
PRECISION-FORESTRY.O
TreeView
Precision Forestry to Tackle Climate Change
www.precision-forestry.org

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

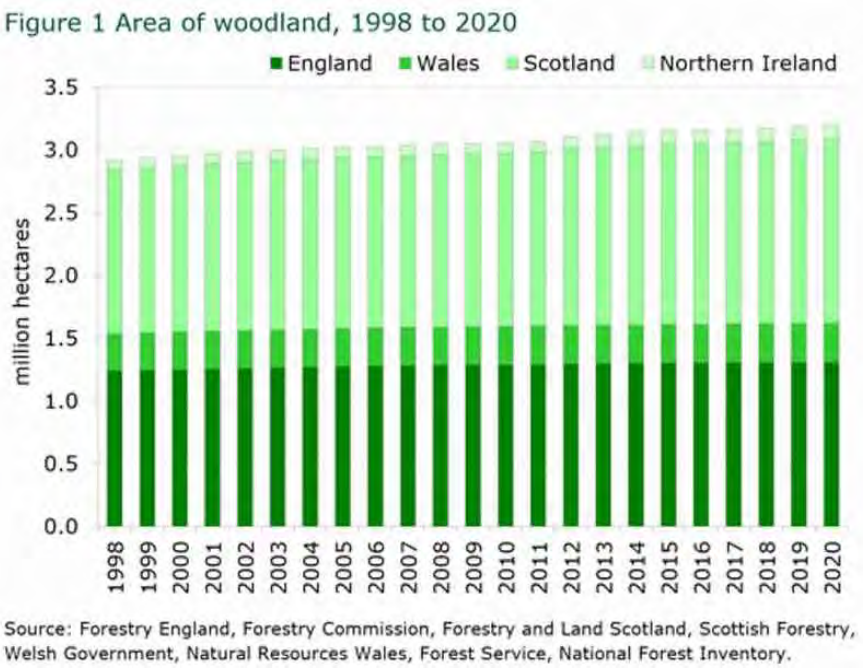
Valuations of trees and woodlands

- 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)

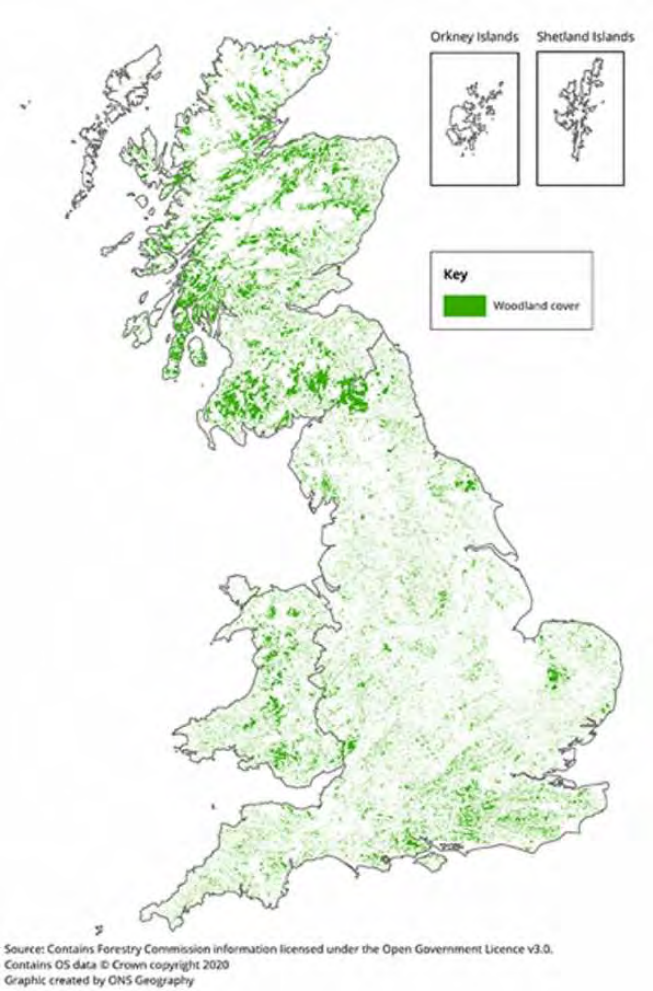
ONS 2020 – Woodland Natural Capital Accounts

Current distribution and trends

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



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



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Graphic created by ONS Geography

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

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)

TreeView: a new satellite mission to support the UK's response to tackle climate change

Through the UKSA National Space Innovation Programme, the OU has led a feasibility study 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

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Forest Research

UK Centre for Ecology & Hydrology

2EXCEL geo

Science & Technology Facilities Council
RAL Space

Primary Mission Objectives

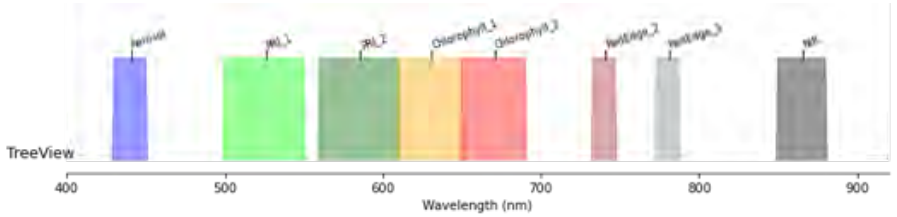
Possibly the first fully UK-funded and developed science satellite mission

- To map and identify the species of UK's trees
- To monitor the green infrastructure of the cities and large towns 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 when UK is under cloud cover



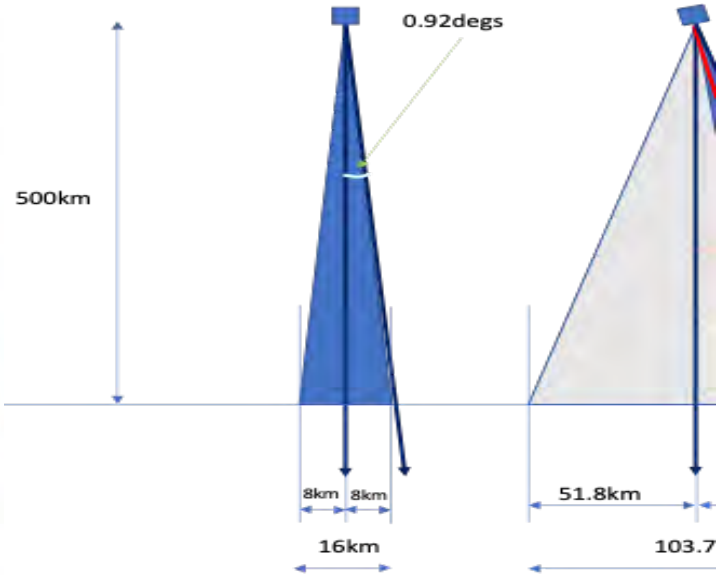
Mission requirements

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



Requirement	Target	Outcome
Ground Sample Distance	2 m	2 m
No. of spectral bands	6 - 10	8
Bandwidths	10 – 40 nm	15 – 50 nm
Swath	> 40 km	> 16 km (104 km)
Full UK Coverage	1 per year	Every 6 weeks
Repeat Coverage (spring – summer)	10 x for target locations	15
SNR	> 100	> 100

Orbit

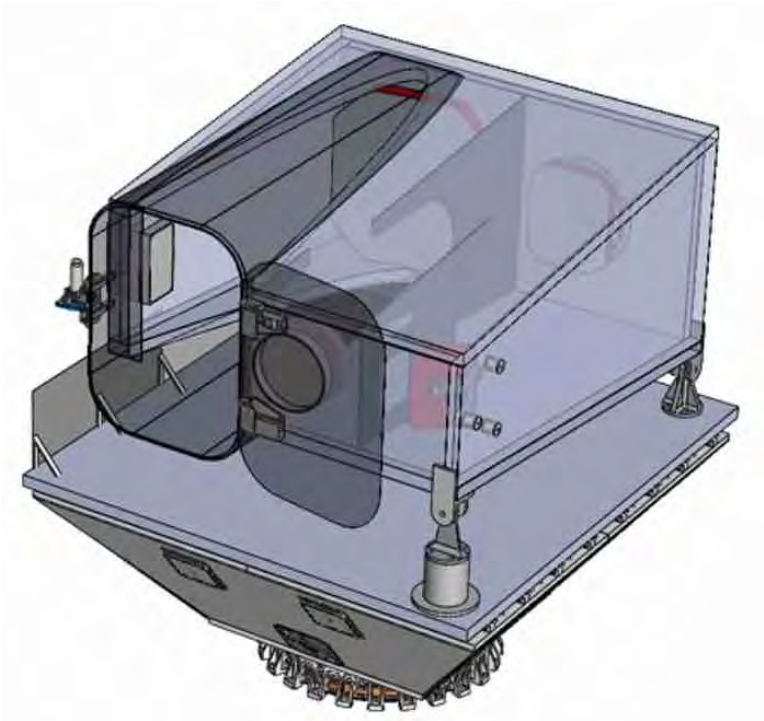


Orbit selected: Sun Synchronous, 501km, 11:00 LTAN, Local pass time over UK ~10.25am

Assumed off-nadir pointing capability of 5 degrees from nadir with a 16km swath on the ground.

Spacecraft

- In-Space's modular Faraday-2G
  - Total mass less than 100 kg
  - Volume within 800 x 800 x 250 mm + PL
- 800mm by 800mm payload deck:
  - Optical payload
  - Star trackers
  - Sun sensors
  - S-Band and X-Band antennas
- Spacecraft platform development and qualification due to complete in 2021 under an ESA/UKSA contract
- Compatibility with an extensive range of launch vehicles

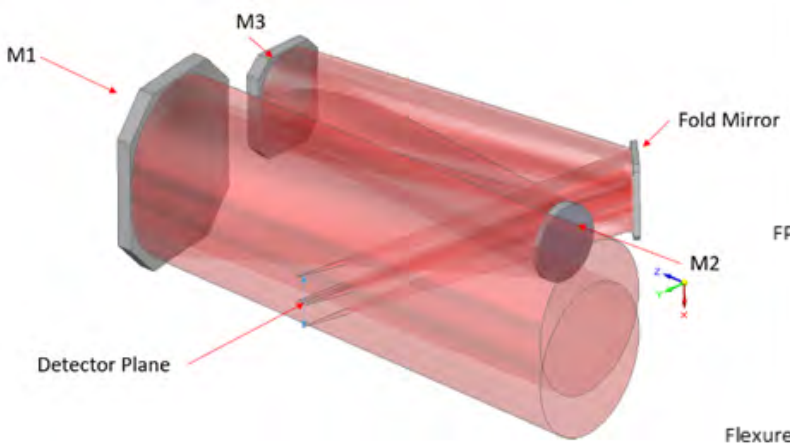


Payload – Optics and Focal Plane Array

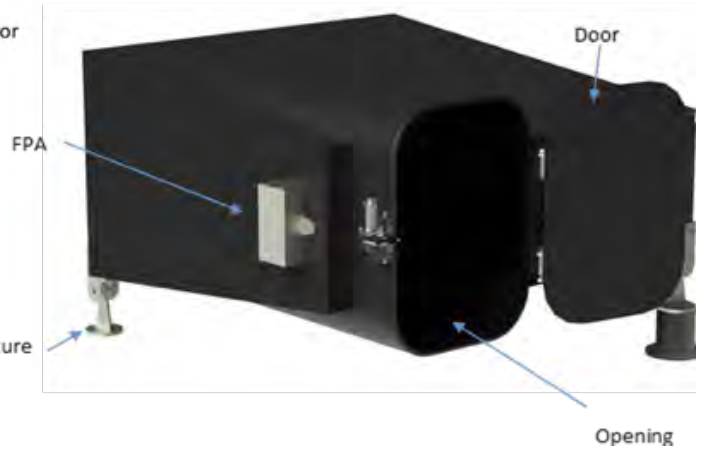
Science & Technology Facilities Council
RAL Space

Telescope

Telescope baseline is an off-axis Three Mirror Anastigmat with a folding mirror shown below:



Mass: < 30kg
Height from the mounting feet: 492 mm
Width: 694 mm (734 mm inc. FPA box)
Depth: 764 mm



Materials

Item	Material
Mounting Feet and Brackets	Titanium Ti-6Al-4V
Structural Panels	CFRP Skins and Aluminium Honeycomb
Baffles and aperture	CFRP
FPA	Titanium Ti-6Al-4V (Housing)
Mirrors	Zerodur (Aluminium coating)
Mirror Mounts	Titanium Ti-6Al-4V and Aluminium
Door	CFRP

Payload – Thermal Modelling and Optical Performance

Science & Technology Facilities Council
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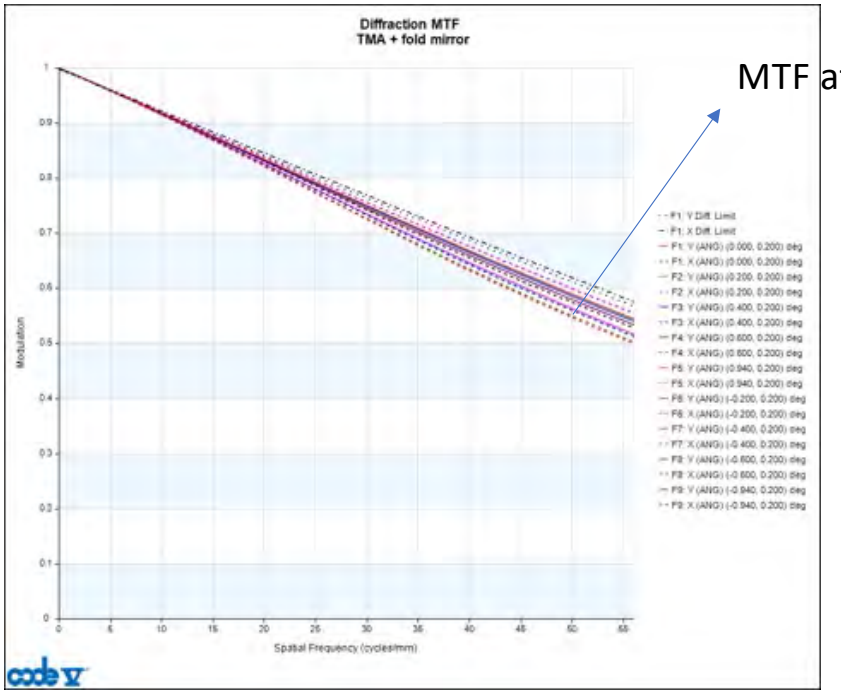
Telescope Thermal Limits:

	Tmax (°C)	Tmin (°C)
FPA (Hot)	0.5	-3
FPA (Cold)	-1	-5
Structure (Hot)	-4	-7
Structure (Cold)	-6	-9
Non-operational	-10	-27

Optical Performance:

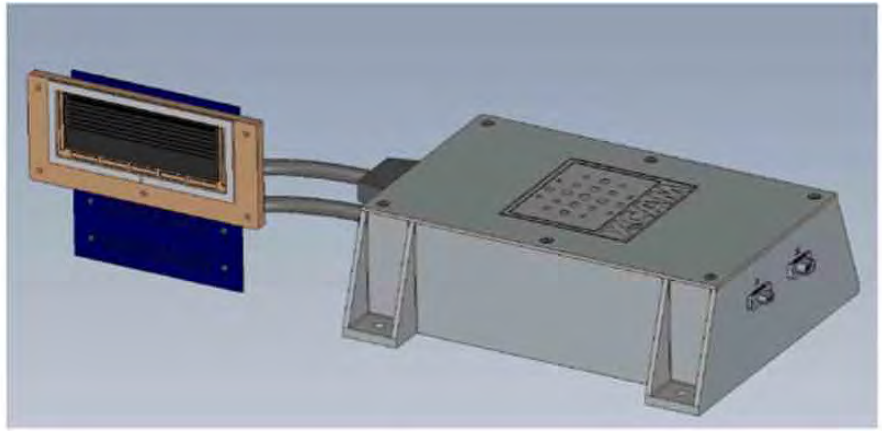


MTF at Nyquist > 0.54

MTF plot for the edge of the along-track Field of View as-designed.

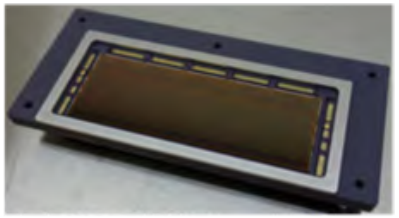
Payload – Camera Electronics and Data Handling Unit

- Camera Sub-System
  - FPA – Focal Plane Array
    - Detector
    - Optical Filters
    - Mechanical/thermal mounting
    - Temperature sensor
  - FEE – Front End Electronics
    - Detector power and control
    - Generation of image tiles and strips from raw data
    - FPA Temperature control (operating temp)
    - Telescope Temperature Control
    - Payload Data Handling Unit



Detectors
Baseline – Teledyne e2v CIS125 developed with CEOI funding

- Up to 8 bands available
- 8k columns @ 2m GSD, 16 km swath

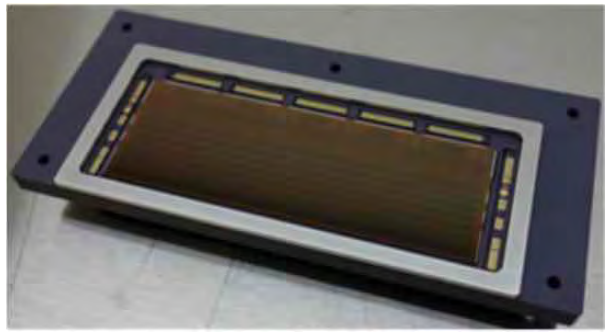


Payload – Detector

TELEDYNE e2v
Everywhereyoulook™

Multi-Spectral Time-Delay and Integration CMOS Image Sensor CIS125

	CIS125	**TreeView Use**
Panchromatic Channels	4 Pan channels each made up of 2 sub arrays	2 Pan channels both sub-arrays (A & B)
MS Channels	6 MS channels each made up of 2 sub arrays	6 MS channels only sub-array A
Pixel Pitch	5 µm Pan, 10 µm MS	Pan pixels binned 2x2 in the FEE
Number of pixels	Pan: 16k columns 64/32 lines MS: 8k columns 32/16 lines	
Full Well Capacity (per pair)	Pan: 60 ke- MS: 240 ke-	Pan: 60 ke- MS: 120 ke-
Max. Line Rate	30 klines/s	7000 lines/s 3500 lines/s
Read-out speed	2.0 Gbits/s per output	2.8 Gbits/s for the whole device!



Data Estimates

Example 1 : Longest continuous strip – 1000 km
Req: TV-SCI-06-M

~50 GB in a 143 s track

Example 2 : Entire coverage of the UK
Req: TV-SCI-04-M

~ 790 GB

Example 3 : Total area of ten major UK cities (10 x per year)
Req: TV-SCI-05-M

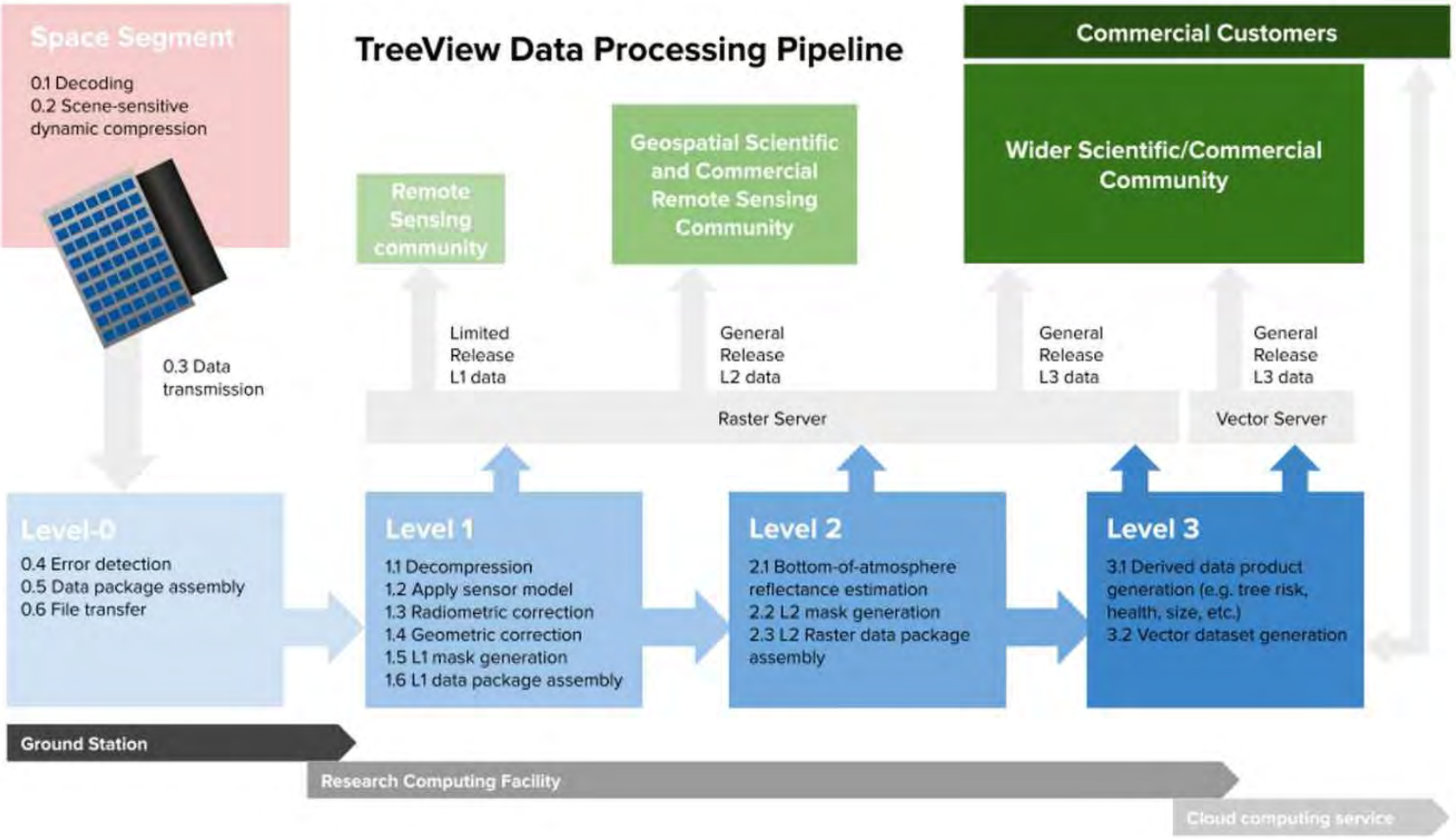
~360 GB in 5 years

Requirement	Revised Value	Data
Entire coverage of the UK	8 times per year	~ 6.4 TB / yr
Ten Target Cities	15 times per year	~ 540 GB / 5 yrs

Imaging Capacity	GB	km^2
Daily	504	166,000
Annual	184,000	60,000,000
Lifetime	920,000	3,000,000,000*

* twice the global land surface area

Data Processing

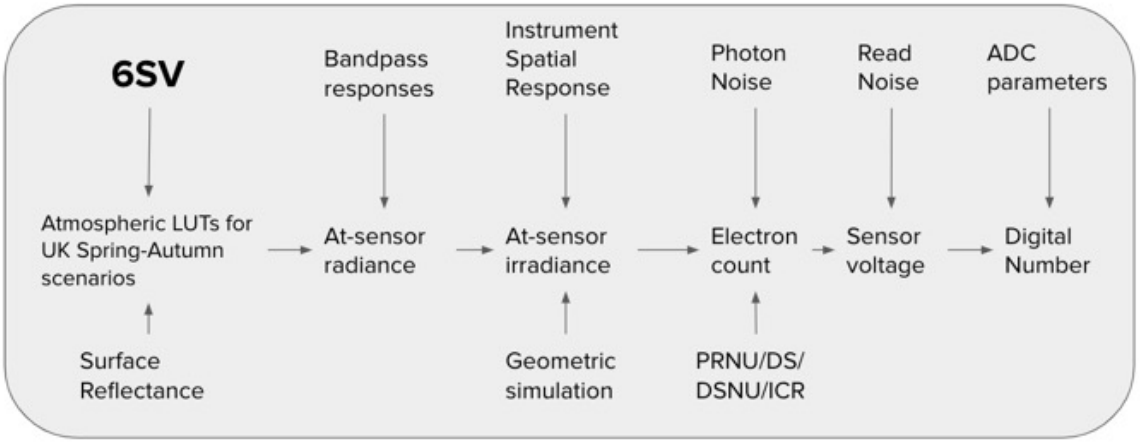


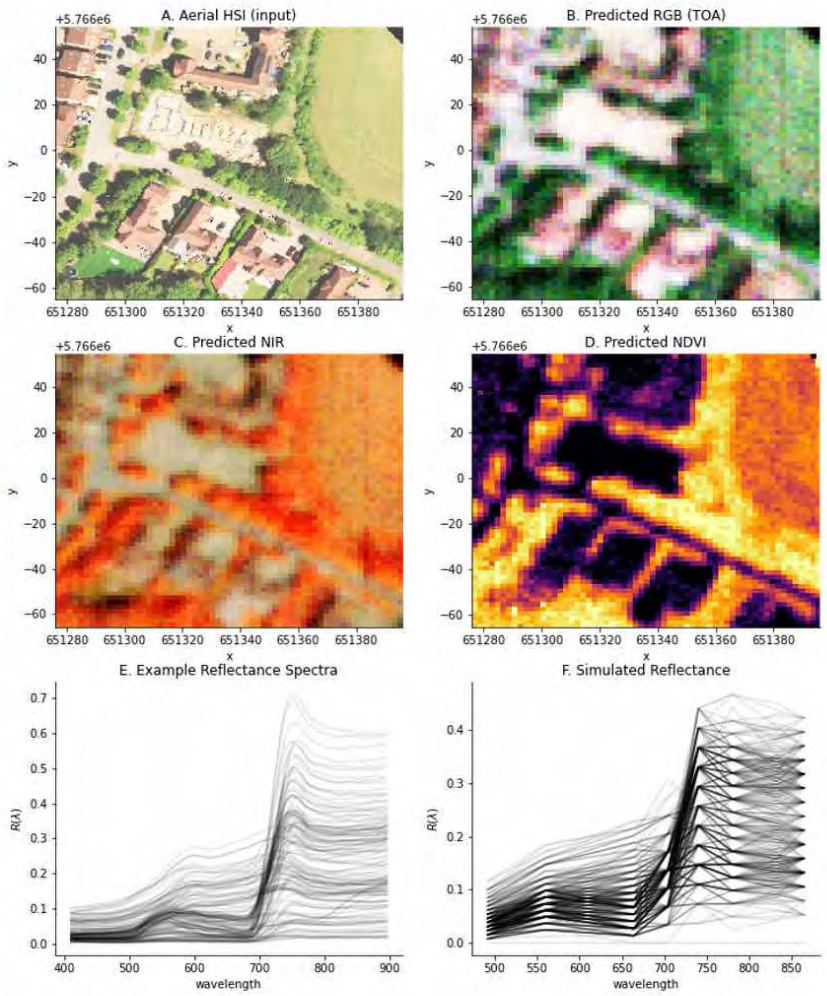
TreeView simulation work

Joseph Fennell (OU)

Simulation pipeline based on real-world scenarios; scene reflectance from hyperspectral airborne data (2Excel-geo)

Urban areas and rural woodland



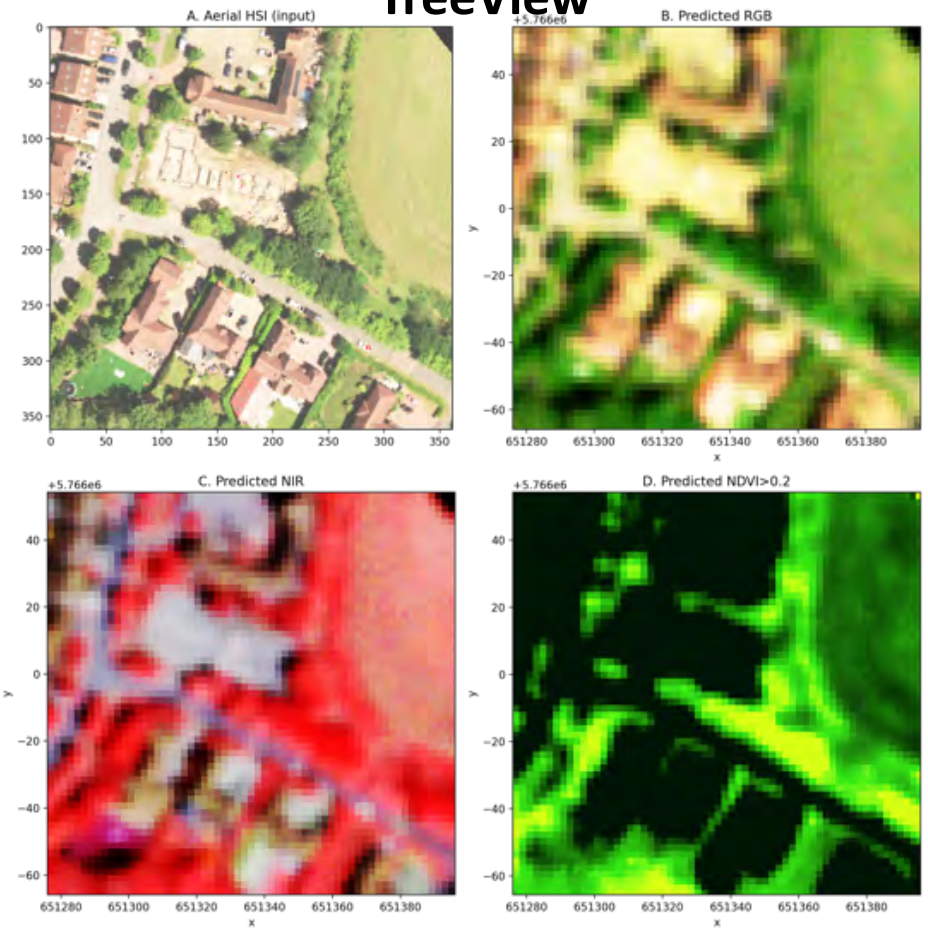


Vegetation indices at 2 m GSD

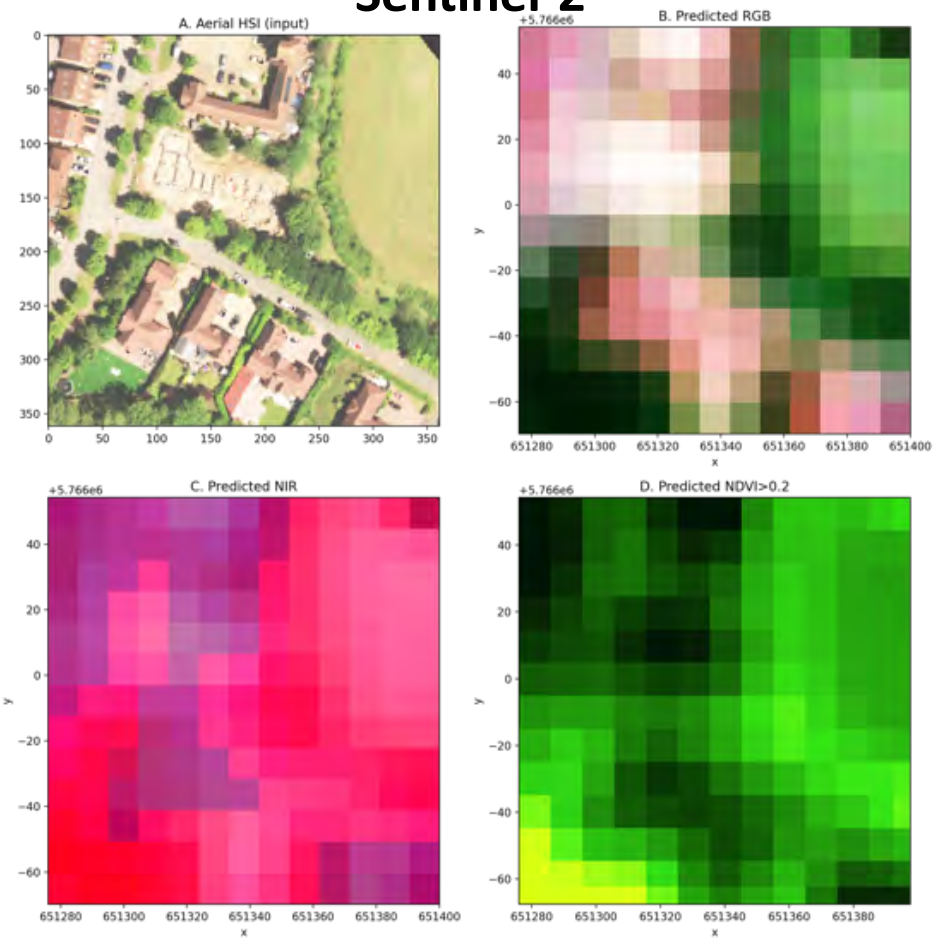
We have simulated data from Milton Keynes, and compared to equivalent 10 m simulations (Sentinel-2)

TreeView won't produce RGB images; these are for comparison

TreeView

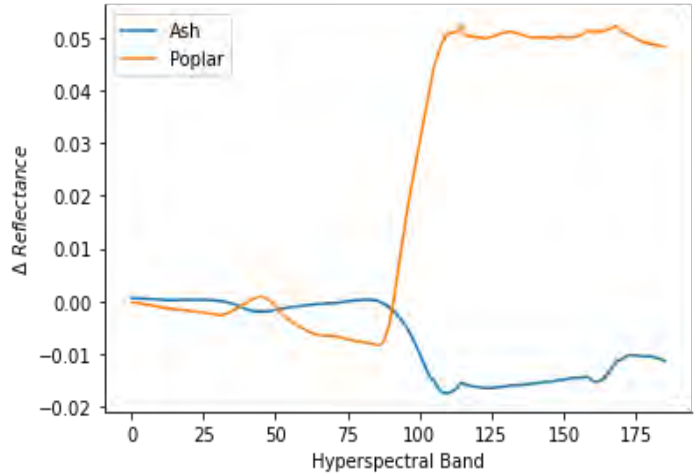


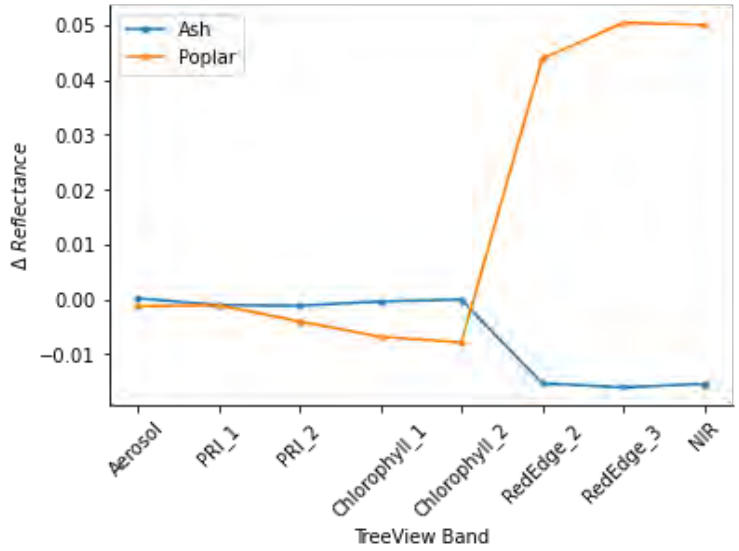
Sentinel-2



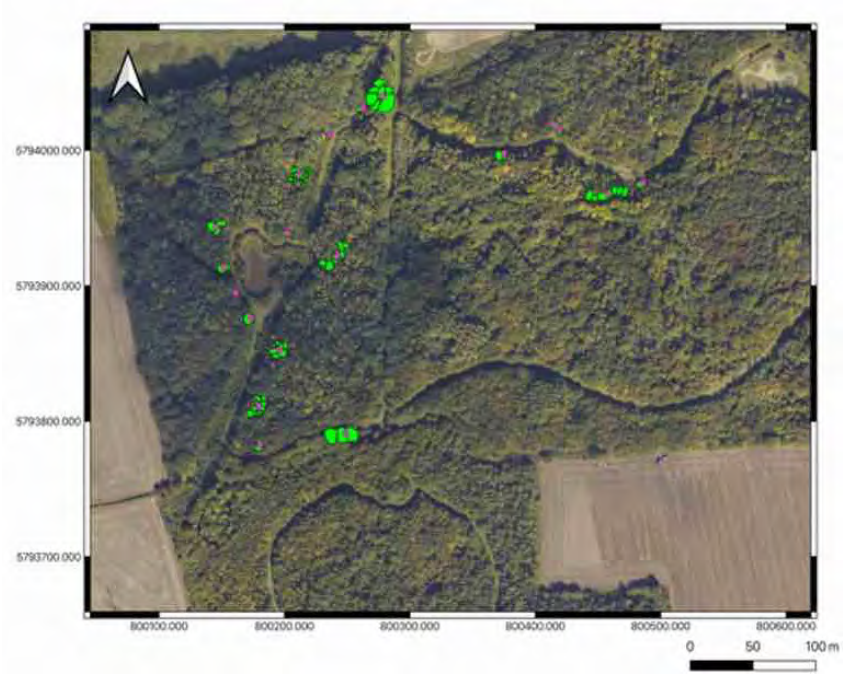
Discriminating between species

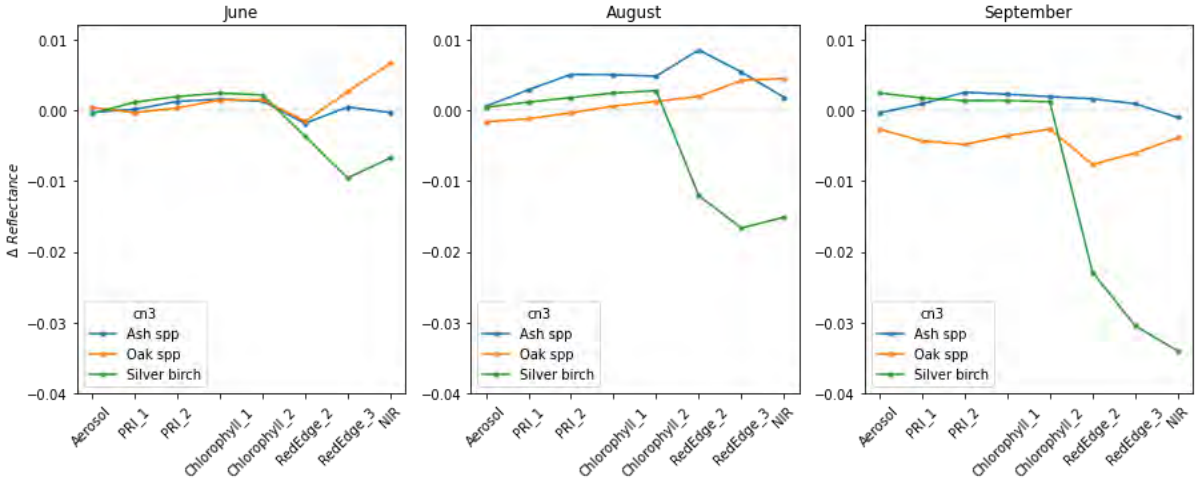
Location of tree species, Treezilla citizen science database

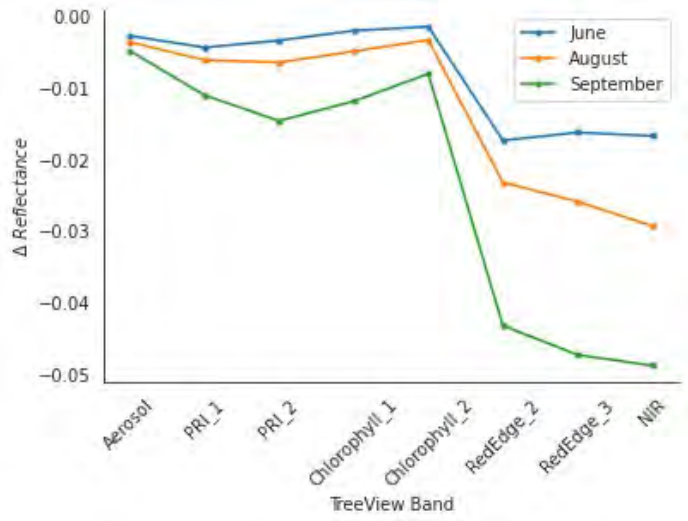




Temporal information and disease impacts







Trees experiencing ash dieback

Summary

- A feasibility study into a SmallSat mission with a new multispectral payload has been conducted
- The system can achieve 2 m GSD from 8 bands in the VIS-NIR
- The aim is for full UK coverage in a year, with off-pointing to achieve repeat visits of key sites
- Build up a comprehensive characterisation of the UK Treescape during mission life time
- End to end simulation pipeline is being used to explore the science and application potential