département Sciences de l’Atmosphère et Génie de l’Environnement, F-59000 Lille, France

⁵UTINAM - UMR 6213, CNRS - Université de Franche-Comté, F-25030 Besançon, France

⁶INERIS, Institut National de l’Environnement Industriel et des risques, 60550 Verneuil-en-Halatte, France

⁷LSCE, Laboratoire des Sciences du Climat et de l’Environnement, Unité Mixte CEA-CNRS-UVSQ, 91191 Gif-sur-Yvette, France

⁸Aerosol Physics, Faculty of Natural Sciences, Tampere University of Technology, FI-33101 Tampere, Finland

⁹Instituto Nacional de Técnicas Aeroespaciales (INTA), Torrejón de Ardoz, 28850 Madrid, Spain

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Contact: Ismael.ortega@onera.fr

Introduction

Aviation emissions are not limited to greenhouse gases like CO₂ or water but include as well other gases like nitrogen oxides (NO_x) or sulfur oxides (SO_x) and volatile and non-volatile particulate matter (vPM and nvPM respectively). nvPM is defined as particles present in the engine exhaust at temperatures higher than 350°C and consists essentially in soot particles produced by the incomplete combustion of the fuel. vPM is formed by nucleation from gaseous precursors in the cooling exhaust gas downstream the combustor, when the concentration of preexisting particles has decreased, favoring homogeneous nucleation versus heterogeneous one (absorption of gases onto preexisting particles). Sulfuric acid formed in the engine exhaust seems to be linked to the formation of vPM. However, the amount of sulfur present in the fuel converted to sulfuric acid in the exhaust is too small to explain the amount of vPM observed. Chemi-ions and organic compounds emitted by the engine are one of the most suitable candidates to explain the formation of vPM in the engine exhaust, but the molecular mechanism behind this phenomenon is still unknown.

The main objectives of this project are:

- 1) To determine the mechanism behind vPM formation in the engine exhaust and if there is a link with fuel composition
- 2) To establish a sampling protocol for vPM measurements that can be used in certification processes

- 3) To determine the impact of fuel chemical composition on the physico-chemical properties of vPM and nvPM

Within this project we plan to use the state-of-the-art Combustion Aerosol Standard (CAST) generator especially designed to work with aeronautic fuels available at ONERA as emission source. To study the formation of vPM in detail, we will use the atmospheric chamber CESAM available at LISA and a Potential Aerosol Mass flow Reactor (PAM) available at LSCE and operated in collaboration with INERIS to induce the formation of vPM from the exhaust of CAST. We will use the experimental means available at ONERA and CESAM to characterize the emissions. In addition, key chemical characterization will be performed by SAGE and PhLAM. To get further insight into the molecular mechanism behind vPM formation, we will perform a series of theoretical simulations led by UTINAM. To complement the consortium, two foreign partners will join as well: Tampere University of Technology (TUT), that will participate in the characterization of molecular clusters emitted by CAST through the Atmospheric Pressure Interface Time of Flight Mass spectrometry (API-toF), and the Spanish national institute for aerospace (INTA) that will collaborate offering its sampling line in the stack of their test bench to measure vPM formation in one of its standard measurement campaigns with a complete engine.

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