CIDAR PROJECT: DEVELOPMENT OF A NON-INTRUSIVE CAPABILITY FOR SOOT MEASUREMENT ON AIRCRAFT ENGINE EMISSIONS

V. Archilla[1], G. Aragón[1], P. Wright[2], K. Ozanyan[2], J. Black[2], M. Lengden[3], I. Burns[3], W. Johnstone[3], V. Polo[4], M. Beltran[4], M. Johnson[5]

[1]INTA, Torrejón de Ardoz, 28850, Spain

[2]The University of Manchester, Manchester, M13 9PL, UK

[3]University of Strathclyde, Glasgow, G1 1XQ, UK

[4]DAS Photonics SL, Valencia, 46023, Spain

[5]Rolls-Royce plc, Derby, UK

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Presenting author email: archillapv@inta.es

The complexity of Very High Bypass Ratio (VHBR) lean burn combustion systems requires careful fuel control and optimised staging to minimise non-volatile particulate matter (nvPM) emissions. Fuel flow variation across injectors will impact the temperature distribution through the turbine and thus influences rates of nvPM formation and consumption. Through Clean Sky 2, Rolls-Royce are developing technologies required for VHBR engines. CIDAR (Combustion species Imaging Diagnostics for Aero-engine Research) supports this initiative.

Extractive sampling systems are the current standard method for measuring exhaust gas and fine particle emissions from various types of aircraft engines under actual operating conditions. Emerging non-intrusive approaches to gas and particulate measurement offer alternatives to extractive methods, with some significant advantages (no impact on engine performance and no hardware installed in engine exhaust, bypass or entrained flows). CIDAR will develop and demonstrate exhaust measurement technologies required to deliver robust VHBR engine performance prediction, using approaches described in (Wright, 2016). The novel technologies developed in CIDAR, will make it easier to increase the number of tests that can be implemented in-situ without affecting the performance of the engine and make it possible to characterize the combustion process in both the stationary and transient regimes, allowing the detection of anomalous phenomena in both states. Therefore, VHBR engines will be subjected to continuous monitoring of their combustion process under different operating and environmental conditions (health monitoring).

The CIDAR programme includes demonstration of cross-sectional imaging of nvPM in exhaust plumes during a full engine test at INTA's jet engine test facility. The measurement system will meet TRL6 (technology demonstrated in relevant industrial environment). Laser induced incandescence (LII) based on orthogonal imaging of a light sheet is a well-established tool for the quantification of soot concentrations and distributions in small flames. However, this configuration is not scalable to large engine exhaust measurements. Scanned beam LII with light collection in the backward direction has been demonstrated in jet exhaust (Black, 2008 and 2010). CIDAR will use *in-plane* near-orthogonal collection of incandescence from a scanned excitation beam (Figure 1). Cross-sectional images of nvPM concentration will then be produced by autoprojection tomography.

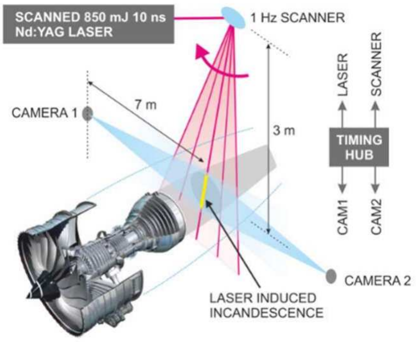

Figure 1. LII system layout at INTA test cell.

Implementation of autoprojection-based nvPM imaging in a testcell requires synchronous operation of a high energy pulsed laser excitation source, a system for the dynamic scanning of the excitation beam and a camera system for LII signal acquisition. The laser, scanner and camera systems are positioned within the test cell but entirely outside of the flow. This technology can provide non-intrusive nvPM/soot imaging (<10 cm spatial resolution across a 1.6 m diameter flow at 1 Hz) if signal levels are adequate. However, the very low nvPM levels of modern engines may require additional signal averaging to achieve good measurement precision under typical operating conditions, resulting in a lower final frame rate.

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Wright, P., et al. (2016) Aerospace *Conference*, IEEE (pp. 1-14). IEEE.

Black, J. D., & Johnson, M. P. (2010). *Aerospace Science and Technology*, 14(5), 329-337.

Black, J. D., et al. (2008). *26th AIAA Aerodynamic Measurement Technology and Ground Testing Conference.* (p. 4265).