Space PFO Monitor

Particulate contamination monitoring for space launch applications

Introduction

Launch vehicles, and their enclosed satellite payloads, experience significant degrees of mechanical and acoustic shock and vibration during their short journey into space. Nothing is currently known about the sources and types of particulate contamination inside a rocket fairing during launch; however, it is certain that contamination can seriously affect the performance, accuracy and reliability of the multi-million dollar instruments which are routinely sent into space to study our planet and explore the universe.

For the past few years XCAM have been leading a technology development programme, with the support of the European Space Agency (ESA), to manufacture a unique instrument which will provide the first measurements of particulate contamination during launch inside a launch vehicle fairing.

This Space PFO (particle fall out) Monitor is targeted to be launched on a Vega-C launch vehicle around 2024.

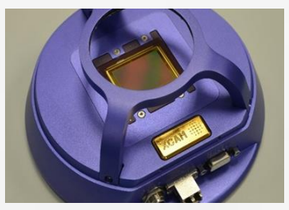
Development Timeline

Pre-2016

Existing Methods

Existing methods for PFO monitoring (i.e. PFO plate, PFO meter, tape-lift etc… cannot operate remotely in-flight and do not provide real-time detection and classification

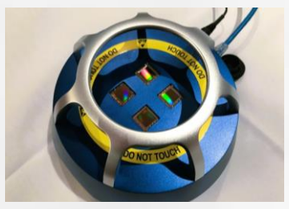
2016



Prototype

Under contract to the European Space Agency (ESA), XCAM successfully demonstrate proof-of-principle of a real-time PFO measurement technique using CMOS imaging technology

2018



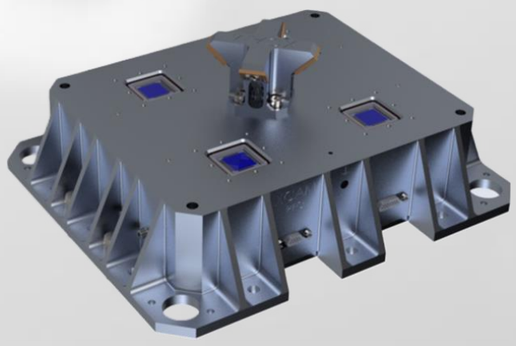
PFO1040

XCAM evolve the design to develop version of the PFO monitor for ground-based cleanroom applications, selling to clients in multiple different industries around the world

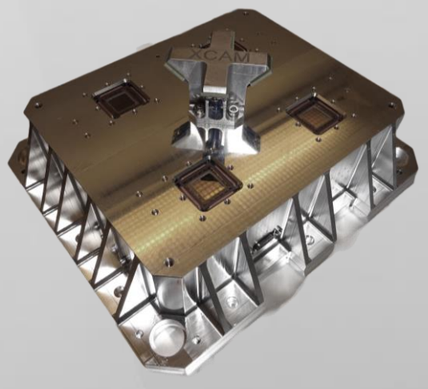
2020 - 2024

Space PFO Monitor

XCAM develop the Space PFO Monitor, a ruggedised evolution of the PFO1040 designed to withstand the varying vibration, shock, acoustic, pressure, temperature and humidity environments experienced during space launch. The Space PFO Monitor incorporates standardised mounting points for shock absorbers commonly used for space launch applications enabling the instrument to be deployed across a wide range of different launch vehicle families.



Rendering (left) of the Space PFO Monitor at the time of Preliminary Design Review (PDR) in Dec 2021.



Photograph (right) of the Engineering Model (EM) Space PFO Monitor in July 2022 ready for performance, environmental and electromagnetic compatibility (EMC) testing.

Flight Instrument Requirements

Parameter	Requirement
Particle Fall Out (PFO) Monitoring	ability to detect and classify particles and fibres and measure PAC and PFO level based on particle size distribution
Minimum particle size	5 micron
Detection Area	5 cm^2
Sampling frequency	At least every 10 s
Instrument Volume	< 2 litres
Instrument Mass	< 2 kg
Electrical Interface	28V power, RS422 data
Maximum power consumption	75W on a supply of 28V
Operational temp. range	-20ºC to +80ºC
Operational humidity range	0% to 95%
Operational lifetime	data acquisition (at least 254s) data transfer (at least 5 hrs)
Shock and vibration	as per Vega C requirements
Placement	able to operate both horizontally and vertically

Concept of Operations (CONOPS)

Central to the CONOPS is the elimination of the need for tele-commanding between the launch vehicle (LV) and the instrument. When power is supplied to the unit it automatically enters a pre-programmed power-up sequence before moving to a pre-flight data acquisition and transmission mode. For the Vega-C this will occur after encapsulation, enabling PFO monitoring inside the encapsulated fairing during fairing assembly.

Using a combination of environmental sensors the unit can autonomously detect when launch commences and move to the flight data acquisition and transmission mode, operating for a fixed duration between launch and fairing ejection. Following fairing ejection the unit enters a post-flight data transmission mode – transferring the remaining data to the LV for telemetry to the ground.

All the data from the entire launch campaign can be analysed at any time with particles detected and classified using XCAM's proprietary algorithms.

Integration
Satellite(s) integrated into LV fairing in cleanroom environment alongside Space PFO (powered-off)

Image Credit: Arianespace

Assembly
Encapsulated fairing moved and assembled atop LV – Space PFO Monitor in pre-flight data acquisition and transmission mode

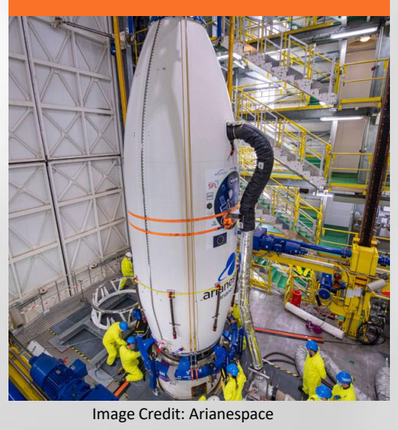
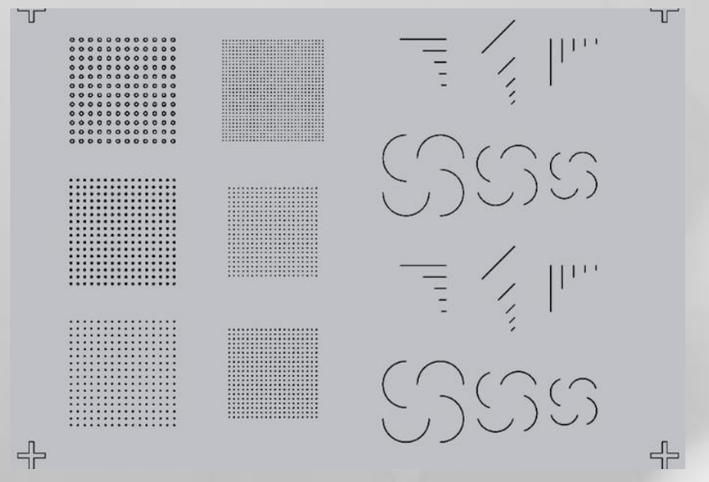


Image Credit: Arianespace

Launch
Space PFO Monitor in flight mode data acquisition for 254s from launch to fairing ejection – then ~5hrs data transmission

Image Credit: ESA–Pierre Carril, 2016

Performance Verification



Detection and classification performance verification is achieved using a special chrome-on-glass test mask containing 3.5, 10, 20, 40, 75 and 150 µm particles and simulating 5 and 10 µm straight and curly 'fibres'. XCAM detection and classification algorithms can detect 100% of particles > 5 µm and 80% > 3 µm.

XCAM Ltd. | 2 Stone Circle Road, Northampton, NN3 8RF, UK | +44 1604 673700 | www.xcam.co.uk

MKPU-XCAM-MS-00048