

# TRUTHS: Enabling a Space based Climate-Calibration Hyperspectral Observatory

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With support from the scientific and industrial consortium:

30<sup>th</sup> April 2018



# Outline/Summary Description

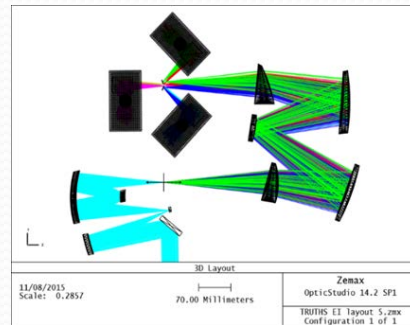
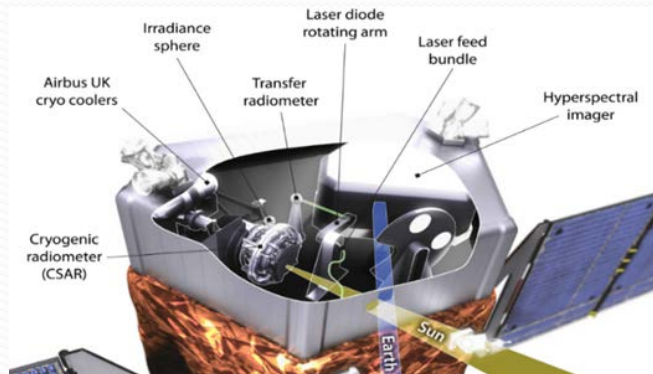
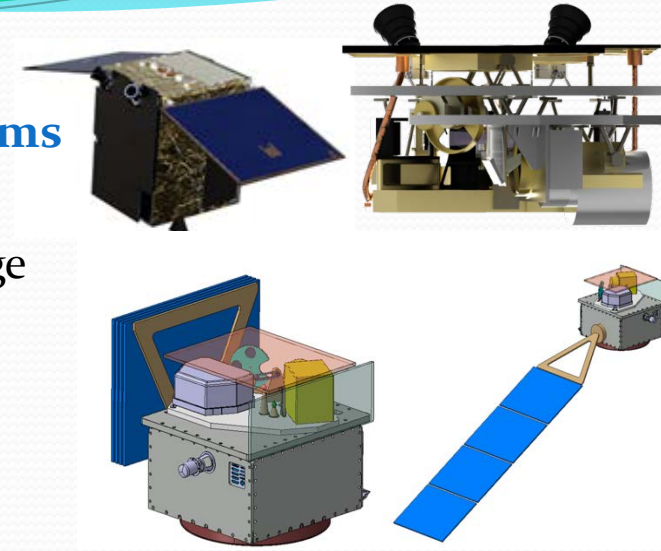
- **Mission Title: TRUTHS** (Traceable Radiometry Underpinning Terrestrial- & Helio- Studies)
- **Primary objective:** Enable a space based Climate-Calibration Hyperspectral observatory through increasing confidence (Trustability) in information derived from EO data
  - **Near term:** Facilitate an internationally integrated climate quality Earth observing system
  - **Long term:** Benchmark state of the planet (a) to allow climate model forecast testing  
(b) provide unequivocal observational evidence of climate change in shortest time possible
- **What will the mission/instrument be measuring/observing?**
  - Earth Hyperspectral Radiance: (320 – 2350 nm)      **0.3% uncertainty** (spectrally & globally continuous @50 m)
  - Solar/Lunar Spectral Irradiance:                      **0.2% uncertainty**
  - Total Solar Irradiance:                                      **0.02% uncertainty**

**Note:** hyperspectral L1 can be re-convolved to address many Level 2 applications as a secondary benefit  
(possible that some L2 may be delivered as part of mission)

Upgrades performance/Establishes Traceability for EO system from space through ‘cross-calibration’
- **Competing missions/instruments and complementary measurements (if any)**
  - CLARREO (NASA) demonstrator on ISS, Chinese copy, EnMAP (hyperspectral data not climate)
  - TRUTHS complements the majority of optical EO satellites especially S2 & S3, FORUM will add IR

# Technical Implementation (1)

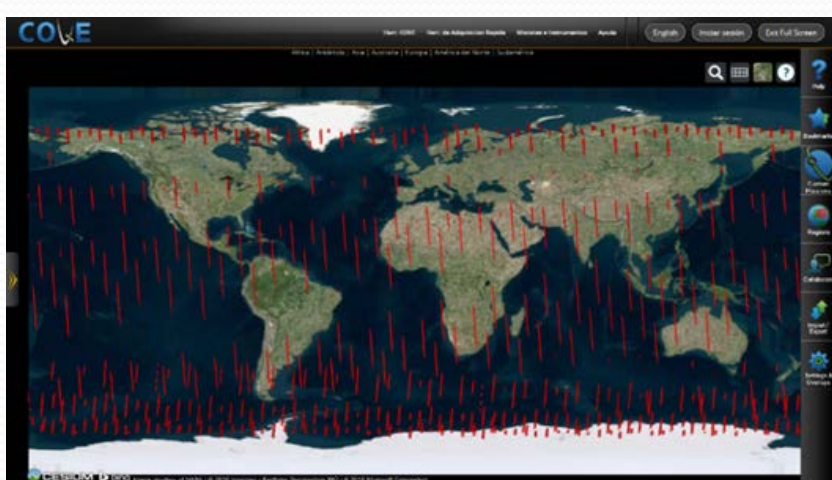
- **Small agile satellite, 5yr+ life, mission evaluated for both SSTL and Airbus platforms**
  - As a demonstrator achieving all near term goals using ISS,
  - In combination with constellation of microsats enhanced to provide high temporal coverage
- **Payload Power/Mass**
  - 150 kg (inc 20% margin)
  - 280 W (continuous in shadow) (inc 20% margin)
- **Single telescope/spectrometer (Hyperspectral Imager). 2 & 3 detector designs,**
- **Novel on-board cal system based uniquely around flight of a primary reference standard cooled to  $<\sim 65\text{K}$** 
  - Based on 30 yr terrestrial heritage. Space prototype built and performance proven under vacuum TRL 5/6 (CEOI funding)



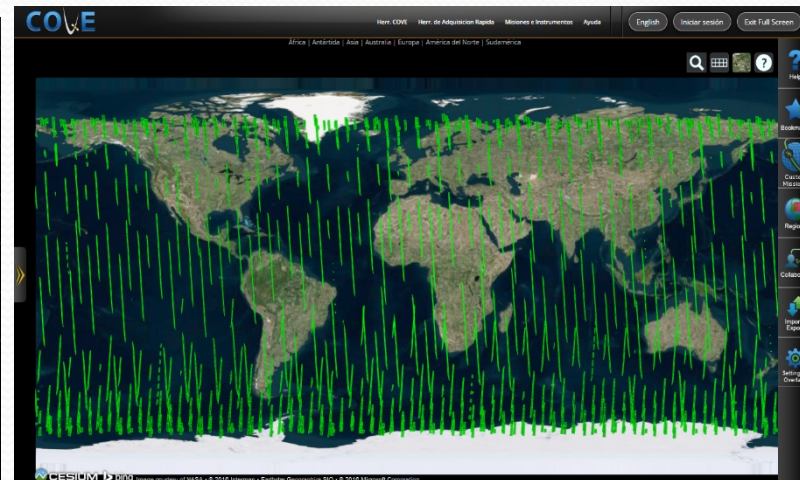
- **Hyperspectral imager** (Dan Lobb design)
- Can utilise UK Detectors (Si & HgCdTe (some small developments to optimise)
- Optics and Build capabilities exist in UK (also options for supply from another country)

# Technical Implementation (2)

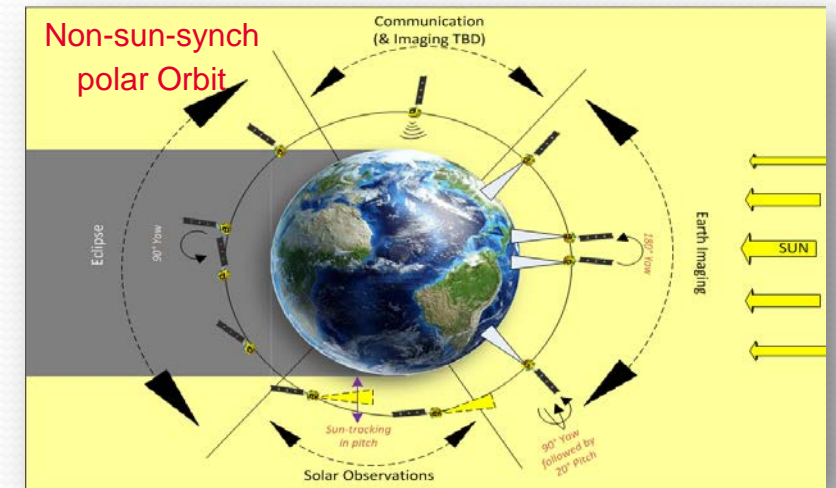
- **Recessing polar (non-synchronous orbit) 609 km to facilitate full diurnal sampling and enable multi-cross-Cal opportunities (CONOPS evaluated)**
  - Observes Sun/Moon on transition to shadow, On-board Cal during shadow
  - Up to TWO max per orbit manoeuvres to view sites of opportunity/BRF/angle matching of non-nadir sensors for Cal etc
  - Single ground station (Svalbard) allows data download (4500 Gb/day)
  - UK flight control and data centre (Harwell/CEMS)
  - Thermal analysis shows that heat dissipation can be achieved with a fixed radiator (using a manoeuvre)
  - Power achievable with single deployable 2 DoF PV sail ,
- **Mission Reliability analysis (0.97 for 5 yr life) limited by Cryocooler (heritage flight on S3),**



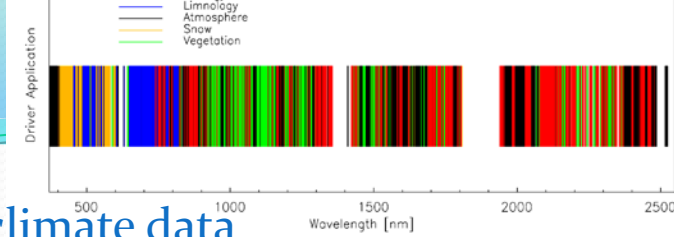
Nadir (30 min) cross-overs S2 per yr



Nadir (30 min) cross-overs S3 per yr



# User need



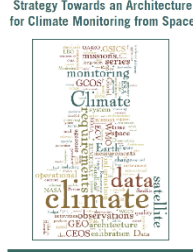
## • Main Users

- **Government:** (a) response to the Paris agreement; enabling greater accuracy/trust in climate data  
(b) Step forward for UK public and commercial EO systems, providing a reference framework and asset for international EO systems (potential independent UK contribution to Copernicus, GEO and CEOS)
- **Industry:** Commercial services exploiting early access to (ARD) with high accuracy, provenance – combining TRUTHS with other EO systems through UK architecture (public good enhancement of ISCF wave 3 digital revolution).
- **Science:** UK-controlled data set of unprecedented accuracy able to immediately resolve key questions e.g.  
Anomalies in measurements of incident solar irradiation, spectrally resolved (ToA & BoA) and Total.  
Robustness of FCDRs & CDRs caused by unexplained biases (~3%) between sensors e.g. S3 OLCI and MERIS

## • User Need

- Climate monitoring needs trustable FCDRs of higher accuracy/reliance for earlier detection of signals enabling timely mitigation and adaptation (30 strong international science team provided case studies for EE9 - UK team formulated)
- Integrated EO system e.g. 'Analysis ready data', 'on-demand' needs interoperability. Integrity and provenance
  - Constellations of micro-sats can provide temporal info but V-limited QA for science/services (end user expectation to specify accuracy (not necessarily high but reliable). Commercial data being incorporated into space agencies & gov use.
  - A 'gold standard' space reference (multiple scene types) is sought to enable understanding and removal of effects of bias
    - Commercial Sats rely on vicarious methods. Much interest in systems like CEOS RadCalNet. **TRUTHS is next step**
- Hyper-spectral data allows Earth System Science approach matching spectral signatures of many ECVs / applications
  - Allows improvements to existing retrieval algorithms and opportunities to develop new multi-parameter retrievals
  - Opportunities for UK science to lead in unlocking the potential of hyperspectral imagery

# Policy Alignment



## Alignment with national policy objectives?

- **EO Technology Strategy:** *world leader in new EO technologies.* / *UK able to lead national/bilateral mission*
  - **low cost access to space-** small sat mission capable of revolutionising EO & climate science
    - Enables prospect of science quality measurements from constellations of nano-sats
  - **Showcase UK technology-** Cryo-coolers, imaging detectors (UV/VIS/SWIR), Calibration, QA, innovative ground segment, & opportunity to rebuild leadership on hyperspectral (CHRIS)
  - **International cooperation** Unique high profile mission (GCOS/CEOS/WMO) allows UK to select partners of choice.
- **Industrial (growth) strategy**
  - **Technological uplift**– UK firsts in space for optical calibration technology & compact high performance hyperspectral imager
  - **Big data** – exploits and promotes UK initiatives – encouraging global data sets through UK infrastructure – First to market advantage for new Quality Assured ARD inspired EO services.
  - **UK Seamless climate delivery chain** – provides national controllable upstream asset to complete ‘end to end’
  - **Post-Brexit mitigation** – can be offered as UK contribution to Copernicus and GEO (help maintain priority access to data)
  - **National grand challenge project** – media friendly, UK kudos and global dependence inspires next generation of STEM
- **Climate science/services: UK seeking leadership in climate related technologies and services**
  - Corner stone of ‘space climate observatory’ responding to GCOS/COP (Paris)
  - **International Request** -International climate community explicitly requesting a TRUTHS like mission
  - **UK leadership** -UK led mission would emphasise UK expertise and authority in climate services and international policy
  - **User need** -Letters of support from key potential users: C3S, insurance sector, Gov departments...

# Benefits

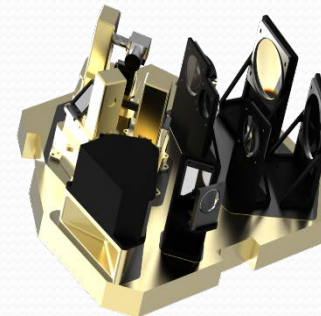
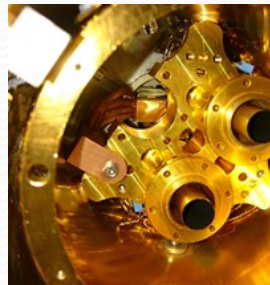
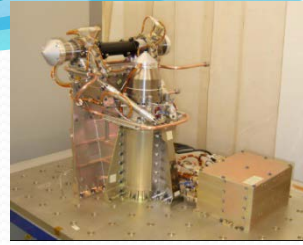
## Identify the impact and potential growth generated by the investment

- **National prestige project / showcasing innovation in science and technology**
  - **Ties the global EO system to UK technology** – a ‘gold standard’ for EO and **World first** capability creating environment for growth
  - **Leverage the World’s data** driven through UK infrastructure (e.g. CEMS) → new services → skilled jobs (SMEs)
    - Exploiting data sciences particularly for risk related sectors: energy, Finance but also agriculture, carbon markets ...
  - **Can be a UK contribution to Copernicus** – maximising UK selectivity and geo-return on any ongoing investment
  - Helps UK’s **continued leadership** in climate sciences, **inspires** next generation of STEM workforce
  - High profile demonstration of value of a national space programme – unique mission providing step change in sector
  - Treasury compliant economic model **yields 10:1 ROI**
  - **In-flight cross-calibration** reduces need for high cost on-board cal systems on each space craft - enables commercial sat constellations to achieve and demonstrate traceable products and ultimately a **fair market place**
  - Potential to underpin a UK led (**global hub for QA (certified!)**) EO data and information services
  - Provides UK science community with direct access to hyperspectral data and control of its acquisition of unprecedented accuracy and flexibility - Keeping **UK science and government at heart of international decision making**

# Innovation

## Innovation - A globally unique nationally conceived mission

- Disruptive use of relatively mature technology provides SI traceability in-flight @ 10X improvement in accuracy
  - Highly innovative combination of largely flight heritage components/Sub-systems – thus low risk
  - Significant reduction in complexity of realising concept in space form from original idea following CEOI studies (e.g. 7 movements to 2)
  - Most critical technologies exist or readily evolvable in UK enabling a flight capable mission in <4 yrs
- Enables upgrade in performance to climate quality of global EO system tied to UK including micro-sats
  - A new paradigm in Earth Observation
  - As minimum enables SI traceability in orbit of other missions to be established/evidenced
- Opportunity to re-establish national capability in hyperspectral imagery
  - facilitates sales of sub-systems e.g. cryocoolers, imaging detectors, imagers
- Enables UK downstream market to build on first to market advantage with early access to unique data sets and also other sources from across the globe facilitated by cross-calibration
  - Potential for UK led certification service
- First mission to measure spectrally resolved incoming and reflected solar irradiance from same instrument allowing true TOA reflectance to be determined.
- Establishes a benchmark of the radiation state of planet from which evidence and scale of impact of climate change and mitigation strategies can be derived in shortest possible time





# Cost/Value

- **Is the concept cost-effective? – Primarily a ‘public good’ mission but facilitating economic growth**
  - Treasury-compliant economic model finds both bilateral or full UK funding options yields a ~10:1 ROI
    - Outline business case drafted
  - Operations funded by BEIS/DEFRA and/or partnership with ESA (EU)/other
    - Potentially in part through some form of commercial service - early access to data
  - **Data policy:** Free and open access of delivered level-1 hyperspectral data (not necessarily in shortest timescales)
  - **Co-funding options:** Bi/Multilateral options with French, Swiss, Belgium, ESA, India, China ++
  - **Scalability of mission/Future sales**
    - Long-term climate benchmark application fundamentally requires a follow-on mission in decade+ timescales
    - Once proven scientifically – likely demand (Eumetsat/Copernicus/Earthwatch) for operationally deployed series of missions as part of a sustainable climate observing system and facilitating in-orbit traceability
    - Flight of two simultaneously increases sampling and calibration opportunities
    - China has plans for launch of lower performance TRUTHS copy in 2024/5
  - The concept and robustness of the solution is globally leading & already **proven to TRL 5/6** with CEOI
    - Implementation for space now significantly simplified/demonstrated,
    - Most sub-systems already have flight heritage – **Satellite:** thermal, data, power achievable
  - **Mission Costs:** Detailed cost breakdowns exist
  - **Main risks:** Timeliness of opportunity missed,
    - Ability to combine UK expertise to build imager (if national mission).