EO Mission Capability Review 2018

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Introduction

In December 2017, the EO Advisory Committee (EOAC) on behalf of the UK Space Agency initiated a review of EO mission and instrument concepts in progress in the UK. This would be to prepare for opportunistic or strategic support for future EO missions. To carry out a detailed assessment, the Agency set up the 'EO Mission Capability Review (EOMCR) Panel' as a working group of the EOAC. This report describes the outcome of the review undertaken by the Panel of the set of EO mission and instrument concepts proposed by the UK EO community.

The Agency objective is to develop and maintain a list of EO mission or instrument concepts which are generated by the UK EO community, that are near flight-ready and could be taken forward to implementation should a national or international funding opportunity arise. Such missions/instruments could for instance be funded under a national programme, as a bilateral mission or through an ESA or other institutional programme. The end user could be commercial, institutional (e.g. climate / meteorological organisations), public policy or academic. For the purposes of this activity, no mission cost ceiling was imposed. The intention is that the list will be updated regularly to capture new ideas as they emerge.

The UK EO community was invited to respond to a questionnaire with details of a proposed mission or instrument. Each mission/instrument concept was evaluated by the Panel on its own merits and as appropriate for funding opportunities of relevance to the concept. Following an initial assessment, each team was invited to respond to some supplementary questions from the Panel.

The review included a community workshop held on 30th April 2018, where the concepts were presented and discussed. The resulting list of potential, near-flight ready missions/instruments is published in this report to build confidence and help identify potential collaborations. Should funding become available, a full business case – which could be commercial, for public good or for science – would need to be developed to access funding. It should be noted that this list is based on mission proposals from the UK EO community. A future activity could be to collect and assess the priorities for user and their requirements, from which potential EO mission solutions could be evaluated.

The review has identified a short-list of viable mission/instrument concepts which could be launched in a reasonably short time period (3-5 years). Selection, funding and mission implementation would be the subject of a later process for which additional information would be requested. Selected proposals may be partly or fully funded and would have to show value for money.

The endorsement of the review panel applies to the mission concept. No commitments are implied regarding the consortia that may eventually implement a mission.

This report provides details of the mission/instrument concepts that have been shortlisted, together with a summary of the recommendations to the UK Space Agency from the EOMCR, which were endorsed by the EO Advisory Committee in May 2018.

The CEOI Leadership Team provided support to the UK Space Agency in collating the information, preparing documents for the Panel and in preparing this report.

The Review Process

The review was initiated by the invitation of proposals for future EO national, bilateral or international EO missions from the UK EO community via a three-part questionnaire. At the same time, the UK Space Agency appointed EO experts to the EO Missions Capability Review Panel to assess the responses, based on their motivation, knowledge and expertise, whilst ensuring avoidance of any potential conflict of interest. The Call for Panel members is attached at Annex 6.

The Panel presented its conclusions to the EO Advisory Committee in May 2018.

Assessment of Proposals

Each proposal was assessed relative to the five criteria previously approved by the EOAC, seeking evidence of:

- The principal user need for the mission and any existing collaboration with the end user
- The project alignment with the UK EO strategy, national space policy or other UK industrial objectives (e.g. climate science, UK EO Technology Strategy, UK Industrial Strategy)
- The principal benefits that will result (e.g. leading science position; job creation; export growth; national prestige; etc)
- The principal innovative or unique aspects of this project (science, technology, products or services)
- The achievability, realism and cost-effectiveness of the mission / instrument (e.g. by comparison to previous missions)

The first part of the questionnaire requested information about the overall project, including an overview description of the mission/instrument and its objective, the main products and beneficiaries; the characteristics of the instrument; the calibration/validation concepts; details of the instrument hosting, and the main overall mission requirements. The second part requested information on the scientific, technology and mission readiness for implementation, together with a description of the need and opportunities for international partnerships. The third part of the questionnaire requested an assessment of the overall mission cost and complexity. Finally the proposers were invited to make the case for their mission/instrument proposal in terms of the five assessment criteria.

At its first meeting held on 20th April 2018 the Panel made an initial assessment of the proposals. Each proposal was independently reviewed by at least 3 members of the panel in advance of the meeting. The Panel identified a set of clarification questions about specific issues for each mission/instrument proposal, and the proposers were invited to respond in writing to each of the clarification questions. The responses were considered at the 2nd EOMCR Panel meeting held on 30th April 2018.

In consideration of all available information, the Panel assessed the readiness and quality of the proposed missions, resulting in a short list of missions that were considered to be of sufficient quality and maturity to be implemented relatively quickly should an opportunity arise. The Panel also identified other mission/instrument concepts that are close to maturity but require further work to be completed before being ready for implementation.

Community Workshop

All 34 mission/instrument concepts were presented to the UK community at a CEOI Challenge Workshop held on 30th April 2018, including a brief question and answer session from the attending audience, including panel members.

At the final plenary session, the following comments and suggestions were made:

- Considering the overall portfolio of mission/instrument concepts, it is clear that the UK community has a great technical know-how.
- Inclusion on an approved EOMCR list could be useful support to sell the mission/instrument concept.
- In future, a UK mission list could be ordered to reflect readiness and timeliness or with some form of prioritisation. UK could consider how other nations assess their national mission and instrument ideas.
- A deficiency in many proposals was that they failed to relate the technical solutions to user need, domain impact or USP over their competition. A source of funding to develop the proof of need should be identified and additional study activities coordinated by CEOI.
- The UK might also consider 'user-led' needs where an end user identifies a technical / scientific / operational challenge without prejudice to space capabilities. The Space sector would then be challenged to contribute to the solution of the challenge.
- Many of the EOMCR proposals are addressing public need and seeking public funding and such missions are unlikely to secure commercial funding.
- The EOMCR panel should consider mechanisms to encourage overlapping proposals to merge; condensing and preferably strengthening the number of candidate missions. This applies, in particular, to cases where there is strong overlap or synergy between mission concepts or the technologies contributing to them (considering not only payload but also platform and ground segment concepts).
- Consistent (funding) support year on year is required to mature ideas and develop a programme or specific missions.
- The UKSA/EOAC need to consider management and ownership of the mission/instrument list.
- More detail and a selection process would be required for bilateral opportunities. Agility would be required for a fast reaction to any bilateral opportunity.

The Review Panel (May 2018)

The EOMCR Panel received 35 proposals in all. One was considered out-of-scope as it proposed a more general technology development, which although worthwhile, did not address a specific EO mission or instrument concept. Of the remaining 34:

- Six missions are short-listed and considered to be ready for implementation, with another two likely to be ready once current development activities are complete. See Annex 1.
- Five missions/instruments are identified as of significant interest and relatively close to being at an acceptable level to be included on the short-list, but require some further work. The panel encourages further development of these concepts to achieve short-listing at the next opportunity.
- Nine missions/instruments are not yet sufficiently mature, and would require further work before being assessed again. The panel encourages further development of these concepts to achieve short-listing at a later date.
- Eight missions, all of which received a positive assessment from the Panel, have been proposed into an ESA programme for potential implementation. These are six ESA Earth Explorer mission candidates, one Copernicus High Priority Candidate Mission, and one potential Earth Watch mission.

The remaining missions/instruments were considered to be insufficiently mature at present and would need significant further work before any re-assessment.

Whilst every effort was made by the panel, in the time available, to assess the various aspects of each proposal, before proceeding to implementation it will be necessary to further scrutinise the TRL, SRL and MRL claims for each proposed mission/instrument.

EO Mission Capability Review Panel Recommendations

The EOMCR Panel made the following recommendations to the EOAC and the UK Space Agency :

1. To recognise the considerable strength and breadth of UK EO mission capability
2. To endorse the mission concepts identified by EOMCR as ready for implementation
3. To put in place a national or bilateral programme to allow one or more of the mature mission or instrument concepts to be taken through to implementation.
4. To develop a rigorous process to confirm that the SRL, TRL and MRL of any missions being considered for funding are at sufficient maturity
5. To fund studies to advance the maturity of missions and instruments identified in this review, and to enhance the understanding of their user need/business case and critical technologies.
6. Missions that are currently under consideration in ESA Earth Explorer 10, Copernicus and Earth Watch programmes should:
    a. Be supported when the opportunity arises for implementation via those programmes.
    b. Be reviewed as potential national missions if not funded via those programmes
7. To re-consider the mission/instrument list in approximately 12 months

Summary and Conclusions

The EO Advisory Committee reviewed the outcome of the extensive work undertaken by the Review Panel and CEOI. The Committee supported the Panel conclusions and recommendations and recognised that there was a good spread of science, operational and commercial missions proposed and a broad coverage of all the technology areas. This reflects the excellent skills and great capability in the UK in EO missions – science and technology.

Actions recommended include supporting technological development necessary to increase the TRL of promising missions and also supporting the missions which would benefit from an improved business case or development of the user needs. There was also recognition that by sharing ideas some potential overlaps and duplications could be reduced, which could take place through community workshops to join up missions where appropriate.

The Committee was pleased with the high number of applicants and endorsed the list of 'flight-ready' missions. The Committee warmly welcomed the initiative that gave a clear indication of the UK's capabilities, an indication of user needs and that there are mission champions across academia and industry. There was a strong recommendation to increase the evidence of implied user needs for the missions.

EOAC recommended that the Agency makes appropriate use of the list to identify missions best fitted to specific opportunities.

Annex 1 - Missions Assessed by Panel as Ready for Implementation

The following missions have been assessed by the Panel as being sufficiently mature in all main aspects to be taken through to implementation if/when funding is available. They would all benefit from appropriate mission level studies to confirm and update the feasibility, estimated cost and optimal implementation at the appropriate time:

Title	Organisation	Observation	Mission Type	Sensor Technology
Cold Atom Space Payload (CASPA)	Teledyne e2v	Solid Earth (Tech Demo)	Technology Demonstration	Cold Atom Quantum Sensor
Methane Isotopologues by Solar Occultation (MISO)	STFC RAL Space	Atmosphere	Scientific Operational	IR Radiometry
Vivid-i Evolution (VE)	Earth-i Ltd	Earth Surface	Commercial	Optical Video Imaging
TRUTHS (Traceable Radiometry Underpinning Terrestrial- and Helio-Studies	NPL	Climate	Scientific Operational	Optical HSI
ORORO - Ocean Reflectometry and Radio Occultation Constellation	SSTL	Atmosphere	Scientific Operational	GNSS Reflectometry and Radio Occultation
MWS-Lite Constellation	Airbus Defence & Space	Meteorology	Scientific Operational	Microwave sounder
OmniSat HAPI	Thales Alenia Space UK	Atmosphere	Operational	Multispectral VNIR Imaging
Tropical Carbon Mission (TCM)	University of Edinburgh	Climate	EO Science	SWIR Spectrometer, Aerosol Imager and Cloud Imager

Note: OmniSat-HAPI and TCM are likely to be ready for implementation once current work is complete

A summary of each of these missions together with the assessment by the Panel is provided on the following pages.

1 Cold Atom Space Payload (CASPA) (Teledyne e2v)

Price Range	Observation	Mission Type	Sensor Technology
£1-10M	Solid Earth (Tech Demo)	Technology Demonstration	Cold Atom Quantum Sensor

Mission Outline: Technology demonstration mission to produce, image and test the production of laser-cooled Rubidium atoms autonomously in space. It is expected that this primary objective could be completed within 3 weeks of operation. A cold atom platform such as this will become a pre-cursor to using the atoms within ultra-sensitive gravity sensors in future Earth observation missions. The atoms could also be used for magnetic sensors, clocks, quantum repeaters and computers.

- Technology demonstration mission to test a Cold Atom Payload on a 6U CubeSat.
- Uses new sensing technology harnessing the quantum properties of cooled atoms and using them as sensors
- First stage for a next-generation gravity monitoring mission ("GOCE-2"), demonstrating critical new technology
- Cold atom interferometry can be used for sensing accelerations (gravity), magnetic fields, rotation, or used as a frequency reference.

Main Products and Beneficiaries: CASPA is a CubeSat technology demonstrator/TRL raiser only and will not be capable of generating sensor data of the Earth. The main beneficiaries will be the cold atom equipment supply chain and the cold atom research communities in the UK that have been established as a result of the UK National Quantum Technology Programme. A follow-on mission with a sensitive gravity instrument would produce enhanced gravity data products with broad benefits to the Earth science community. Cold atom capabilities are also expected to benefit the quantum timing, sensing and quantum information communities/industries in the UK.

Sensor Technology: The demonstrator payload will include all the critical subsystems and components necessary to create, cool and image clouds of Rubidium atoms autonomously. The atoms will be cooled by lasers to a temperature very close to absolute zero. The payload includes a vacuum system (with atom source, ion pump, magnetic field generation), laser system (based on a telecoms laser) and atom imaging system. All the satellite subsystems are COTS or industrially sourced. The payload weighs 4kg, fits into a 4U (200mm x 200mm x 100mm) envelope within a 6U CubeSat and consumes less than 40W.

UK Footprint: All capabilities are available in the UK.

Development Status: SRL (n/a); TRL-4 and MRL-3

Panel Summary: The panel strongly supported this proposal. This is an area of strategic importance to the UK and one where a national technology lead warrants support. Taking selected technologies from the bench to a free flying cold atom IOD test bed would be a significant achievement. The panel were encouraged by the current de-risk activities. Over-all, the panel judged the mission concept to be well developed with a potential roadmap to IOD flight in 2-3 years.

Advice to the Agency: Mission is ready to implement (Technology Demonstration Mission).

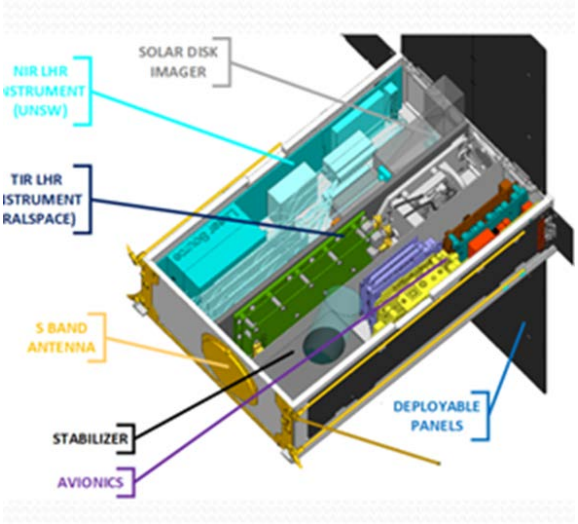
2 Methane Isotopologues by Solar Occultation (MISO) (STFC RAL Space)

Price Range	Observation	Mission Type	Sensor Technology
£1-10M	Atmosphere	Scientific/Operational	IR Radiometry

Mission Outline

The MISO mission will measure methane isotopologue distribution in the upper troposphere and stratosphere (UTS) by limb-sounding solar occultation from a LEO nanosatellite. An initial In-Orbit Demonstrator ISS-launched satellite would be a precursor to deployment of a constellation. The ground segment would be at Harwell, UK with 100Mb/day of data archived and processed on JASMIN, Harwell.

- New or improved commercial methane emission service
- Measurement of methane distribution in the upper troposphere and stratosphere (UTS) by limb-sounding solar occultation
- Laser heterodyne radiometer (LHR) operating in the thermal IR
- High spectral and spatial resolution in a 1.5 U instrument
- ISS-launched satellite for IOD - precursor to constellation
- Possible bilateral mission with Australia



Main Products and Beneficiaries: Enabling new or improved commercial regional methane emission estimation services, by providing high accuracy methane isotopologue profiles to enhance the exploitation of nadir sounders such as Sentinel 5P. The beneficiaries include industries (emitters), governments (accounting reduction targets), local authorities (assessing policy impact).

Sensor Technology: The baseline HIROS (High-resolution IR Occultation Sounder) instrument is a laser heterodyne radiometer (LHR) operating in the thermal infrared, providing very high spectral and spatial resolution in a compact instrument package (1.5U). HIROS is a passive instrument and will carry out atmospheric limb sounding in transmittance using the Sun as a radiation source. In consequence HIROS will be self-calibrating and there is no requirement for in-orbit calibration.

UK Footprint: Potential dual-band bilateral mission with Australia, where HIROS would operate alongside a shortwave infrared LHR (3U size) from the University of New South Wales in a 6U cubesat.

Development Status: SRL-5; TRL-4 and MRL-5

Panel Summary: This is a cost effective mission, with a technically feasible payload providing data which matches the user needs and credible to implement on a CubeSat. It would provide good (but non-commercial) return on investment. There is a well identified science/operational need for methane profiles in the UTLS, however the commercial potential for such data is less clear. Supporting evidence to show that there is a commercial market would strengthen the proposal. The proposal aligns strongly with UK policy priorities and strategies, and supports the UK position in climate science and in EO technologies, where significant innovation is evident.

Overall the mission was judged to be ready to move into the implementation phase.

Advice to the Agency: Mission is ready to implement.

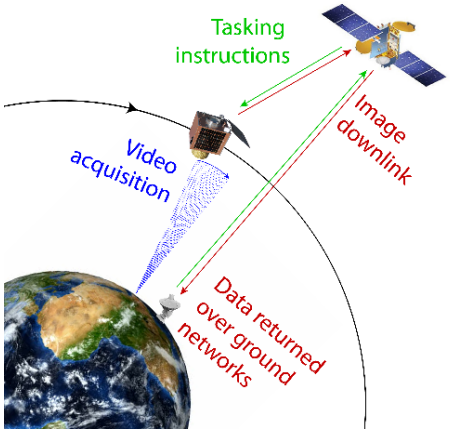
3 Vivid-i Evolution (VE) (Earth-i Ltd)

Price Range	Observation	Mission Type	Sensor Technology
£1-10M	Earth Surface	Commercial	Optical Video Imaging

Mission Outline

Enhancements on a Vivid-i Evolution (VE) satellite to realise a step change in EO services available to UK users: (1) Very high-resolution image and video data, tasked and processed in near real-time into usable information products, optimising data latency from satellite constellations. (2) Information from small satellites in alternate spectral bands. (3) Improved satellite platform and optical designs which enable the above services. (4) Software for constellation mission planning.

- Near-real-time video streaming from satellite beyond the horizon
- New use cases for EO including urban, smart cities, natural resources, bathymetry, security
- Additional dimension of information from video such as moving features and 3D models
- Vivid-i is unique in Europe with few credible competitors globally
- World beating capability combining multiple existing technologies in space



Main Products and Beneficiaries: The products include very high-resolution image and video data, tasked and processed in near real-time into usable information products, optimising data latency from satellite constellations, including information in alternate spectral bands. The principal beneficiaries are users who currently require rapid information availability such as defence and intelligence, security and disaster response personnel. New applications may include live traffic monitoring, smart city management, live port operations, machinery tracking for oil, gas and natural resource major activities, live maps for autonomous vehicles, terrorism response, crowd control, embassy security and others.

Sensor Technology: Staring video sensor, based on the existing Carbonite-2/VividX2 satellite, with improved coverage and resolution and possibly additional/alternative spectral bands. The instrument will be matched to customer needs, based on the existing optical design with mimimal modifications. The primary improvements in utility come from the enhanced comms and on-board processing which enable the temporal improvements. Other instruments may include a deployable antenna from ViaSat to enable the inter-satellite relay at 30-70Mbps and the onboard GPU processing.

UK Footprint: Dedicated mission with incremental developments of flight-proven SSTL design.

Development Status: SRL-5; TRL-3 and MRL-2

Panel Summary The Panel considered this mission as being sufficiently mature in all main aspects to be taken through to implementation. This would require further detailed evaluation of the feasibility, estimated cost and optimal implementation. The Panel was ultimately unsure about the proposed customer base, and felt it lacked examples of tangible use cases. Unfortunately detailed explanation of user need was limited by commercial confidentiality. UKSA support for such a mission would require greater clarity on applications.

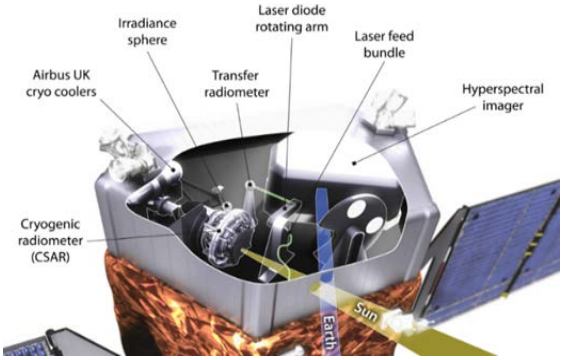
Advice to the Agency: Mission is ready to implement.

4 TRUTHS (Traceable Radiometry Underpinning Terrestrial- and Helio- Studies (NPL)

Price Range	Observation	Mission Type	Sensor Technology
£100-250M	Climate	Scientific/Operational	Optical Hyperspectral

A mission to enable a space based climate-calibration observatory through increasing confidence (i.e. trustability) in information derived from EO hyperspectral data (UV-SWIR). TRUTHS will provide regular SI traceable cross-calibrations from orbit for most optical sensors on other satellites in a consistent manner. A multi-disciplinary science-driven mission which upgrades the performance of operational EO assets like the Copernicus Sentinels and constellations of micro-sats. It will also provide data for other applications such as radiation budget and solar irradiance.

- Space based climate-calibration hyperspectral observatory
- Facilitate an internationally integrated climate quality Earth observing system
- Long term benchmark of the state of the planet to allow climate model forecast testing
- Provide unequivocal observational evidence of climate change in shortest time possible
- Small agile satellite, 5yr+ life
- Mission evaluated for both SSTL and Airbus platforms



Main Products and Beneficiaries: Delivers data of quantifiable quality for a range of commercial and scientific applications, through SI referenced in-flight calibration, triggering a new epoch in climate science. Principle beneficiaries are government (international climate agreement monitoring), industry (commercial services exploiting high accuracy analysis ready data) and science (dataset of unprecedented accuracy).

Sensor Technology: Primary measurements are from a single telescope feeding a hyperspectral imaging spectrometer (near UV -SWIR), which is able to view Sun, Moon and Earth. The baseline design (D Lobb CEOI 8) is prism based and utilises two or three detectors. Fundamental to this instrument, and the disruptive element, is the in-flight calibration method which has been demonstrated to TRL 5/6. This is based on a cryogenically cooled 'primary standard'-quality detector (CSAR), optimised for spaceflight.

UK Footprint: In addition to launch, low power laser diodes, used in the on-board calibration system, are the only critical non-UK component, available from Germany. A number of potential partnerships exist which could take on different roles defined by the UK, including with Switzerland.

Development Status: SRL-4; TRL-4 and MRL-4

Panel Summary: A well-developed mission concept. Significant ground work has already been undertaken to de-risk the critical technologies and a clear conception of the contribution that the mission will make to Climate science. Evidence of buy-in from downstream in the value chain would strengthen the case. For example, in the case of the cross-calibration concept, demonstration that the TRUTHS products would have a material impact on planning for other missions / operators. Over-all, the panel judged the mission concept to be well developed and ready to fly.

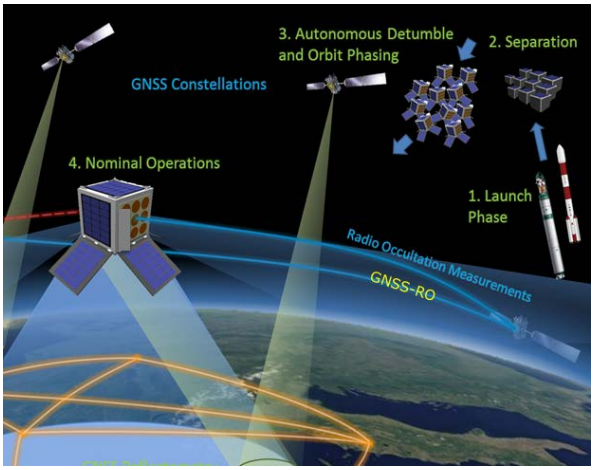
Advice to the Agency: Mission is ready to implement.

5 ORORO - Ocean Reflectometry and Radio Occultation Constellation (SSTL)

Price Range	Observation	Mission Type	Sensor Technology
£50-100M	Atmosphere	Scientific/Operational	GNSS Reflectometry and Radio Occultation

ORORO is a GNSS Ocean Reflectometry and Radio-Occultation LEO constellation in polar orbit. It will provide dense coverage measurements from small satellites, using GNSS/GPS signals from existing and planned operational constellations as the active source. It will provide timely measurements for weather applications.

- Measurements of ocean winds, mean square slope wave-height, atmospheric bending angle (T, P and %RH), ionospheric Total Electron Count
- Offers new global weather measurements
- Small instrument for GNSS reflectometry
  - GPS as radar source, scattered off ocean (OR)
  - GPS observed through atmosphere (RO)
- Satellite constellation (12 or 40), <50kg each
  - Upgraded GNSS Remote Sensing Instrument
  - SGR-ReSI instrument already flown on TDS-1 and NASA CYGNSS



Main Products and Beneficiaries: Main products are ocean surface wind speed, mean square slope wave-height, atmospheric bending angle for assimilation into NWP. Additional products include ice, land & ionospheric measurements. Main beneficiaries are weather agencies and operational weather users.

Sensor Technology: Multi-frequency multi-GNSS compatible receiver picking up reflected and refracted GNSS signals. The addition of dual frequency brings new capability for radio-occultation, and the compatibility with Galileo increases reflectometry coverage.

UK Footprint: Unique technological capabilities and strong scientific lead for GNSS-R within UK, currently supported mainly by ESA.

Development Status: SRL-7; TRL-4 and MRL-5

Panel Summary: The ORORO mission would lead to UK firsts in space for a GNSS receiver capable of both radio occultation and GNSS reflectometry at high latitudes. It has both high UK technology interest and meteorology/science interest. The alignment with UK EO policy and strategy is very good. Given other proposals, it is clear that the value of the mission would be further enhanced by observations over land for soil moisture and over sea ice/snow and the proposers should articulate these more. The user interests and requirements should be assembled into a mission document. The TRL of the new receiver should be confirmed. Overall the panel agreed that this mission was a very good one to fly, building as it does on technology pioneered in the UK.

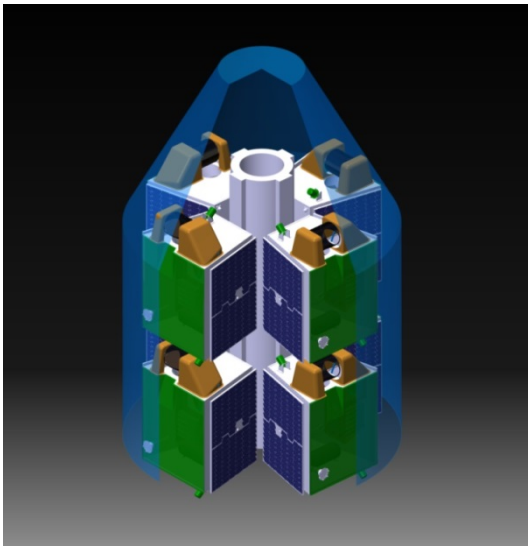
Advice to the Agency: Mission is ready to implement.

6 MWS-Lite Constellation (Airbus Defence & Space)

Range	Observation	Mission Type	Sensor Technology
£100-250M	Meteorology	Scientific/ Operational	Microwave sounder

Building on the heritage of the MetOp-SG MWS instrument, it is proposed to build and launch a constellation of MWS-Lite satellites. The constellation is called MWS-Lite, as the instrument is proposed to be a smaller, lighter version of MWS but to retain the core MWS functionality at the critical humidity sounding frequency, i.e. 183GHz. Continuous sounding measurements would be received via a low latency ground network for processing and ingestion into numerical weather prediction (NWP) models.

- Microwave Sounders are most important instrument for satellite weather data
- Few current data points available and several will be retired over the next few years
- Radically improve NWP with additional data points in precipitation frequencies, i.e. 183GHz
- More frequent revisit, e.g. to 40 minutes, can provide a step-change in rain forecast capability
- Constellation of Microwave Sounder satellites based on the MetOp-SG MWS instrument
- MWS for Metop-SG is already at high TRL and very high SRL



Main Products and Beneficiaries: The main beneficiaries are those dependent on accurate weather forecasting, both global and local. UK Met Office analyses confirm that additional microwave sounding data offers a significant improvement in NWP. There is a nascent commercial market for the exploitation of precipitation data, e.g: Insurance against extreme weather events and real time rain forecasting to help redirect aircraft from rain zones.

Sensor Technology: The instrument proposed is a simplified version of the MWS instrument, essentially a mini-microwave sounding radiometer. Only the most critical frequency bands for humidity sounding would be retained. The instrument would re-use key qualified features from the MWS instrument (e.g. mechanism, receivers), and would also retain a reduced size On Board Calibration Target.

UK Footprint: Majority of components are sourced from the UK, from the current MWS supply chain.

Development Status: SRL-6; TRL-5 and MRL-3

Panel Summary: MWS-Lite is a development for small constellations of a high TRL and very high SRL instrument being implemented on Metop-SG. As a UK instrument with UK-led applications, it is clearly of benefit to UK strategic interests and to UK industry if the mission can be shown to have realisable benefits. This is now one of the challenges. The second challenge is to advance the concept through studies of the performance of the proposed platforms and the instrument concept that would fit to these. Overall, the panel concluded that this mission was ready to fly, noting the need for quantitative evidence of benefit to weather forecasting and the further design and prototyping work on the mission concept.

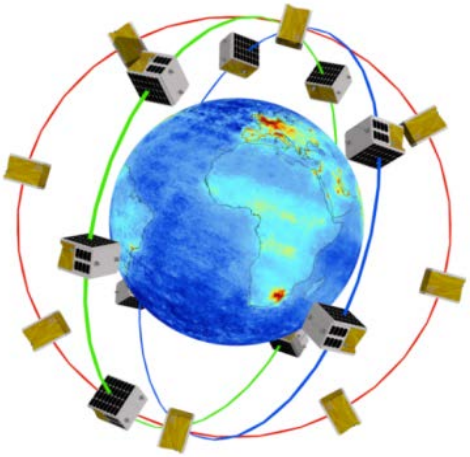
Advice to the Agency: Mission is ready to implement.

7 OmniSat HAPI (Thales Alenia Space UK)

Price Range	Observation	Mission Type	Sensor Technology
£10-50M (£100-250M)	Atmosphere	Operational	Multispectral VNIR Imaging

OmniSat HAPI is a highly agile smallsat constellation to detect nitrogen dioxide (NO_2) in the atmosphere above the world's most polluted towns and cities. The constellation architecture ensures fast revisits with a balanced swath and resolution to achieve a detail of data that can provide breadth and depth insight to clients. The constellation will deliver an unprecedented spatial resolution of up to 600 m by 600 m from a lightweight payload of 3 kg. OmniSat HAPI employs a novel UK-developed concept targeting radiometry in specific channels rather than full spectrum as in Sentinel 5P, lowering hardware complexity, instrument costs, and data bandwidth.

- Constellation of low cost, novel multispectral sensors
- Monitors urban air pollution globally at high spatial and temporal resolution
- Measures short wavelength visible radiances
- Nitrogen dioxide (NO_2) column densities, and surface concentration maps at 600m surface resolution multiple times daily
- highest resolution of any current missions or planned missions



Main Products and Beneficiaries: Operational high spatial and temporal resolution data on NO_2 pollution in urban areas for an array of customers which can be transformed into actionable intelligence. The key benefits are improved understanding and forecasting of urban air pollution and the ability to monitor in an unprecedented level of detail the effectiveness of air pollution mitigation strategies implemented by local, national and international policymakers. The key beneficiaries are the air quality modelling industry, local and national governments, and citizens, including the DEFRA EO Centre of Excellence, NERC and international scientists and commercial organisations.

Sensor Technology: A multi-band NO_2 imaging instrument observing in the UV/visible spectrum to build a definitive image and data set of the NO_2 pollution across a selected area.

UK Footprint: All technologies developed in a partnership between UK industry and academia

Development Status: SRL-2; TRL-5 and MRL-4

Panel Summary: This mission demonstrated strong alignment with national policy objectives and offered substantial growth in national SmallSat capabilities at an affordable price point. However, whilst a user need is demonstrated to exist, it is unclear what engagement with end users has been undertaken to date. The panel also expressed concerns that with only limited innovation and little unique IP the mission concept could be at risk from competition elsewhere in Europe.

Overall, the panel felt this mission was well aligned with the objectives of the EOMCR and will be a strong candidate for a UK mission following completion of the work currently ongoing.

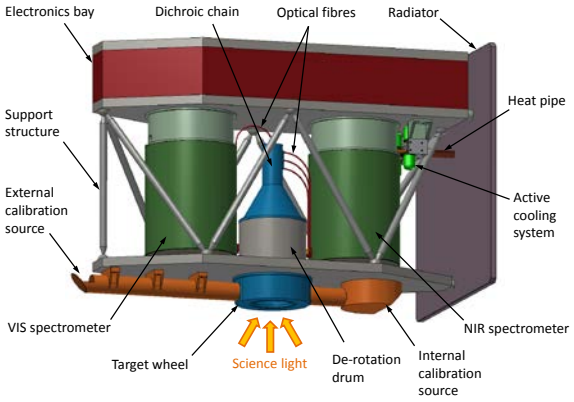
Advice to the Agency: Work on-going - close to flight ready

8 Tropical Carbon Mission (TCM) (University of Edinburgh)

Price Range	Observation	Mission Type	Sensor Technology
£100-250M	Climate	EO Science	SWIR Spectrometer, Aerosol Imager, Cloud Imager

The primary science objective of TCM is to reduce the overall uncertainties in the magnitude and distribution of tropical CO_2 fluxes such that we can determine with certainty whether in any particular two-week period the tropics is a net source or sink of CO_2. A better estimate of tropical fluxes will help improve existing surface measurement networks estimates of extra-tropical CO_2 fluxes.

- Quantify tropical sinks and sources of greenhouse gases - 35-degree inclined orbit
- Measure column CO_2, CH_4 and CO, as well as providing observations of solar induced fluorescence (SIF) and cloud cover
- 4 Channel Vis-SWIR spectrometer based on existing designs & technologies (from GHOST)
- Multi-angle front end to detect and remove aerosol contribution and to improve cloud free observation statistics
- Additional aerosol radiometer (and other diagnostics)



Main Products and Beneficiaries: TCM will deliver tropical CO_2 flux data to confront current basic knowledge and develop predictive models for large-scale Earth system science models. It also provides information to help some of the most vulnerable tropical countries by providing, for example, the carbon cycle of agricultural crops. The main beneficiaries will be scientists, international policy makers, UK government, and governments of tropical countries. Developing robust estimates of Nationally Determined Contributions implicitly assumes good knowledge of the natural carbon cycle.

Sensor Technology: The TCM comprises three instruments, building on current technology: 1) a short-wave IR (SWIR) multi-view spectrometer that will measure CO_2, carbon monoxide (CO), methane (CH_4), and oxygen (O_2); 2) a co-boresighted aerosol imager; and 3) a wide-view cloud imager.

UK Footprint: UK heritage and capability to build the instrument, platform, data and science.

Development Status: SRL-6; TRL-4 and MRL-4

Panel Summary: The mission was judged to be a good fit for the Agency's criteria (including Climate Science and international links), and close to a 'flight ready' status. Some further work is needed to de-risk successful retrieval of intended products (e.g. impact of scattered cloud). The proposal would benefit from a stronger / clearer value-added differentiation with respect to other missions with similar sensing objectives.

Over-all, the panel judged the mission concept to be well developed and close to a flight-ready status.

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Annex 2 Missions Proposed for ESA Programmes

These missions were under consideration for implementation under an ESA programme at the time of the EOMCR.

Title	Organisation	Observation	Mission Type	Sensor Technology	Status (May 2018)
Copernicus L-Band SAR - UK Instrument	Airbus DS Ltd	Earth Surface	Operational	L-Band SAR	Copernicus HPCM
ESA Earth Watch - UK role in Arctic Imager	Airbus DS Ltd	Atmosphere	Operational	VNIR Imager	ESA Earth Watch Candidate
Geosynchronous - Continental Land Atmosphere Sensing System (G-CLASS)	Cranfield University	Hydrology	EO Science	Radar	EE10 Candidate
IRIS - Interferometric Radar for Ice, Glaciers and Permafrost Dynamics	Univ of Leeds/Airbus DS Ltd	Cryosphere	EO Science	Ka-Band SAR	EE10 Candidate
LOCUS - Low-Cost Upper Atmosphere Sounder	STFC RAL Space	Atmosphere	EO Science	THz and IR radiometers	EE10 Candidate
Radar Imager to Sense a changing Cryosphere (RISC)	Airbus DS Ltd	Cryosphere	EO Science	Dual frequency Ku-Band SAR	EE10 Candidate
SEASTAR - Ocean sub-mesoscale dynamics and small- scale atmosphere-ocean processes in coastal, shelf and polar seas	National Oceanography Centre	Ocean	EO Science	Ku-Band Interferometric SAR	EE10 Candidate
WIVERN: A Wind Velocity Radar Nephoscope.	Univ of Reading	Meteorology	EO Science	Radar	EE10 Candidate

Note: The order in the table above is alphabetical by mission name

Annex 3 Missions with Potential

These missions were assessed as having potential but requiring further work on the user need, science and/or technology readiness, or mission concept before being considered further.

Mission Name	Organisation	Mission Type	Need	Sensor
Agri-LIDAR	Thales Alenia Space UK	Earth Surface	Operational	Lidar
CAIROS – Constellation of Atmospheric hIgh-Resolution Occultation Spectrometers	STFC RAL Space	Atmosphere	EO Science	IR Radiometry
Cloud Radar on CubeSat (CRoCS)	S&AO Ltd (visionAIR)	Meteorology	Operational	Radar
Cold Atom Gravity Pathfinder Mission	Teledyne e2v	Solid Earth	EO Science	Cold Atom Quantum Sensor
Compact Air Quality Spectrometer - CompAQS	University of Leicester	Atmosphere	Operational	Optical HSI
Compact Infrared Imager and Radiometer (CIIR)	University of Oxford	Atmosphere	EO Science	IR Radiometry
Compact Multi Angle Polarimeter (C-MAP)	Thales Alenia Space UK	Climate	Operational	Optical Filter Imager
Excelsior Stand Alone EO Mission and 1st Constellation Element	Airbus Defence & Space	Earth Surface	Operational	X-Band SAR
MARSUR Maritime Surveillance System	Airbus Defence & Space	Maritime	Operational	X-Band SAR
MISRlite : mapping 4D winds in real-time from a tandem convoy	UCL Mullard Space Science Laboratory	Meteorology	Operational	Thermal IR Imaging
MWR4ACCRA : Microwave Radiometer for Atmospheric Correction in Coastal Radar Altimetry	JCR Systems	Atmosphere	Operational	Microwave radiometer
Ultra Low-Cost GNSS Reflectometry constellation	Deimos Space UK Ltd	Hydrology	Operational	GNSS Reflectometry
UVSAT - global monitoring of air quality and emissions	AVS Added Value Solutions UK Ltd	Atmosphere	Operational	Optical HSI.

Note: The order in the table above is alphabetical by mission name

Annex 4 Call for EOMCR 2018 Call for Panel Members

Earth Observation Advisory Committee:

EO Mission Capability Review 2018 – Call for Panel Members

Closing date: 23:59 on the 3rd April 2018

The UK Space Agency is undertaking a UK EO Mission Capability Review (EOMCR). The outcome of this process will be a catalogue of credible Earth Observation missions that could be considered for "opportunistic" or strategic support - should funding become available. This funding could come from a variety of sources and could be best placed to fund science, commercial, or public sector orientated missions).

The review is being conducted by the CEOI on behalf of the Earth Observation Advisory Committee (EOAC) who will review the outcomes and provide advice to UKSA at their 10th May meeting.

An initial workshop was held on 2nd March 2018 and short proposals have been sought from the UK entities with mission ideas. A review panel is being formed which will judge each mission proposal against the set of criteria outlined in the call – see Box 1. The panel will be chaired by EOAC ad hominem (Richard Lowe), and will include representatives from UKSA, CEOI, and ESA.

We are seeking up to four additional members for the panel. These members will operate in a personal capacity and will be encouraged to have the freedom to challenge, debate, and provide alternative views. If you feel you have the skills, experience and time in April please send us your application by 3rd April 2018.

Position Specification

The successful applicants will complement the ex officio members of the Panel by bringing specific expertise or experience in one or more of the following Earth Observation-relevant areas including end users and requirements, New Space, or science & academia.

Applicants should have the time to evaluate short proposals from UK industry and academia in April 2018. The time commitment will vary depending on the number and distribution of proposals; UKSA expects approximately 25-30 proposals limited to 5 pages each. The provisional schedule for the review process is as follows:

- w/c 9th April: Reviewers receive proposals
- 20th April (TBC): initial review meeting in London – this is expected to last the full day
- 30th April (TBC): Workshop with presentations in morning, final review meeting in afternoon.

There is no funding available for panel members' time; reasonable expenses may be claimed for the meetings.

The UK Space Agency will seek the best members possible for it but also seeks to ensure and encourages that membership reflects the diversity within the relevant communities.

Applications should include a covering letter and a short CV .

The covering letter should be a maximum of two pages and should include:

- Your motivation for serving on the Panel
- Your area(s) of expertise and current activity and seniority
- appropriate qualities including knowledge of the subject area,
- what you would bring/ add to the Panel
- any possible conflicts of interest or steps to ensure a neutral position

Please send your application to UKSAEOT@ukspaceagency.bis.gsi.gov.uk by 08:59 on Tuesday 3rd April 2018 at the latest. Please mark the email as CONFIDENTIAL EOMCR Panel Application: Your surname

For further information please contact:

The EOMCR chair Richard Lowe (Richard.Lowe@telespazio.com) or UKSA Industrial Sector Lead (Earth Observation) Alasdair Gow (Alasdair.Gow@ukspaceagency.bis.gsi.gov.uk)

BOX 1

Key criteria as well as the general characteristics of the proposed mission:

- Describe the principal user need for the mission and any existing collaboration with the end user
- Show how the project aligns with UK EO, national space policy or other UK industrial objectives (e.g. climate science, UK EO Technology Strategy, UK Industrial Strategy)
- Describe the principal benefits that will result (e.g. leading science position; job creation; export growth; national prestige; etc.)
- Describe the principal innovative/ unique aspects of this project (science / technology / products / services)
- Why is this mission / instrument achievable, realistic and cost-effective? (e.g. by comparison to previous missions)