Contamination assessment of a freely expanding green propellant thruster plume

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A number of propellant/thruster combinations are under development in recent years that aim to replace the prevailing hydrazine-driven reaction control thrusters with less hazardous substances ("green propellants"). With some of these systems already in orbit, characterizing their contamination potential in a space environment becomes relevant. In this paper we discuss experiments on plume induced contamination from a novel propene/N2O bipropellant thruster operated in a high vacuum environment.

Exhaust plume constituents of chemical propulsion systems are known to affect the properties and performance of functional spacecraft materials They may alter the thermo-optical properties of thermal control surfaces, and erode protective or functional coatings. Pertinent data gathered in space and on ground is practically non-existent for either of the many alternative propellant / thruster combinations developed in response to the European REACH Regulation. This absence of data makes reliable plume contamination predictions impossible, and potentially hinders the adoption of the novel propellant/thruster combinations for contamination sensitive missions. This paper presents first results of ESA-funded experiments dedicated to determining the composition of the freely expanding plume from a 20N bipropellant propene/nitrous oxide reaction control thruster. We investigate the thruster plume expansion, chemical composition and non-gaseous effluents. Measurements are conducted in the DLR high-vacuum plume test facility Göttingen for chemical thrusters (STG-CT). STG-CT's test section is almost completely enclosed by copper walls cooled to 4.2K using liquid helium, thus maintaining high vacuum during pulsed operation of the thruster. Non-gaseous effluents, i.e. droplets and particulates, are recorded with a high-speed camera, providing information on size, velocity and trajectories. The data experimentally obtained for the plume composition and expansion from an additively manufactured propene/nitrous oxide green propellant thruster is novel and unique, and provides engineers not only with contamination-relevant information to this particular thruster, but also gives an indication of the potential contamination behavior of green propellant thrusters that use carbon-based fuels. The impact of plume contamination on the properties of relevant surface coatings and materials is studied in a second phase of the activity.

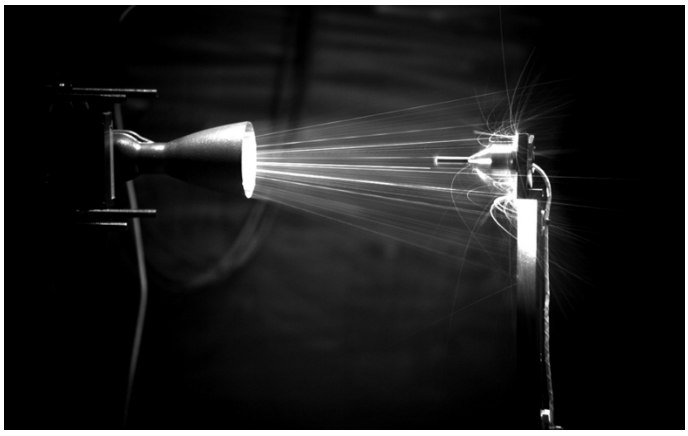

Fig. 1: Still image from a high-speed recording taken during preparatory experiments in coarse vacuum, showing particulate matter ejected from the thruster and iminging onto a Pitot pressure probe.