CEOI Showcase ESCAT Harwell

CompAQS

Compact Air Quality Spectrometer

Presented by

University of Leicester
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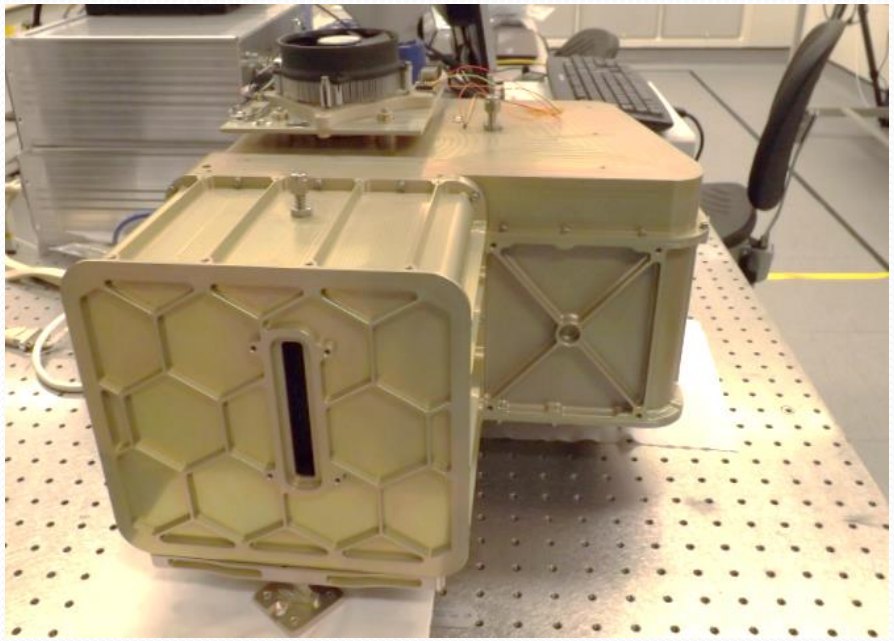
10th December 2018

Outline/Summary Description I

- CompAQS (Compact Air Quality Spectrometer)
  - 400-500nm hyperspectral 125km pushbroom swath imaging from ~600-650km
- Measure NO_2 at 1km spatial resolution
- NO_2 measured using gas absorption lines and DOAS technique
  - DOAS takes measured spectrum and compares it against spectrum with trace gases



User need I

- Main and Possible Users
  - Science Users
  - Local and National Governments (especially in data sparse regions)
  - Local and Global air quality data companies and environmental consultants
  - ESA, World Bank, WHO, philanthropy
  - Companies interested in monitoring their air quality footprint (large retail, logistics, etc.)

- User Need
  - Monitoring NO_2 pollution for population health, and transport monitoring and control
    - Global economic cost £3-5B p.a. with 92% of world population exposed to unhealthy air pollutants
  - Need "space" overview as well as in-situ sensors
  - Understand NO_2 sources and gas distribution in atmosphere
  - Potential Products
    - Global Protocol Compliant Verification
    - National and local emission assessment
    - Urban environmental services including integrated urban management systems

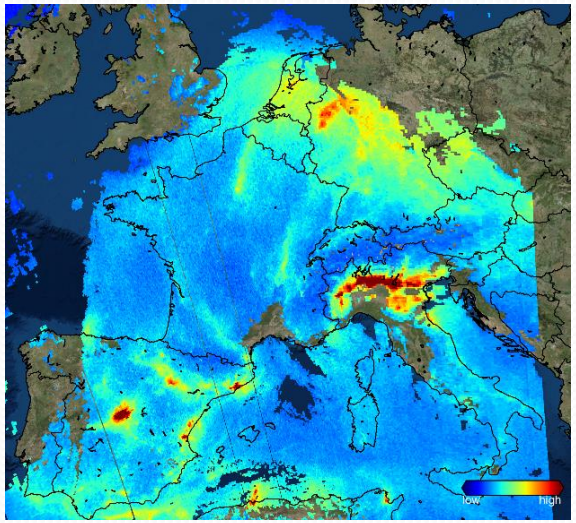
User need II

- Health
  - Elevated NO_2 concentrations have been associated with short term and long term effects, including:
    - Respiratory Inflammation
    - Asthma Exacerbation
    - Reduced Childhood Lung Development
  - There is growing evidence that NO_2 is not just a marker of air pollution but has it's own direct health effects [COMEAP STATEMENT ON THE EVIDENCE FOR THE EFFECTS OF NITROGEN DIOXIDE ON HEALTH]
  - NO_2 legal limits are frequently exceeded in the UK

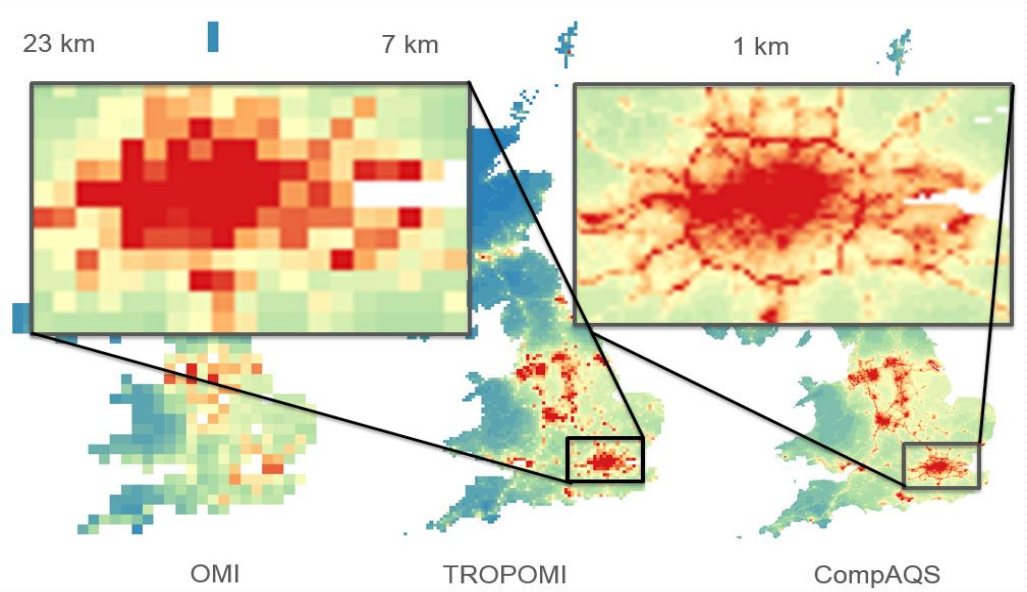
- High Resolution Coverage in Data Sparse Regions
  - Where surface in situ air pollution data are sparse, high resolution EO data can:
    - Enable identification of hot spots
    - Inform hot spot management policy
    - Provide first order validation for bottom-up air quality models with limited ground validation

Outline/Summary Description II

- Competing missions/instruments and complementary measurements
  - TROPOMI Sentinel 5P 7 by 7km pixels
  - CompAQS data can be compared to TROPOMI by rebinning
  - TROPOLITE proposed with high resolution (TROPOMI Light would be approx. 1 x 1 km)
  - Solar reference spectrum needed via spacecraft pointing (and calibration system)
  - Surface pressure and surface albedo needed for DOAS and level 2 data product
  - TAS Omnisat HAPI (multi-spectral) higher revisit with flexible tasking but NO2 only, needs cross check with CompAQS type instrument

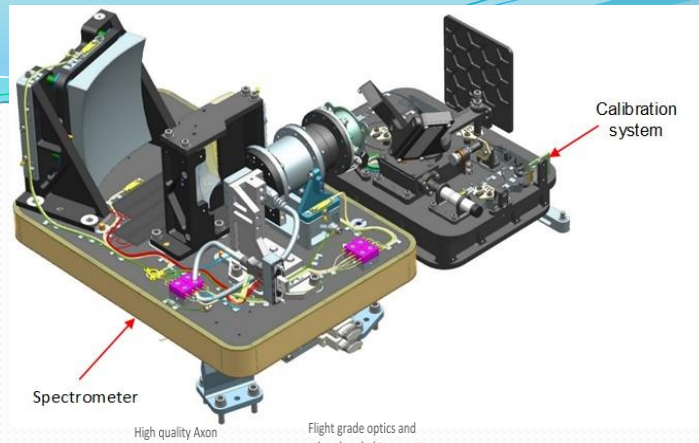


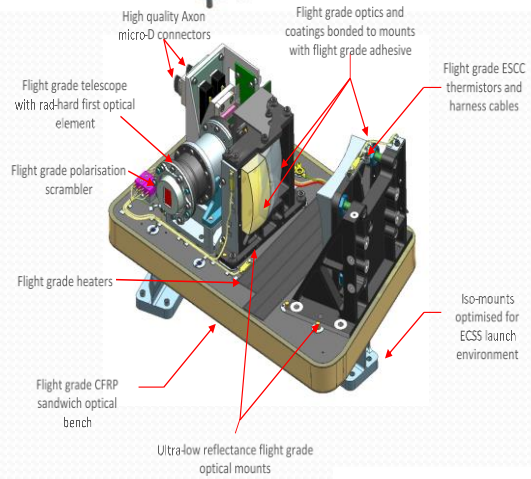
NO2 Image Sentinel 5P
Courtesy
ESA

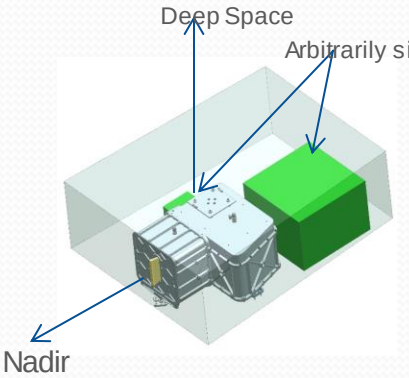


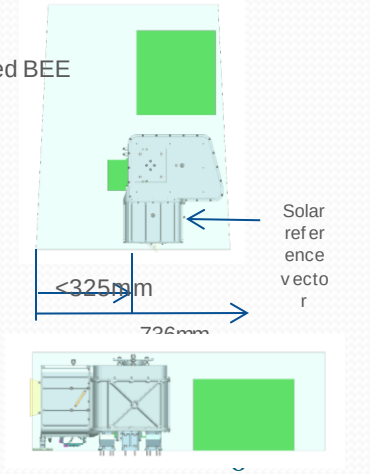
Outline/Summary Description III

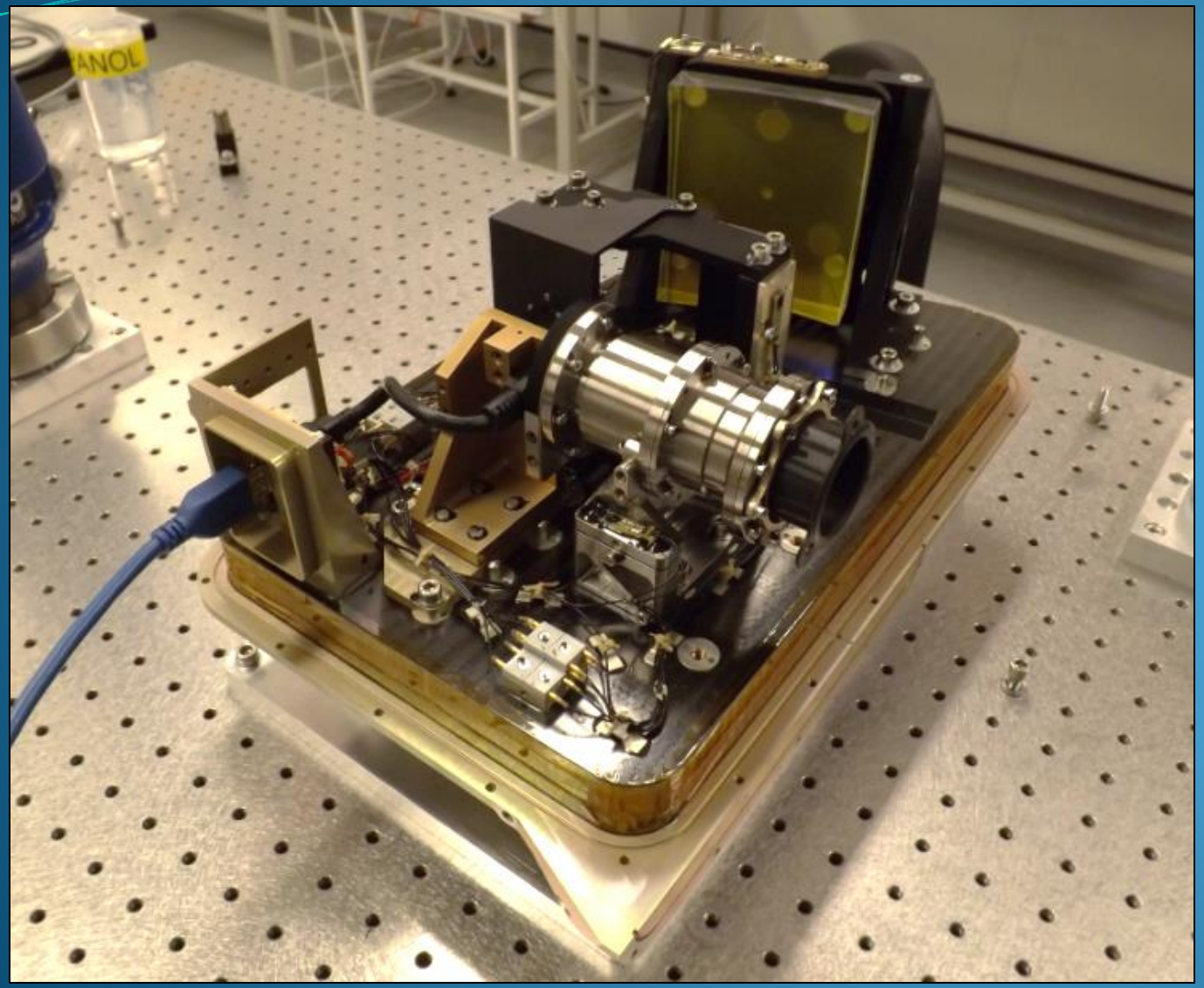
- Technical implementation
  - Polar sun-synchronous orbit
  - Can be hosted on a number of missions
    - Small spacecraft to large (Earth Explorer)
    - Bilateral, UK only, Agency missions, Hosted payload
    - Complimentary Instrument for Trace Gas Mission
    - Demonstrator Mission, Operational Constellation LTAN 10.30, 13.30, 16.30
  - Compatible with small spacecraft e.g. SSTL 150
    - Second payload can be hosted
    - Mass ~21kg
  - Spectrometer Optics and Calibration System TRL5
    - Flight standard build, plus vibration test, Thermal Vacuum planned
    - Needs TRL upgrade for detector (CCD) (7fps) and back-end electronics based upon developments for other missions
    - MLI specified



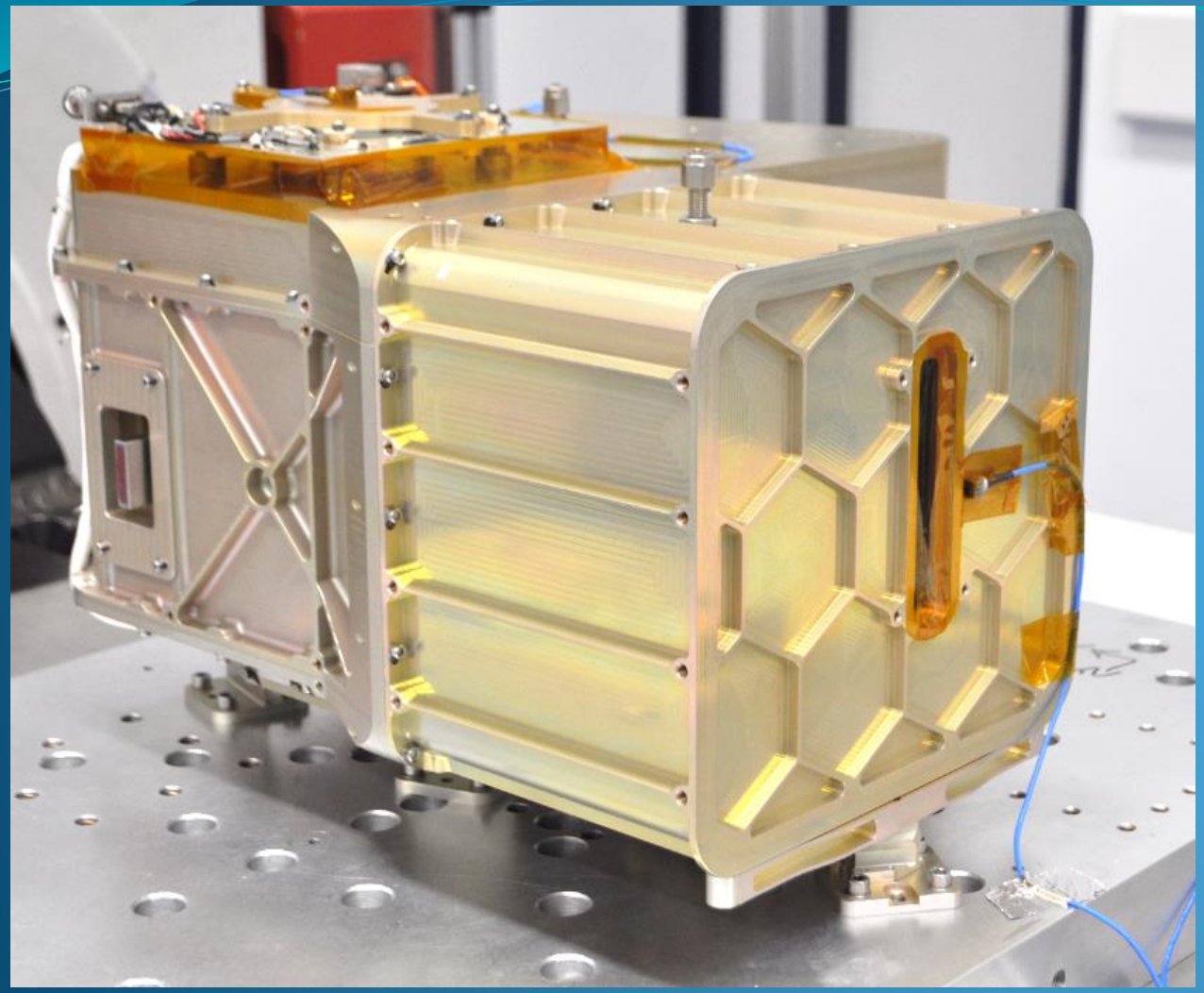


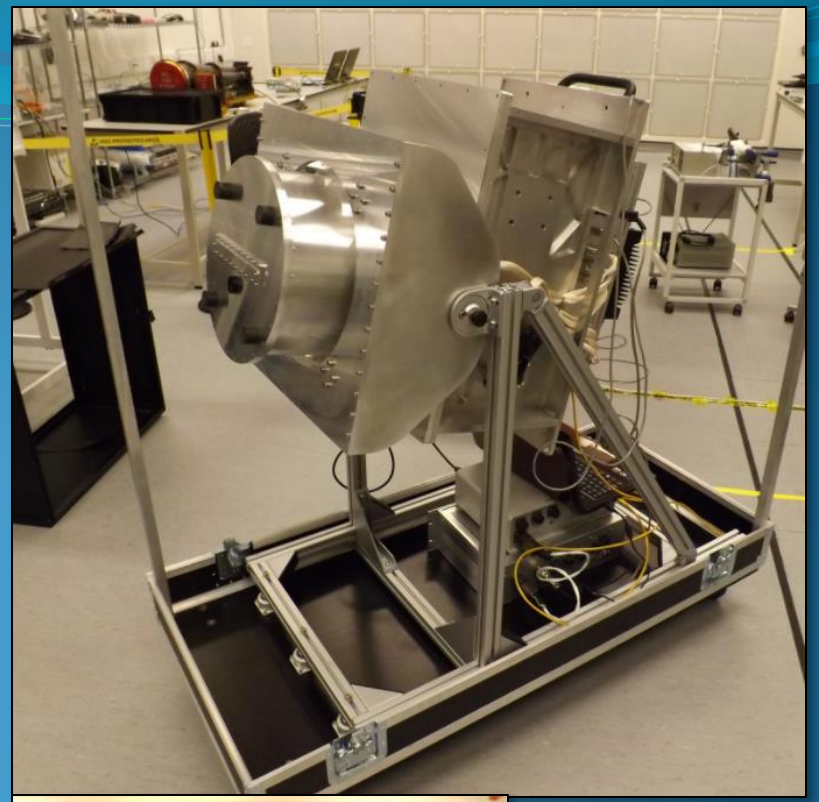


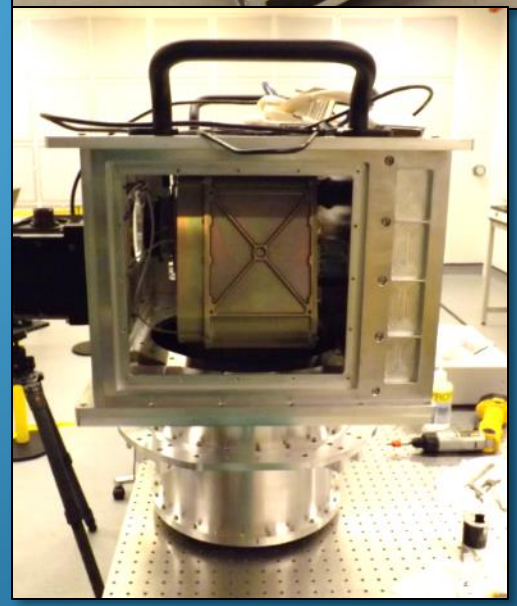




Images of Built Hardware (Spectrometer and Calibration System)
Build Funded by CEOI and NSTP and UL



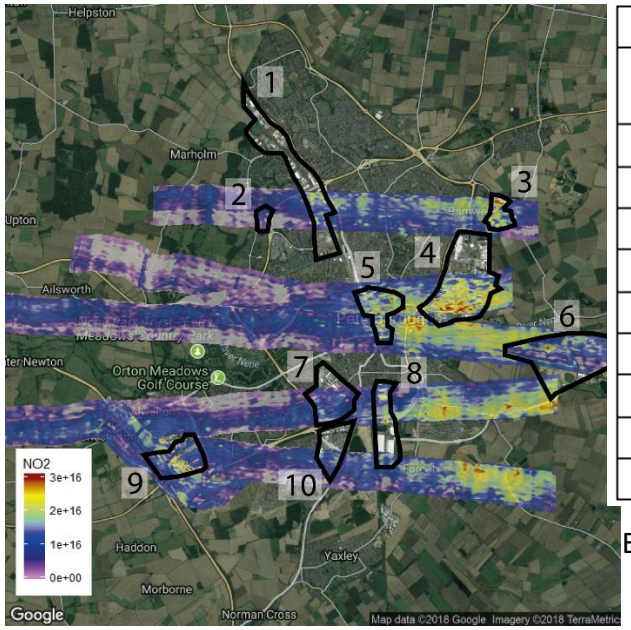




Vibration Test and Aircraft Configuration

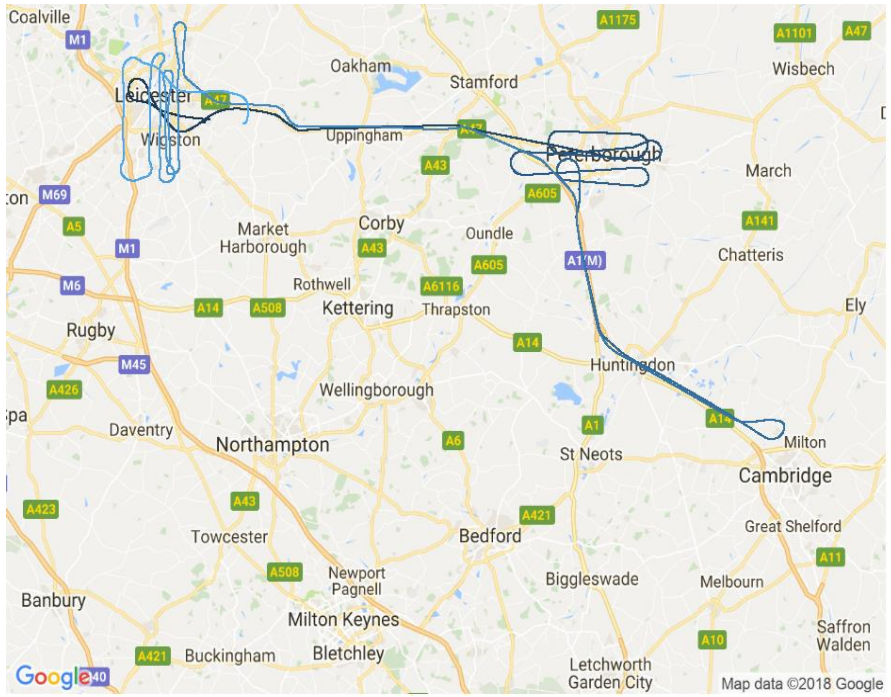
Compact Air Quality Spectrometer CompAQS

Flight Results from 7/2/18

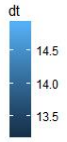


No.	Land use
1	Commercial, distribution, offices and shopping
2	Shopping
3	Commercial and distribution
4	Commercial and heavy industry
5	City centre
6	Brickworks
7	Commercial, distribution and offices
8	Distribution
9	Distribution
10	Shopping

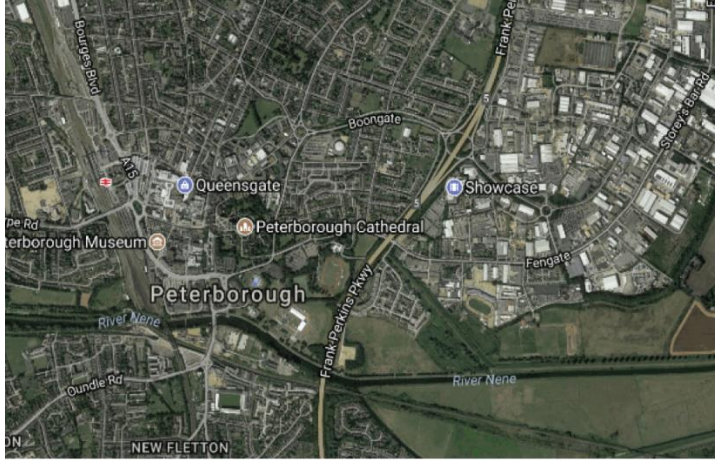
Expected hotspot locations in Peterborough

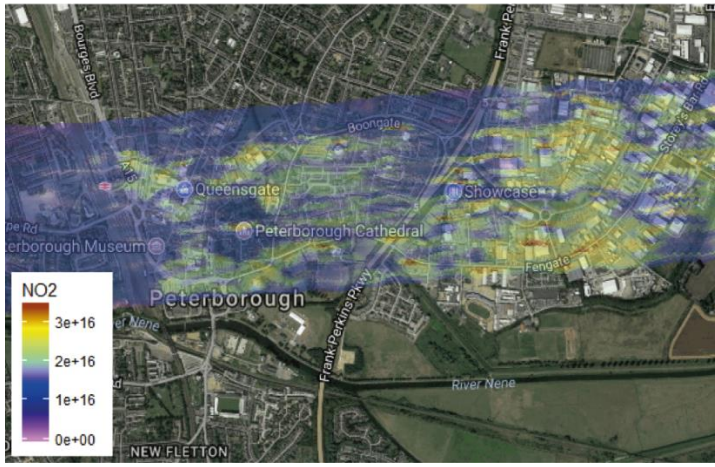


Flight Path



Transect over Peterborough city centre and Fengate industrial estate (13:40 local time) superimposed on Google map images





Policy Alignment

- Aligns with UK policy goals, e.g. atmospheric science, the EO Technology strategy , Industrial Strategy, UK Space Agency
- Need to understand atmospheric distribution, sources, sinks of NO2
- Uses novel UK spectrometer design and can utilise UK (Teledyne (e2V) detectors) building upon developments for other missions e.g. ESA ExoMars etc.
- Could use UK small satellite capability and could be target for UK Launch
- Can be built and operated within UK or in collaboration with others
- With funding could be flown on 2020-2021 timescale

Benefits I

- Identify the impact and potential growth generated by the investment
- *High Profile Role in Pollution Monitoring which can be linked to health objectives*
  - *Main impact is societal*
  - *Principle beneficiaries Government departments relating to environment and climate*
- *Commercial Services but needs further investigation, initial work shows potential viability*
- *Build of instruments and spacecraft – demonstration of UK technology for both partnerships and inward investment*
- *Good outreach and education tool given public understanding of the role of pollution*

Innovation

- *Innovation small UK designed spectrometer capable of flying on small satellite*
- *Not unique on global scale but from a European scale UK is a leader in both technologies*
- *This will further develop national capability by providing a UK flight opportunity with high impact*

Benefits II

Benefits of the Data (based on already well developed scientific methods)

- Obtain **improved understanding of NOx chemistry and sources**
- Routinely **monitor air quality in data sparse regions**
- Improve air pollution early warning systems
- **Evaluate existing emission inventories** (as NO_2 is short-lived and collocated with its sources)
- Critically evaluate air quality models that are used to inform air quality policy
- **Evaluate the effect of air pollution mitigation strategies** and demographic changes on air quality

Benefits for UK EO

- **Unique UK capability extending a core capability area**
- **UK-based hardware supply chain**
- **UK-based downstream service improvement**
- **UK benefits of improved monitoring**

Cost

- *Cost to develop CompAQS to TRL6*
  - *£1M detector and back-end electronics*
  - *£0.1M MLI*
  - *£0.6M rebuild of optical bench if needed*
  - *£0.5M on-board data processing and ground system requirements study*
  - *Flight cost dependant on mission opportunity*
- *Time to flight 2-3 years 2021-22*
- *Flight ready instrument for ~£2M with many opportunities e.g. UK only, bilateral etc. Low cost investment for high return.*
- *Operational costs funding depends on mission*
- *TBD co-funding, either with Industry or another national Agency*
- *Main risks: Unexpected costs in detector development, issue of need for on-board processing, development by other countries/agencies, industry partners selection*

Next Steps

- Intensive Integrated Field Campaign
  - Demonstration flight showed very high fidelity results
  - To evaluate the accuracy, precision and stability of the instrument and retrieval, an integrated field campaign is needed.

  - Funding is needed for:
    - CompAQS Flight
    - Extensive in situ ground network (new or existing)
    - Surface passive remote sensing
    - High resolution chemical transport modelling
    - Vertical in situ profiling
    - Location in an urban landscape in UK or internationally

- Complete Flight Instrument Development Funding Needed

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Additional Slides for Questions

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User Need – Additional Info

User Needs:

- Science:
  - Resolving NO2 at unprecedented spatial and temporal resolution from space will enable radically new understanding of urban air pollution: sources, sinks, transport, chemistry, and interactions between urban and near-urban environments and land use
- Local and National Government:
  - providing evidence to monitor their interventions and transport of pollution into the their jurisdiction
  - providing seamless high resolution coverage across their jurisdiction over the 25 year mission, particularly as austerity and frequent relocation of monitoring instruments inhibit consistent long term monitoring in many locations.
  - reduce uncertainty in NOX emissions inventories
- Commercial air quality services:
  - Copernicus approach: get data out there for innovators to generate USPs and further revenue
  - Exceptional spatiotemporal information to improve existing commercial products and provide new information on data sparse urban areas
  - Environmental consultants can validate air quality models, deliver improved emission inventories, test efficacy of policy interventions, and expand international services

Policy Alignment – Additional Info 1

Alignment with UK policy goals—DEFRA[1]:

- **The most immediate air quality challenge is tackling the problem of nitrogen dioxide (NO_2)** concentrations around roads - the only statutory air quality obligation that the UK is currently failing to meet.
- There is considerable uncertainty on the real world impact of speed limits on NO_2 concentrations and there is limited data available showing the impact of speed limit changes. Given this, there is a need to collect data from further monitoring in real world conditions…
- Access to information is essential to enable the public to make informed choices to help tackle the sources of, and to avoid exposure to, air pollution
- The UK Government and the devolved administrations also publish near real-time air pollution monitoring and forecasting information, with social and other media used to communicate actual or forecast episodes of high pollution.
- Local authorities, non-government organisations and other stakeholders play a key role in disseminating advice and guidance to those affected by poor air quality.

[1] Improving air quality in the UK: tackling nitrogen dioxide in our towns and cities Draft UK Air Quality Plan for tackling nitrogen dioxide May 2017, DEFRA

Policy Alignment—Additional Info 2

Alignment with EO Technology Strategy:

- Strong alignment with
  - objective 2—**Innovation**, and
  - objective 3—**Capability,** in UK strength area and market growth technology area **Optical Spectroscopy**
- Data flowing from the ESA/EU Copernicus programme will contribute to the requirements for EO data by DEFRA and other government departments, but other sources of EO data will also be required.
- Institutional EO science missions
  - driven by challenging science requirement, are a major driver of innovation, usually demanding new sensor types or greatly improved performance from existing sensor configurations.
- Operational missions
  - driven by societal need… It is possible to target technology development for operational missions as the requirements are often well known in advance, and government funding can be crucial to allow UK consortia to bring instrumentation to a sufficient level of maturity to gain access… A unifying technology theme for all these mission types is miniaturization.

Policy Alignment—Additional Info 3

Alignment with UKSA Strategy:

- **to grow the knowledge base**
- **to meet societal needs**
- to support growth of commercial space markets such that the contribution of UK industry to the economy is increased… **new technologies for EO and miniaturisation**

Policy Alignment—Additional Info 4

Alignment with Industrial Strategy:

- Clean Growth: We want everyone to feel the benefits of clean growth, so we will work to **create a future where our cities benefit from cleaner air**, our businesses from enhanced resource security and our countryside from regenerated natural capital.
- **The UK is already one of the most successful countries at growing our economy while reducing emissions.** We have cut emissions by more than 40 per cent24 since 1990, while our economy has grown by two thirds25. Our recently-published Clean Growth Strategy26 sets out our ambitious proposals for continuing this progress through the 2020s.
- Clean Growth: An important benefit of a cleaner economy is cleaner air. **We are determined to tackle air pollution and support affected areas, given the significant negative impact it has on public health, the economy and the environment.** We will provide £220m for a new Clean Air Fund that will allow local authorities in England with the most challenging pollution problems to help individuals and businesses adapt as measures to improve air quality are implemented. This new fund is in addition to the £255m provided to implement the Air Quality plan earlier this year, and takes the total amount invested in cleaner air since 2010 to £3.2bn.
- We will **explore ways to use data to accelerate development of new mobility services and enable the more effective operation of our transport system**
- We will **leverage our health data to improve health outcomes**
- Our country has world-class data, from the highest quality geospatial and climatic analysis to company information. **We are committed to making this data available to innovators and businesses throughout the UK** to create products and services that will transform our economy and society.