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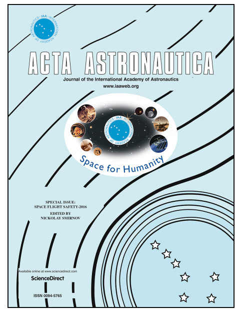

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Combustion dynamics in cryogenic rocket engines: research programme at DLR Lampoldshausen

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Abstract

The Combustion Dynamics group in the Rocket Propulsion Department at the German Aerospace Center (DLR), Lampoldshausen, strives to advance the understanding of dynamic processes in cryogenic rocket engines. Leveraging the test facilities and experimental expertise at DLR Lampoldshausen, the group has taken a primarily experimental approach to investigating transient flows, ignition, and combustion instabilities for over one and a half decades. This article provides a summary of recent achievements, and an overview of current and planned research activities.

Keywords: Liquid propellant rocket engines, cryogenic propellants, transients, ignition, combustion instability

Acronyms/Abbreviations

GHe	Gaseous helium
GN_2	Gaseous nitrogen
GOx	Gaseous oxygen
LPRE	Liquid propellant rocket engine
LOx	Liquid oxygen
Pcc	Combustion chamber pressure
RCS	Reaction control system
ROF	Ratio of oxidiser to fuel mass flow
T_F	Fuel injection temperature (H_2 or CH_4)
T_{H2}	Hydrogen injection temperature
T_{O2}	Oxygen injection temperature

1. Introduction

At the German Aerospace Center (DLR), all activities related to research and testing of liquid rocket engines can be found at the Institute of Space Propulsion in Lampoldshausen, southern Germany. The site is a test centre in service of the European space programme, with facilities for testing propulsion systems of all scales, from mN-class thrusters up to main stage launcher engines.

Within the Rocket Propulsion research department is the Combustion Dynamics research group which addresses unsteady phenomena in rocket engines. A largely experimental approach is taken to investigate these topics, capitalising on the experience in test facility design, existing infrastructure, and operational experience at DLR Lampoldshausen. The scope of research efforts is confined to liquid propellant rocket engine (LPRE) configurations of interest to European space flight. This means working with the propellant combinations LOx/H_2 and LOx/hydrocarbon (particularly CH_4), and simulants for storable propellants.

The experimental objective has primarily been the practical observation of dynamic phenomena under conditions representative of those in industrial LPREs. State-of-the-art diagnostics are applied to capture fluid flow and combustion processes with high temporal and spatial resolution with the aim of gathering detailed insights into the phenomena and expanding the experimental database available to the community. The ultimate goal of these efforts is to provide industry with design guidelines for LPRE development.

The work in this group can broadly be categorised under transient flows, ignition and start-up, and thermoacoustic instabilities. Each of these will be elaborated upon in this article.

Understanding the behaviour of fluids under transient conditions and upon injection into the combustion chamber is the basis for successful ignition and start-up of a rocket engine. The opening and closing of valves in propellant supply lines of rocket engines causes unsteady variation in flow and thermodynamic conditions. Capturing these variations and their influence on flow processes and phase changes requires specialised test benches. Predictive models based on both 1D lumped parameter and high-fidelity CFD approaches are also developed to describe these phenomena.

Work on ignition in the group focusses primarily on examining laser ignition processes in close cooperation with industry. Ignition testing is performed with GOx or LOx and with H_2 or CH_4 as a fuel in a windowed, contoured thruster, or in a sub-scale thrust chamber.