DLR

esa

living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

# TreeView: A small satellite supporting precision forestry for nature-based solutions in a changing climate

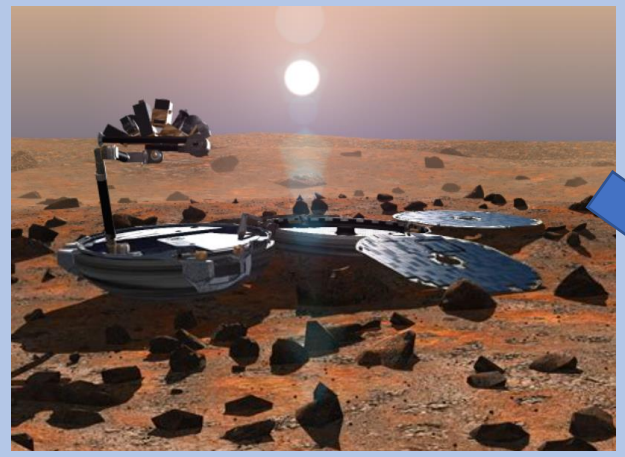
J. Endicott, A. Holland, K. Maseyk, J. Fennell
The Open University

26th May 2022

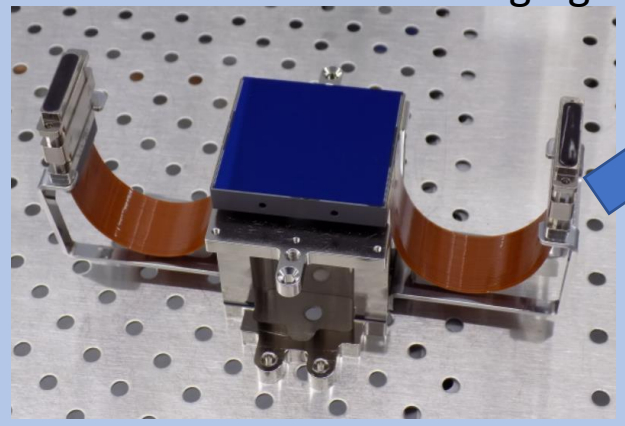
# TreeView: Bringing together strengths across the University

School of Physical Sciences

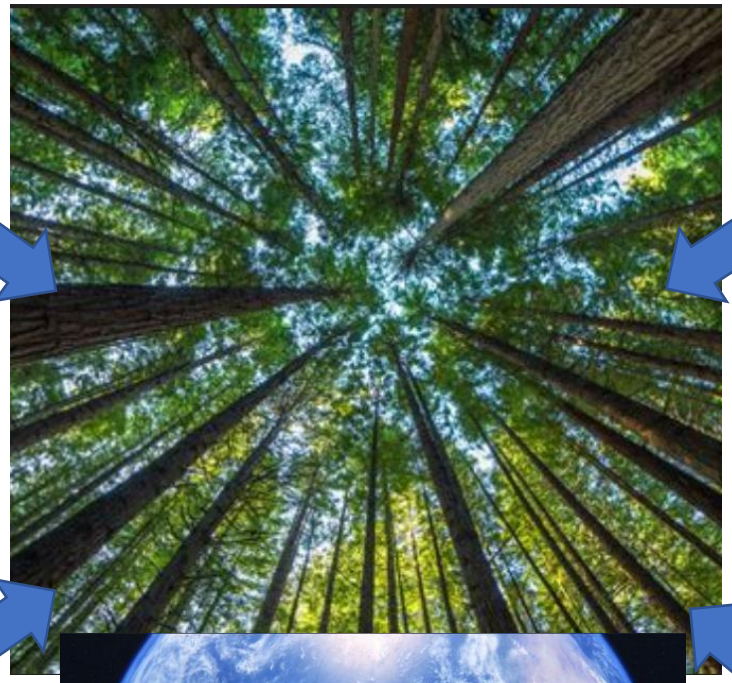
Space Instrumentation



Centre for Electronic Imaging



**TreeView**




School of

Earth, Environment & Ecosystems

School of

Computing and Communications

# TreeView: Precision Forestry for a Nature-Based Solution to Climate Change

Through the UKSA National Space Innovation Programme, in 2 phases the OU has led a feasibility study *and held a Preliminary Design Review* for a new Earth Observation mission for tree-level studies from Space

A "Newspace" mission:

***we aim to fly a SmallSat for 5 years, for a total cost of £15M***

For reference:

- ESA Scout "Newspace" missions are up to 30 M euro
- ESA Earth Explorers are ~ 100s M euro
- ESA Sentinels and Copernicus programme ~ 300 – 500 M euro

The Open University

space@ou

Environment, Earth and Ecosystem Sciences
Physical Sciences
Computing and Communications

INSPACE MISSIONS

XCAM

TELEDYNE e2v
Everywhereyoulook™

GREY CONSULTANTS

Forest Research

UK Centre for Ecology & Hydrology

2EXCEL geo

beck optronic solutions

ADIUVO ENGINEERING AND TRAINING, LTD.

plastron mobile satellite cleanrooms

TALEX (UK) LTD

# TreeView: Why do we want to monitor trees?

## Trees: pillars of nature-based solutions to climate change

Trees are the conduits for natural carbon transfer out of the atmosphere

Tree-planting is a central tenet of policy responses from governments and organisations

Tree are 'fundamental units' of ecosystems and plantings; require studies at the scale of individual trees

Increasing value is being placed on the role of trees in urban areas for climate, health and well-being roles

UK Treescape is valued at £130 billion


## Valuations of trees and woodlands

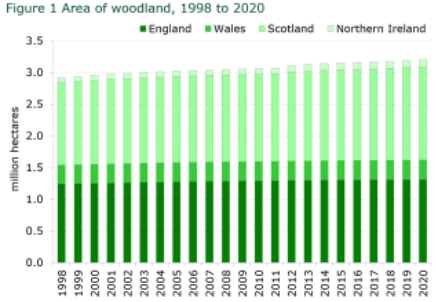
- Asset value of woodlands (2017) = £130 billion
  -Timber - £8.9 billion (6.9%)
- 475 million visits to Woodland areas and 718 million hours (2017)
- 269 thousand tonnes pollutants removed - £938 million saved in health costs (2017)
- 18 million tonnes carbon sequestered - £1.2 billion (2017)
  - 4% of UK greenhouse gas emissions
- Urban woodlands cooled 11 city regions to save £229.2 million in labour productivity and avoided air conditioning costs (2018)

ONS 2020 – Woodland Natural Capital Accounts

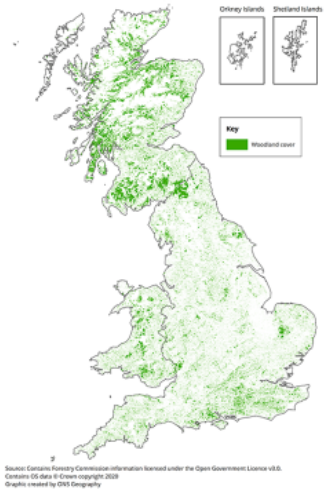
## Current distribution and trends

- Total tree and woodland cover: 3.7 million hectares
- Tree outside woodlands: 14 %

Figure 1 Area of woodland, 1998 to 2020




Source: Forestry England, Forestry Commission, Forestry and Land Scotland, Scottish Forestry, Welsh Government, Natural Resources Wales, Forest Service, National Forest Inventory.




## Threats

- Non-natives, pest and diseases
  - Non-native species cost to forestry £109 million (Williams et al. 2010)
    - Phytophora spp = £600,000 annually
    - Green spruce aphid = £3.6 million annually
  - Ash dieback – total cost to Britain £15 billion over next 100 years (Hill et al. 2019)
    - 955 ash-associated species – 71 at high risk from declines in Ash (Broome & Mitchell, 2017
- Climate change (Morison & Matthews, 2016)
  - Increasing range of pests and diseases
  - Greater frequency of drought, heat stress and waterlogging
  - Shifting tree species suitability ranges
- Increasing woodland fires (ONS, 2020)

**GOAL: 12% land coverage by 2060 (180,000 ha in the next 20 years)**

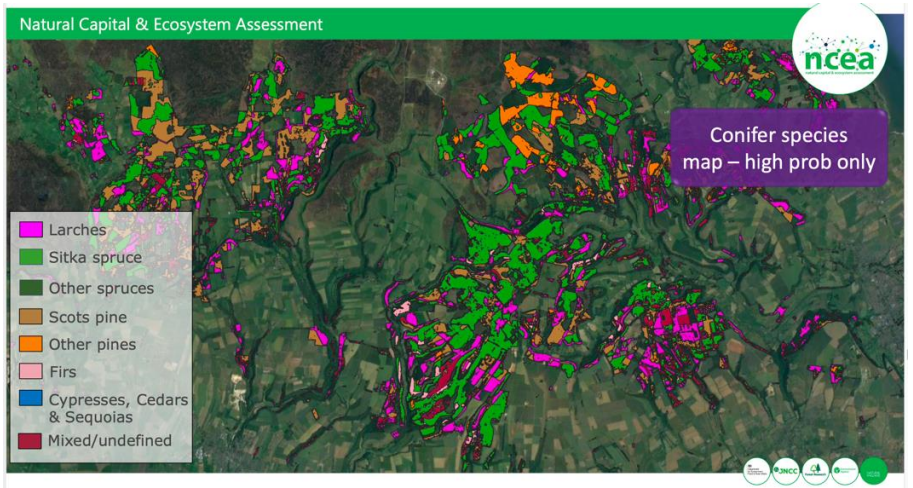
# TreeView: Scientific Case

The national treescape requires science informed management and policy to maximise treescape benefits and mitigate against threats from pests, disease, fire, and climate change.

National tree species and habitat mapping
- To understand the diversity, resilience and vulnerability of our treescape
- To quantify ecosystem services (e.g. carbon sequestration, pollution removal)

National Forest Inventory
- 5-year rolling ground survey of forest and woodland size, distribution, composition and condition for woodlands > 0.5 hectares (>5000 $m^2$)
- TreeView will fill gaps between infrequent aerial surveys and coarser scale satellite data used to update between surveys

Trees Outside Woodlands and small-scale planting
- Small woodlands, linear features and trees in groups or single trees
- ~ 20% of all trees in GB, probably increasing, important ecosystem services
- Provide MS data of comparable resolution to aerial and LiDAR data



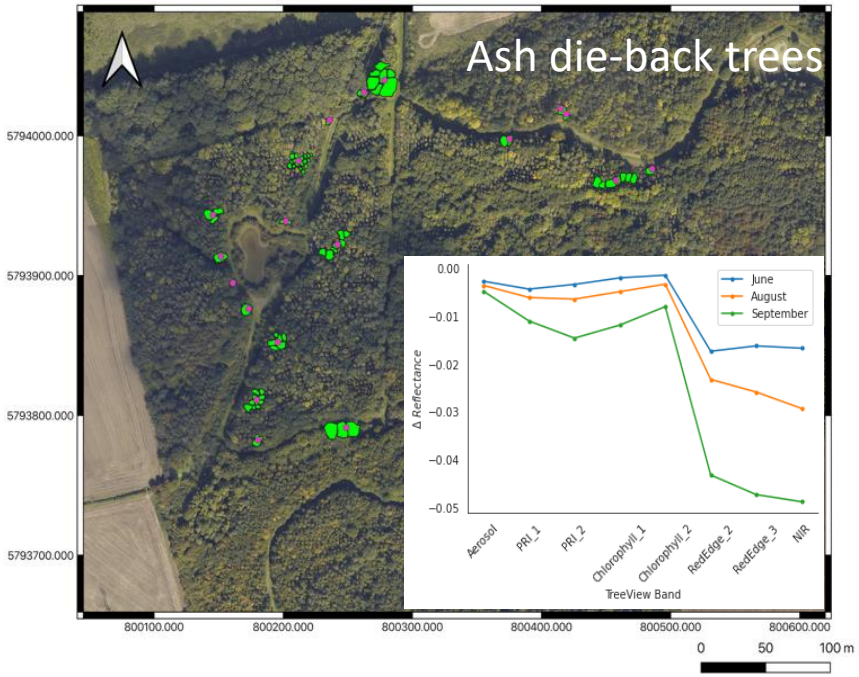

# TreeView: Scientific Case & Validation

Urban environments
- Sustainable cities are essential in a warming, urbanising world
- Quantification of the benefits and management of green infrastructure in a heterogenous environment (climate mitigation, pollution removal, runoff mitigation and wellbeing benefits)
- Responses to climate and urban-specific environmental drivers

Plant Health
- Loss to pest, disease, and climate stress is an enormous cost, and increasing
- Early stress detection is critical for intervention and mitigating damage
- High spatial resolution data essential for detecting ‘first trees infected’

Supporting forest science in the field
- Forest and grassland sites where detailed measurement, monitoring and experimentation take place
- Both validation of TreeView data and data supporting in situ measurements

(a) Map showing locations of trees by species

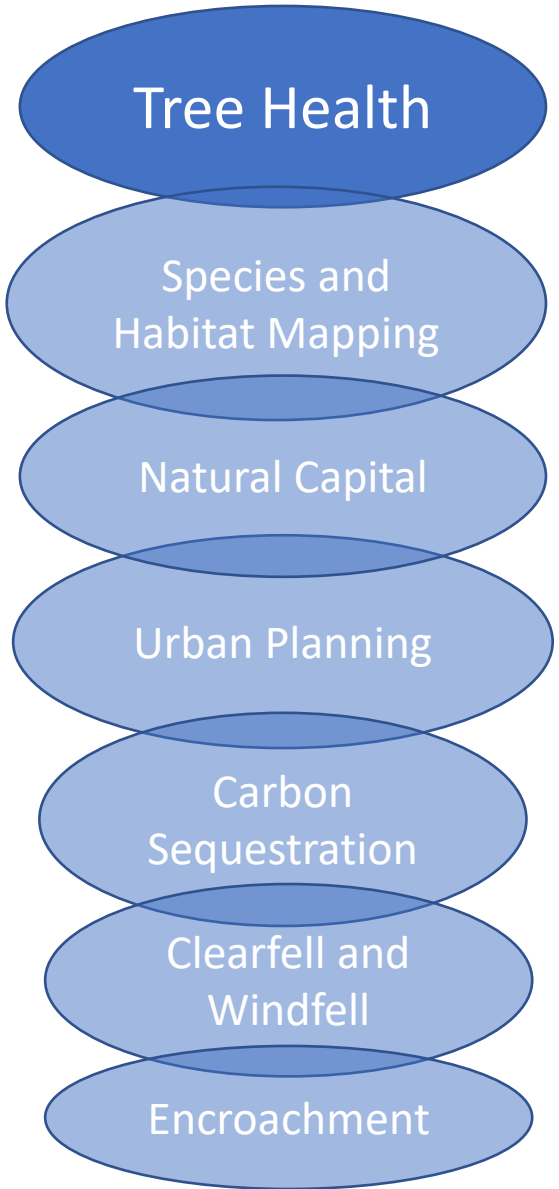
# TreeView: Primary Mission Objectives

**<u>Possibly</u> the first fully UK-funded and developed science satellite mission**

- To map and characterise the UK treescape
- To monitor the green infrastructure of cities across the UK
- To provide early warning of pest, disease, and climate stress on tree populations
- To provide space-based observation of large field-based climate change experiments (e.g. BIFoR FACE) and forest monitoring sites (e.g. Alice Holt)
- To image other countries of interest such as China, Australia, Brazil and cities such as Hong Kong, Singapore, Auckland



# TreeView: Applications of the data




Monitoring of tree health will be improved by establishing a baseline over multiple years
We envisage establishing an alert system for follow-up by aircraft, drone or ground assessment

First step will be identification of individual tree signatures, followed by broad classification of tree type. The aim will be to progress towards species and habitat mapping with improved confidence using a range of additional data

More detailed knowledge of trees particularly those outside of woodlands (~20% est. in UK)
Tree classification, alerts, and richer information on the contribution of trees to natural capital

A more complete knowledge of trees in the urban environment for example their contribution to reducing the urban heat island effect

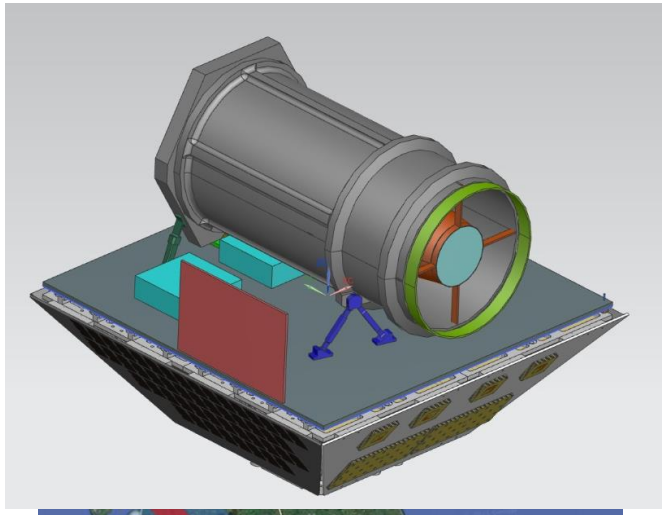
Monitoring of any afforestation or reforestation will be a long term outcome
Nearer term a contribution can be made to the estimate of carbon captured

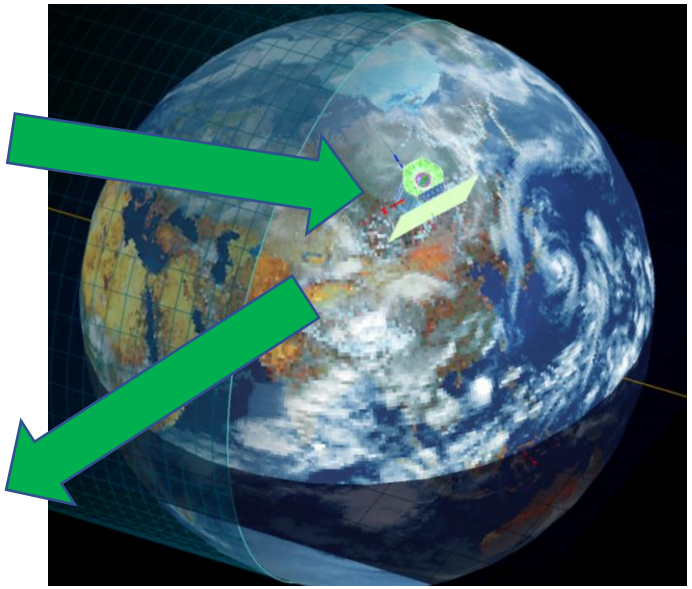
Finer resolution than Sentinel-2 and some other satellite data will provide clearer insights into small scale tree loss.

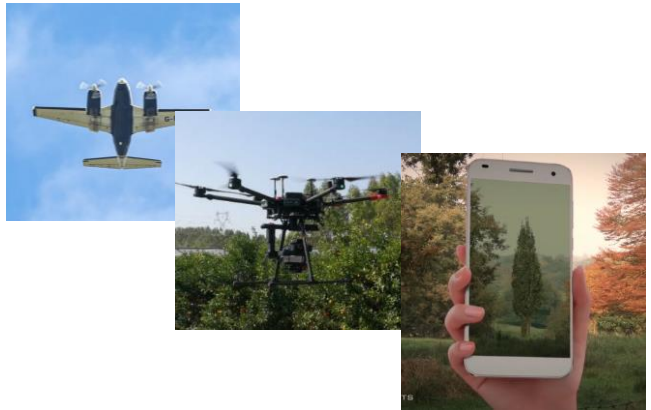
Some potential to advise on encroachment to infrastructure, but the resolution is considered to be quite limiting

# TreeView: Mission Outline

A small satellite to monitor trees from space

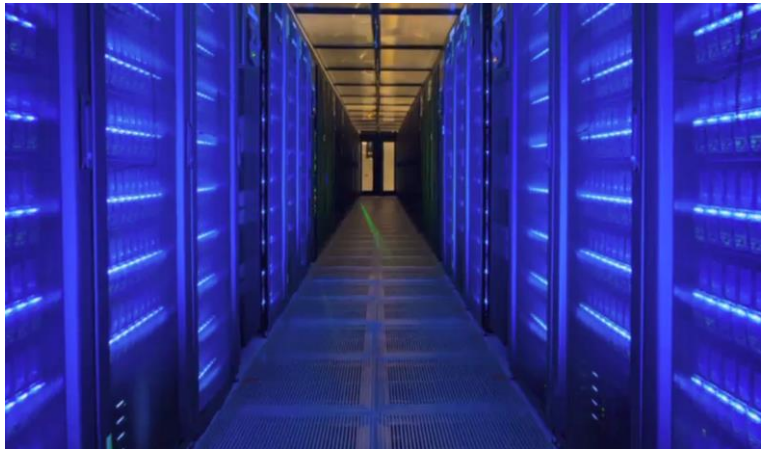




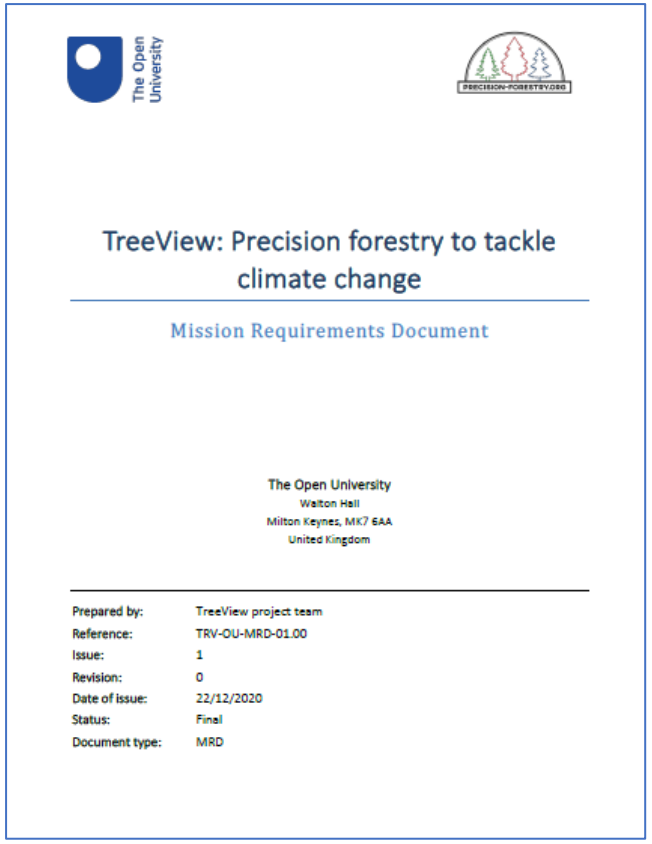
Other data, for example:

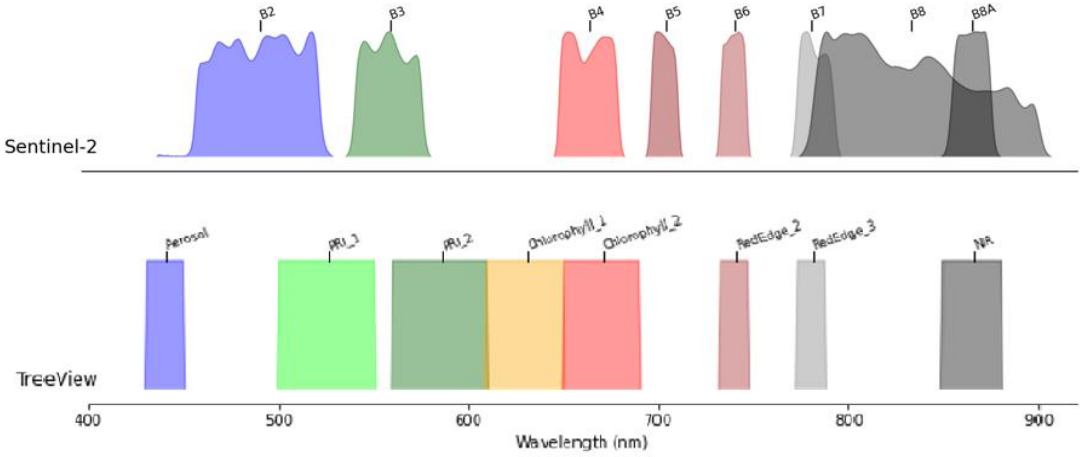
- High resolution reference imagery
- Cloud cover data
- Digital Elevation Models
- Tree inventory catalogues / NFI
- Treezilla database



# TreeView: Mission Requirements

Precision forestry: ‘the use of advanced technologies for a more granular data capture and management’

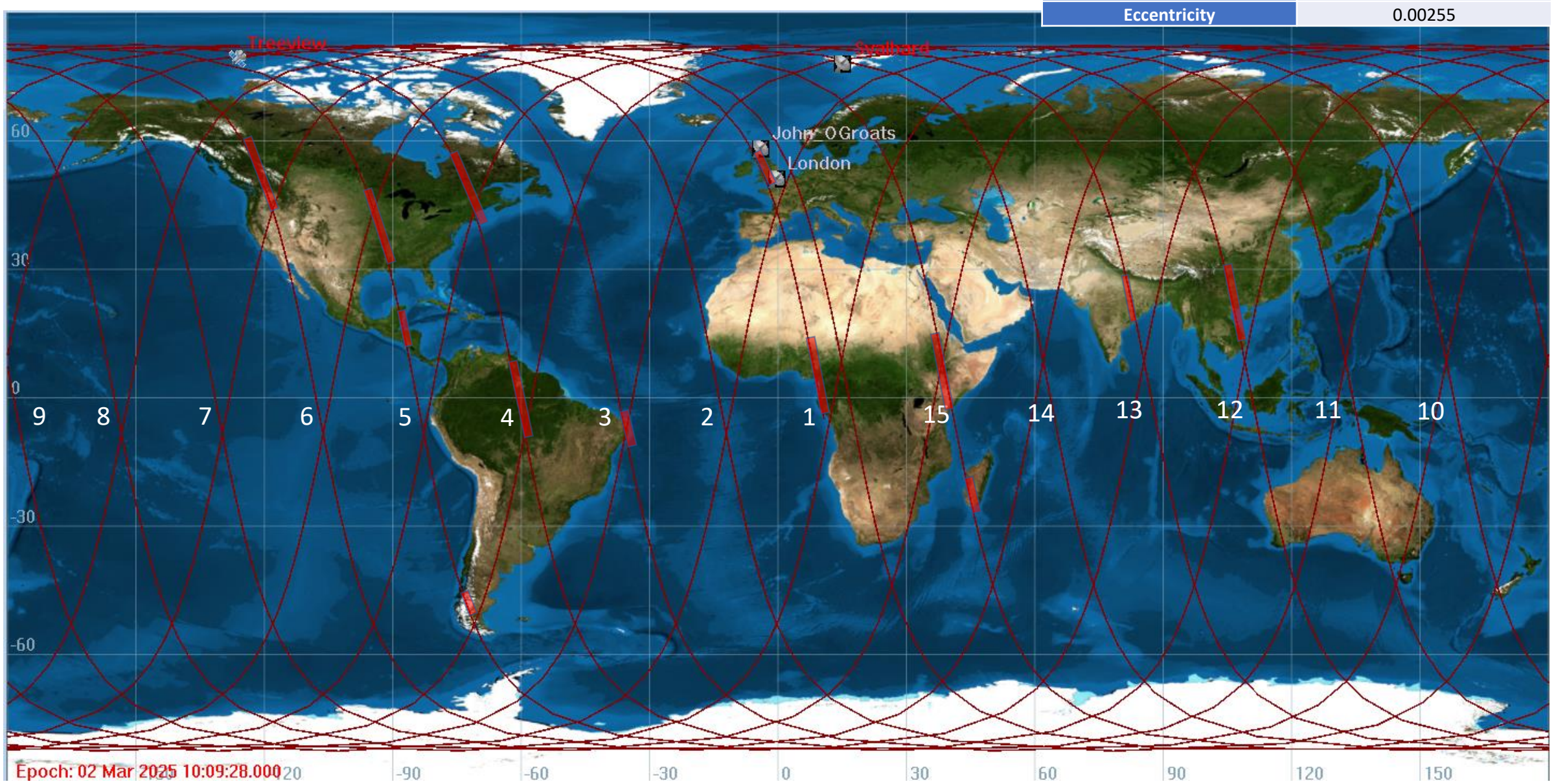



| Requirement | Target | Current |
|---|---|---|
| Ground Sample Distance | 2 m | 2.2 m |
| No. of spectral bands | 6 - 10 | 8 |
| Bandwidths | 10 – 40 nm | 15 – 50 nm |
| Swath | > 40 km | > 18 km (105 km) |
| Full UK Coverage | 1 per year | 1 per Year |
| Repeat Coverage | 10 x for target locations | 15 – 9 allowing for 50% loss to cloud cover |
| SNR | > 100 | > 100 |

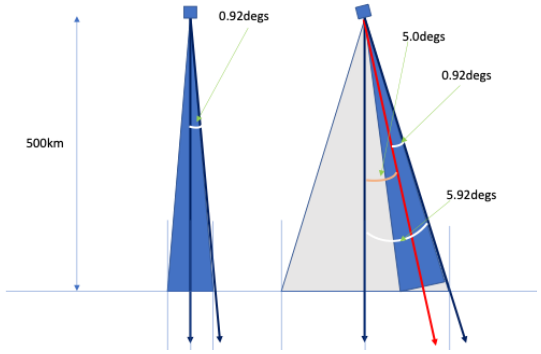
# TreeView: Mission Analysis Review – DITL 2

| Target Launch Date | December 2024 |
|---|---|
| Altitude | 500 km |
| LTAN | 11:00 |
| Inclination | 97.38° |
| Eccentricity | 0.00255 |



# TreeView: UK Coverage

Analysis of coverage across Wales and England for one year with one satellite
Each corridor represents the accessible swath with off-Nadir pointing
6 passes are required for full coverage of the corridor
Cloud cover increases the number of passes required





| | Location 1 | Location 2 | Location 3 | Location 4 | Location 5 |
|---|---|---|---|---|---|
| **Latitude** | 51.957 | 52.07075 | 52.1845 | 52.29825 | 52.412 |
| **Longitude** | 355.452 | 356.9655 | 358.479 | 359.9925 | 1.50606 |
| **Number of Passes** | 31 | 17 | 23 | 22 | 18 |

# TreeView: System Overview

## Satellite and Payload

beck optronic solutions

Optical design

TELEDYNE e2v Everywhereyoulook™

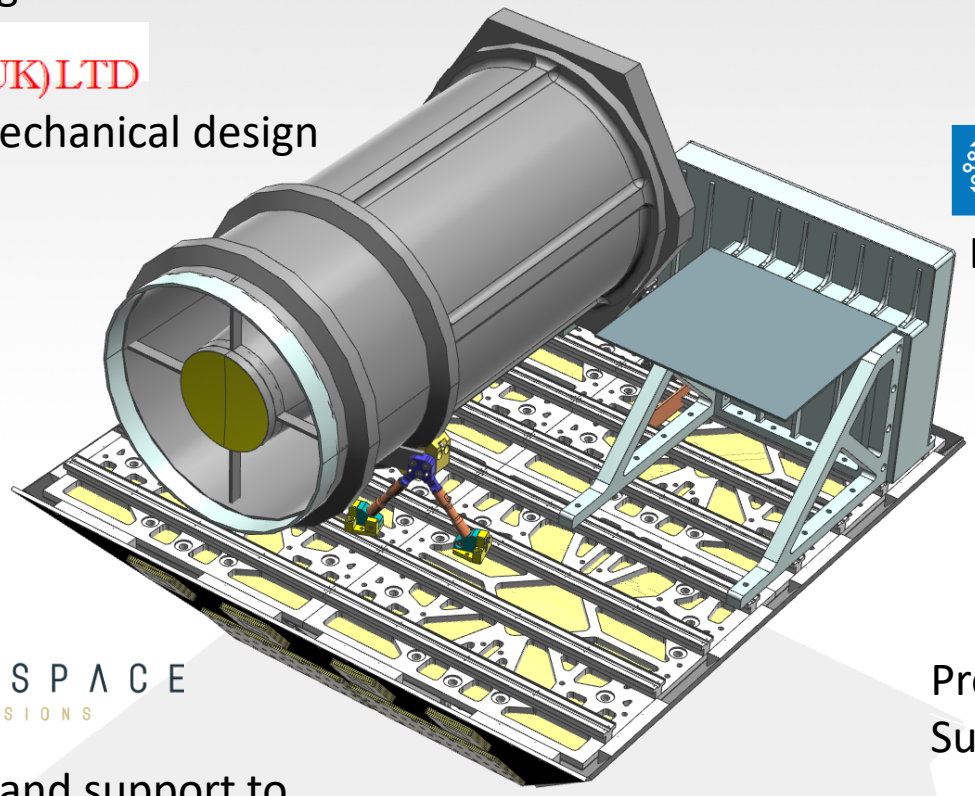
Detector

XCAM

Camera System

TALEX (UK) LTD

Telescope mechanical design



ADIUVO ENGINEERING AND TRAINING, LTD.

Data Handling Unit

plastron mobile satellite cleanrooms

Process and Systems Support

INSPACE MISSIONS

Platform and support to mission development

## Data Processing

The Open University

**Level-0**

0.4 Error detection
0.5 Data package assembly
0.6 File transfer

**Level 1**

1.1 Decompression
1.2 Apply sensor model
1.3 Radiometric correction
1.4 Geometric correction
1.5 L1 mask generation
1.6 L1 data package assembly

2EXCEL geo

Geometric correction

**Level 2**

2.1 Bottom-of-atmosphere reflectance estimation
2.2 L2 mask generation
2.3 L2 Raster data package assembly

UK Centre for Ecology & Hydrology

Atmospheric correction

**Level 3**

3.1 Derived data product generation (e.g. tree risk, health, size, etc.)
3.2 Vector dataset generation

Forest Research

Definition of data products

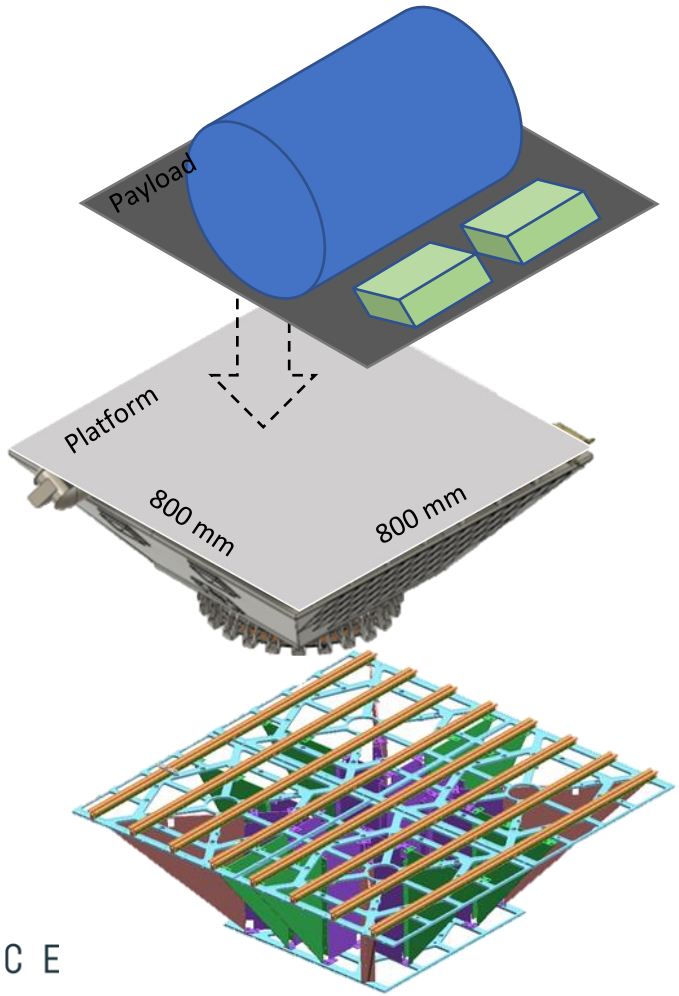
# TreeView: Faraday 2nd Generation Platform Development Status

List of sub-systems which are being developed for the CubeScale platform.

| Sub-System | Review Status | Next Review | Risks |
|---|---|---|---|
| Structure | CDR Passed | TRR expected Q4 2022 (Structure Qualification Model) | Potential design change required ahead of TRR |
| Avionics | | | |
| CubeScale Platform Electronics | TRR Passed | TRB expected Dec 2022 | Requires Software development work Expected Sept 2022 |
| Faraday Expansion | TRR Passed | TRB expected May 2022 | |
| Data Storage | TRR Passed | TRB expected Dec 2022 | Requires Software development work Expected Sept 2022 |
| System Level | CDR Passed | TRR expected Dec 2022 | |

Final Review expected Q1 2023.

TreeView Satellite Concept

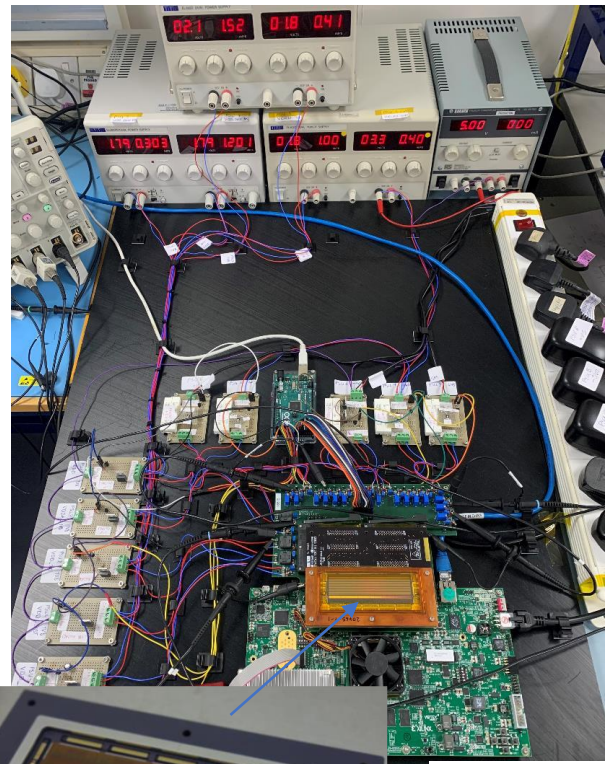


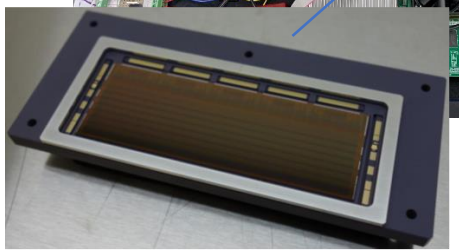


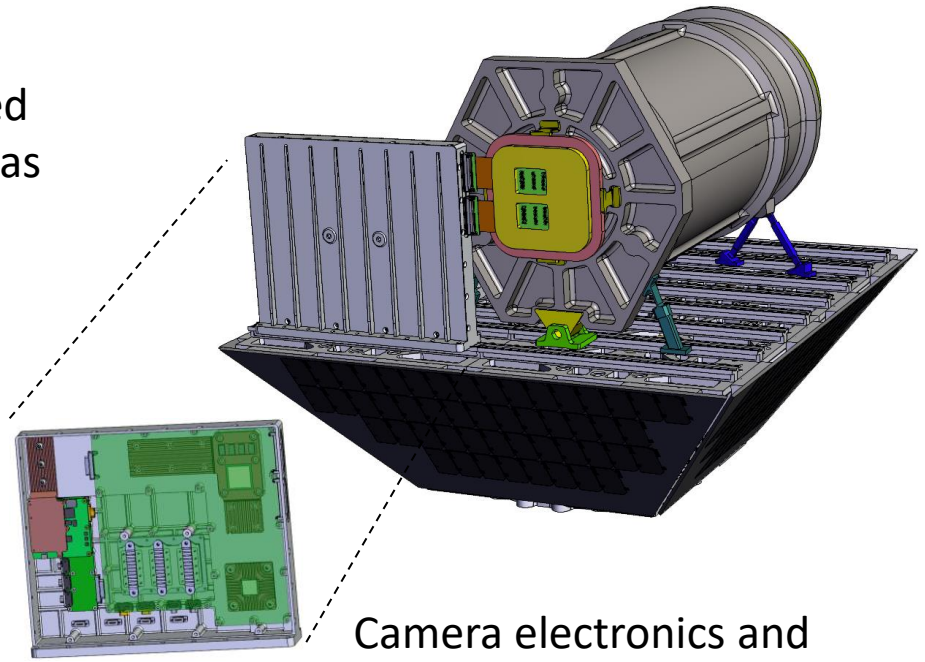

INSPACE MISSIONS

# TreeView: Payload Development Status

Camera Controller: Flatsat breadboard assembled
First stages of “bring-up” completed
Next steps are to output an image as already demonstrated by Teledyne





Camera electronics and Data Handling Unit mechanical design

Staring mode image from Teledyne for TreeView’s CIS125 new-generation sensor

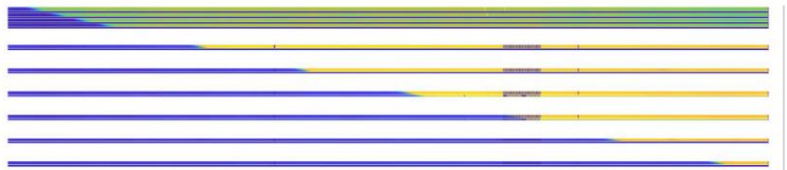
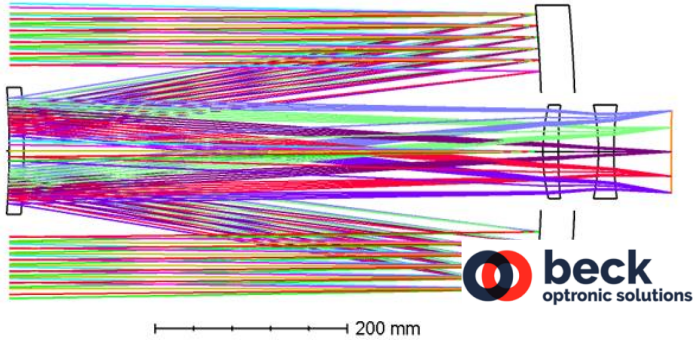
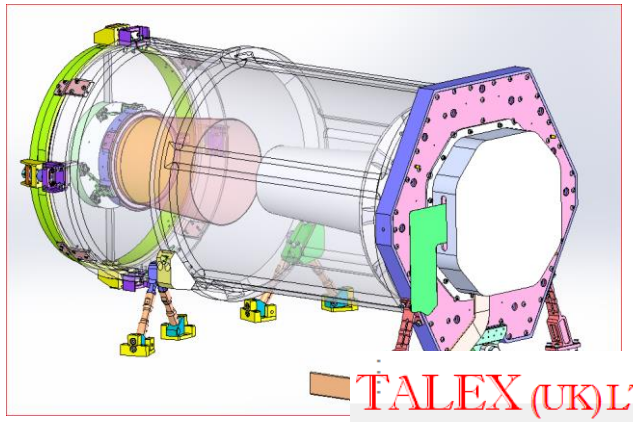


*Figure 1. A staring mode image from BSI CIS125 device 20465-15-01 with a slanted shield acros the width of the device.*

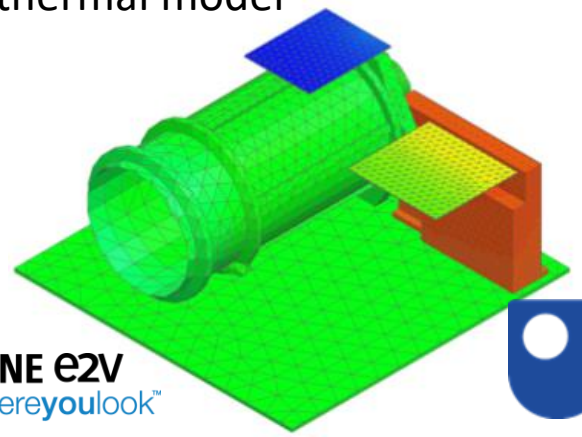
Richey-Chretien optics design




Telescope mechanical design



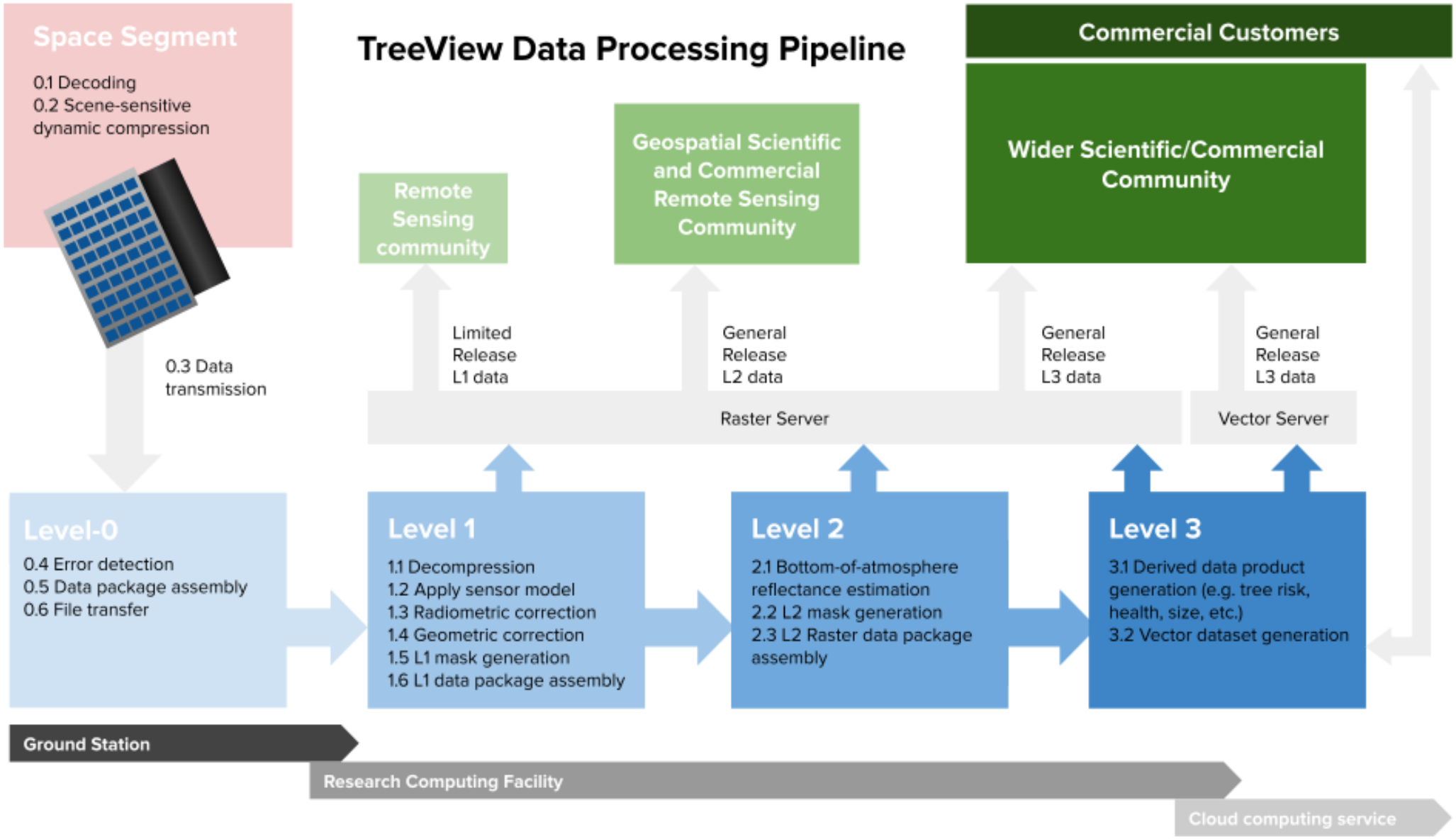

Integrated payload preliminary thermal model



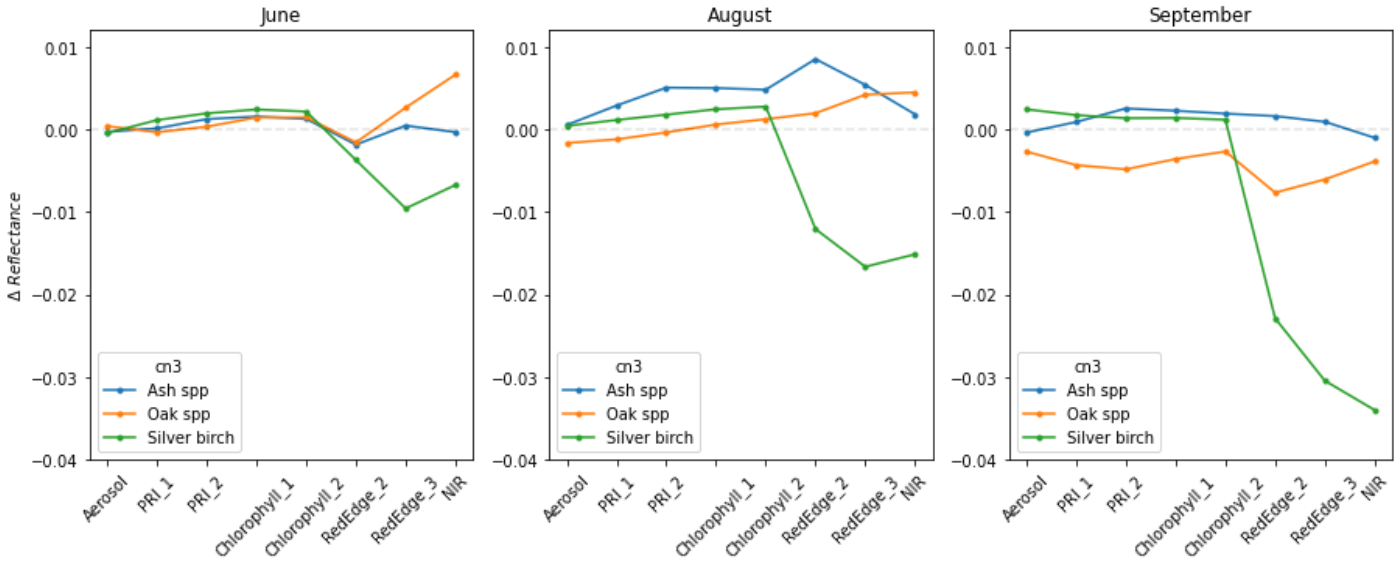
TELEDYNE e2v
Everywhereyoulook™

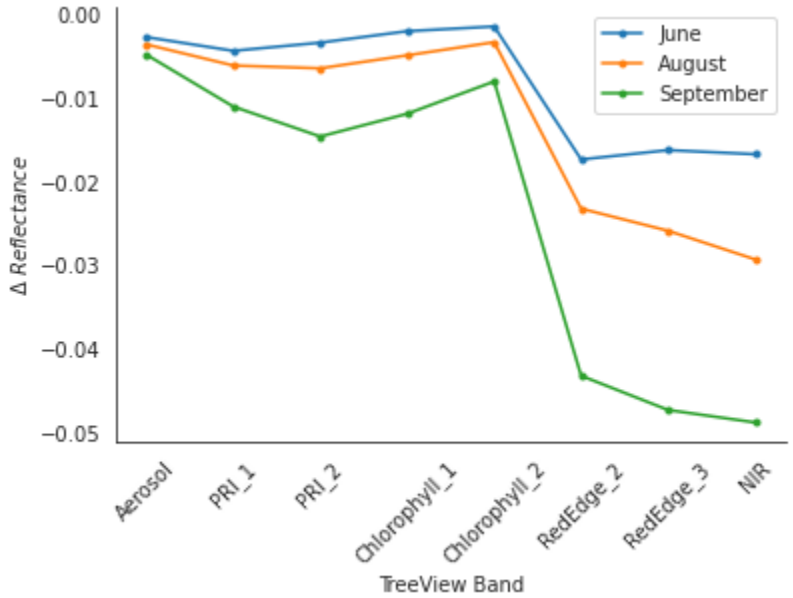
The Open University

# TreeView: Data Processing Pipeline



# Temporal information and disease impacts


Trees experiencing ash dieback

# TreeView: Status and Next Steps

The most recent phase of activity ended in March 2022 with a Preliminary Design Review

3 example short-term follow-on activities:

- Data processing pipeline development
- Develop the payload
- Prepare mission operations and planning

**Establish funding for the mission!**


Acknowledgements:
UKSA National Space Innovation Programme funding
STFC Impact Accelerator Award funding
Colleagues across The Open University and nine partners