Orpheus: An international mission to characterise the space domain and advance future concepts for defence

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Background

On the 9th January 2023 the first UK launch reached space but failed to get into orbit, resulting in the loss of the Prometheus 2 and CIRCE R&D missions. The Orpheus mission aims to leverage the achievements made in delivering these missions in order to address the extant goals.

Prometheus 2 was a UK led pair of 6U CubeSats. The mission aimed to collaborate with international partners to develop expertise and advance international space architectures.

The CIRCE mission was a pair of 6U satellites seeking to accurately characterise the ionosphere at a regional scale, combining US payloads measuring electron distribution in the night-time ionosphere, with a UK developed suite of in-situ and remote sensing environmental payloads.

The Mission

Orpheus will consist of two near identical CubeSats in a lead-trail Low Earth, Sun Synchronous Orbit. The mission aims to characterise the ionosphere and drive the development of the underpinning international architecture.

Each CubeSat which will host one of each payload, except the WINCS payload which will be on one satellite.

The satellites are currently in development, and are looking to be launched in the 2026/27 timeframe via the DoD Space Test Program and will operate for 1-3 years.

Identification of Spectral Signatures

Orpheus will host a Hyperspectral Imaging (HSI) payload on each spacecraft. These will capture imagery to support Earth observation and SDA (Space Domain Awareness) applications. HSI allows for the detection and identification of materials or land types based on spectral signature.

Two HSI payloads in a lead-trail configuration will enable additional experimentation, including:

- Simultaneous collection over an area with different sets of wavelengths.
- Sequential imagery over the same area to detect short time-scale changes/movement.
- Analysis of the degraded sensor functionalities of one payload over the other, with impact on calibration issues.

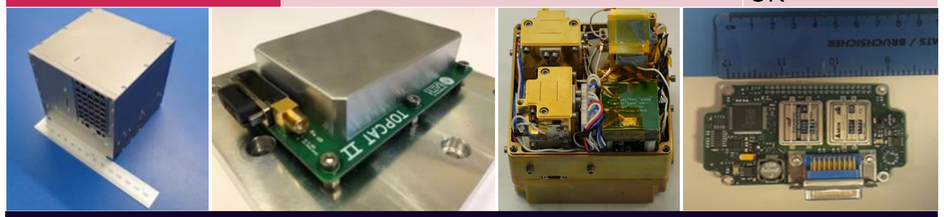
Ionosphere Characterisation

Orpheus will characterise ionospheric effects on a regional scale in the ionosphere/thermosphere system. The two near-identical satellites will maintain a lead-follow tandem configuration, allowing short time-scale dynamics to be observed by both in-situ and remote sensing techniques.

The Tri-TIP payload will observe the UV emission of atomic oxygen on the night side of the Earth from multiple different viewing angles, with the goal of characterising the distribution of electrons. Meanwhile, a suite of sensor payloads (TOPCAT II, WINCS, RadMon) will generate a wealth of contextual environmental information from remote and in-situ sources – enriching the data derived from the Tri-TIP payloads.

The suite of payloads carried on Orpheus will generate observations enabling a greater understanding of the driving processes of geophysical phenomena in the ionosphere/thermosphere system, distributed across a wide range of latitudes. Understanding the characteristics of the dynamic ionosphere is vital for a range of both civil and defence applications such as GNSS, communications, sensing technology and space sustainability.

Payload	Purpose	Developed By
Tri-TIP (Triple Tiny Ionospheric Photometers)	Characterise the ionosphere through observation of UV wavelengths on the night-side of the Earth, using two payloads with multiple different view angles to allow multi-point sampling.	US Naval Research Laboratory, US
Hyperspectral Camera	Improve characterisation of spectral signatures for space objects and land regions. Exercise international data dissemination and processing.	Commercial
TOPCAT II (TOPside ionosphere Computer Assisted Tomography)	Derives total electron content of the propagation medium from differential phase of received GPS signals.	University of Bath, UK
WINCS (Wind Ion Neutral Composition Suite)	Provide in-situ observations of ions and neutrals (density, temperature and winds/drifts).	US Naval Research Laboratory, US
RadMon (Radiation Monitor)	Comprised of a particle detector, dose rate monitor and total dose monitor.	Surrey Satellite Technology Ltd, UK



Payloads from the Orpheus Suite. From left to right: Tri-TIP (courtesy NRL), TOPCAT II (courtesy University of Bath), WINCS (courtesy NRL), RadMon (courtesy SSTL)

Space Architecture Integration

Orpheus will integrate into and help further develop international efforts towards a joint space architecture. The architecture aims to enable more collaborative mission planning, satellite tasking and data dissemination across international partners.

Data Exploitation

The main goal of Orpheus is to generate a rich data set for Space Domain Awareness. This includes accurate characterisation of the dynamic ionosphere, informing ionospheric models to improve our ability to specify the impact of space weather, in addition to spectral sensing for Earth observation and SDA applications. The Orpheus mission will additionally continue to strengthen ties between international partners in developing the supporting architecture.

Further Reading

CIRCE: A. Agathanggelou et al. 2020 “CIRCE: Coordinated Ionospheric Reconstruction Cubesat Experiment” Proceedings of the Small Satellite Conference, Science/Mission Payloads, https://digitalcommons.usu.edu/smallsat/2020/all2020/117/

G. Attrill et al. “Coordinated Ionospheric Reconstruction CubeSat Experiment (CIRCE), In situ and Remote Ionospheric Sensing (IRIS) suite” *J. Space Weather Space Clim.*, vol 11, Feb 2021 https://doi.org/10.1051/swsc/2020066

A. Nicholas, et al. "Coordinated ionospheric reconstruction CubeSat experiment (CIRCE) mission overview." in *Proc. SPIE 11131, CubeSats and SmallSats for Remote Sensing III*, vol 11131, Sep 2019 https://doi.org/10.1117/12.2528767

WINCS: F. Herrero, et al. “The small-deflection energy analyzer (SDEA): Enabling multi-point investigations in the thermosphere-ionosphere.” *Review of Scientific Instruments,* vol 91, Sep 2020 https://doi.org/10.1063/5.0001903

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