ASTeRN

Advanced Surface Temperature Radiometer Network

A Next Generation In-Situ Radiometer

ISFRN Workshop – Southampton 2025

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University of Southampton
UKRI Science and Technology Facilities Council RAL Space
NPL National Physical Laboratory
University of Leicester
Space ConneXions

ASTeRN

- ASTeRN = Advanced Surface Temperature Radiometer Network
- The project is to design and manufacture radiometers with the capability for measuring sea, land and ice surface temperatures with high accuracy and precision.
- The design is based on the findings of a study funded by ESA and performed by RAL and the University of Southampton.
  - Nightingale, Lee and Wimmer - Presented at ISFRN 2022
  - FRN4SST-SR-RAL-001-C – Case Study for Next Generation Radiometer
- The radiometers will be calibrated to standards traceable to SI realised by NPL standards.
- Initial deployments planned for 2025
- Funded by UK Government EO Investment Plan via UKRI/STFC and overseen by UKSA

Background to Project

- Measurements of surface temperatures from satellite observations make an important contribution to long term climate data records

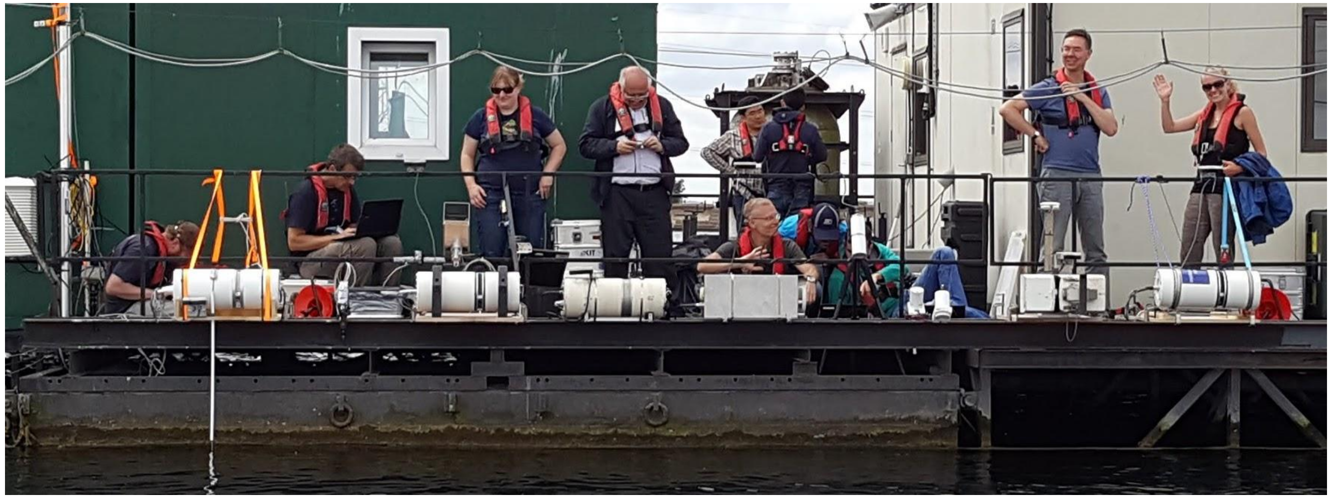
- To ensure the quality of these satellite data post-launch validation and in some cases recalibration against traceable ‘truth’ surface measurements is a fundamental element of the measurement system. This ‘truth’ data needs to be globally sampled across a range of surface types, ocean, in-land waters, land, ice etc to maximise utility of the satellite data.

- Future missions are being developed for Land Surface Temperature (LSTM (ESA/Copernicus), TRISHNA (CNES), SBG (NASA)) and CEOS are exploring a network of radiometers to validate/calibrate the missions.

- Sea Surface Temperature measurements require enhanced capability to include measurements of the atmosphere.

Participating Organisations

- Consortium is based on UK members of the Ships4SST consortium
- RAL Space
  - Consortium lead
  - Opto-electronics and calibration subsystems.
- Space ConneXions Ltd.
  - Project management support.
- Southampton University.
  - Overall mechanical and electrical design.
- Leicester University
  - Land Surface Temperature radiometer specification and deployment of a radiometer at a calibration site
  - Data analysis
- NPL
  - Calibration the radiometers at against a standard reference blackbody source.



Ships4SST radiometer intercomparison at Wraysbury reservoir

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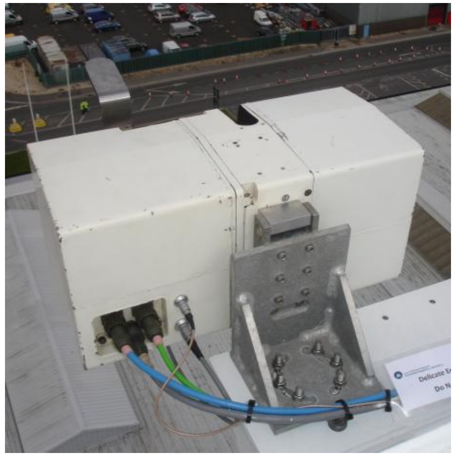
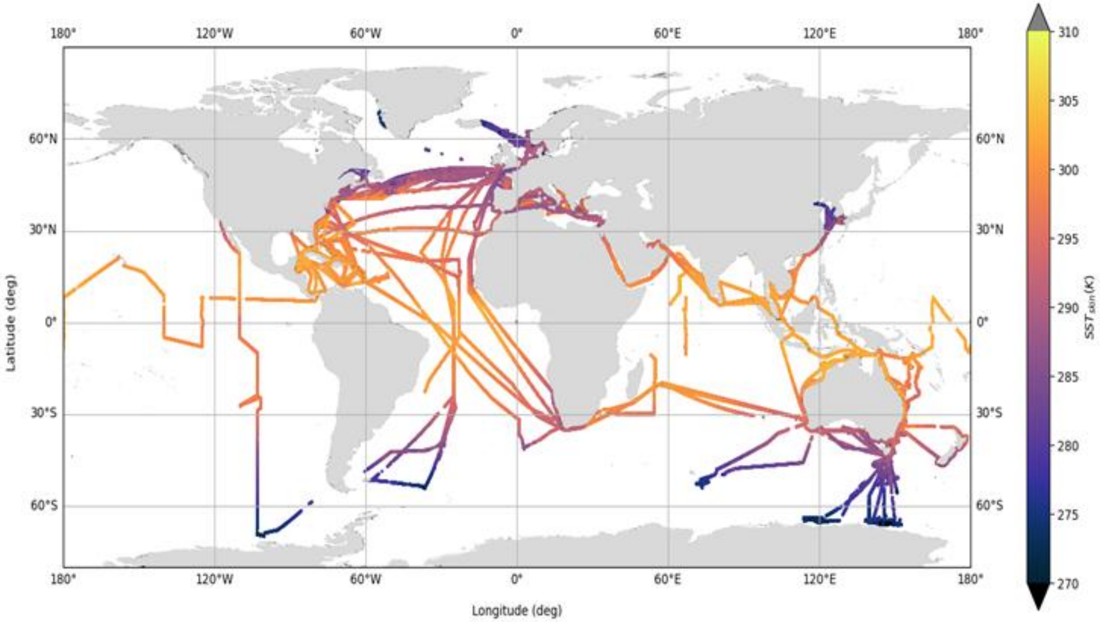
Current SST Radiometer Deployments

ISAR (UoS) >20 Deployments globally operated by different institutes



SISTeR (RAL Space)



- SST validation is supported by a number of autonomous self-calibrating ship-borne radiometers deployed by a number of institutes.
- ISARs have been deployed for LST measurements in Namibia and Greenland
- Validation of SST instruments is supported by periodic radiometer intercomparisons hosted by NPL
    - First intercomparison at Miami was initiated by IVOS

A new radiometer

- The current UK in situ radiometer designs (ISAR, SISTeR) are now 25+ years old.
- A new generation of radiometers are required to enhance and maintain capability for next decade.
  - Additional spectral channels for atmospheric characterisation
  - Extend capability for measuring Land Surface Temperatures
  - Address obsolescence issues,
  - Improve manufacturability and maintainability
- New radiometer design will be an evolution of existing designs:
  - Same basic measurement approach as existing instruments but drawing on lessons learned and incorporating modern components.
  - Ships4SST study has already defined requirements for the next generation

Key Requirements

- The instrument shall be capable of measuring radiances / brightness temperatures suitable for the calculation of:
  - SST for all combinations of sea and atmospheric temperatures
  - LST for most (T) / all (G) combinations of land and atmospheric
  - temperatures
  - IST for a limited range of ice and atmospheric temperatures
- SST in the range −2 °C to 35 °C
- LST −30 °C to 50 °C.
- NEΔT 50 mK (T) / 25 mK (G)
- BT systematic uncertainty (1σ) of 70 mK (T) / 40 mK (G) near to ambient temperature
- Skin SST measurements with a systematic uncertainty (1σ) of 100 mK (T) / 50 mK (G).

Key Requirements

- **Self Calibrating**
  - Thermal InfraRed (TIR) radiometer containing two blackbodies placed at the end of the detector optical chain. I.e. calibrates full optical chain.
  - One blackbody operated at the ambient temperature of the instrument and one black body operated at an elevated temperature
  - Provides traceability to SI

- **Multi View**
  - Views to an external scene in a range extending at least $\pm 90^{\circ}$ from local nadir to zenith.
  - Allows measurement of surface at different view angles and air temperatures

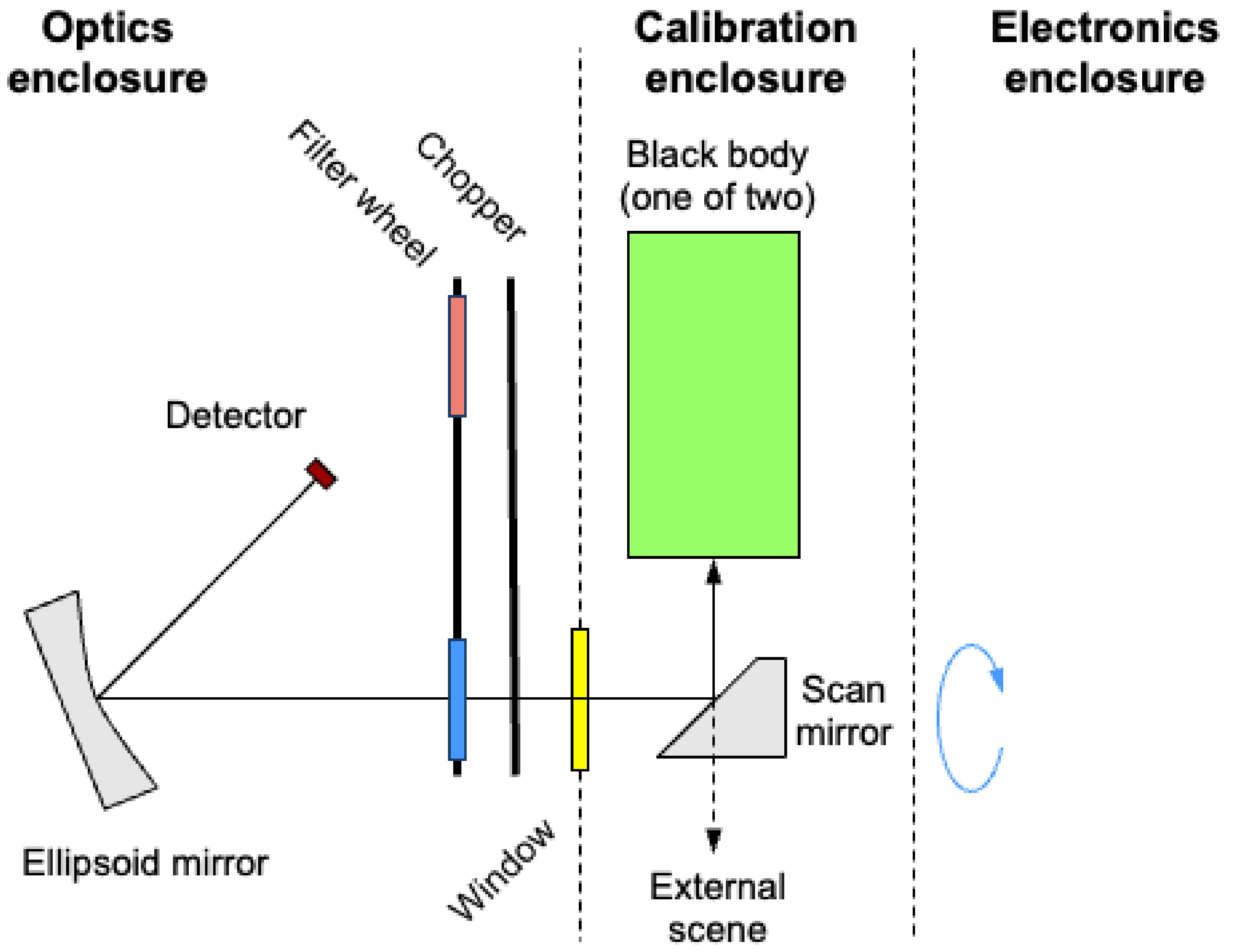
- **Autonomous Operation and Data Transfer**

- **Transportability**
  - Mass < 20kg
  - Dimensions able to be handled by single person

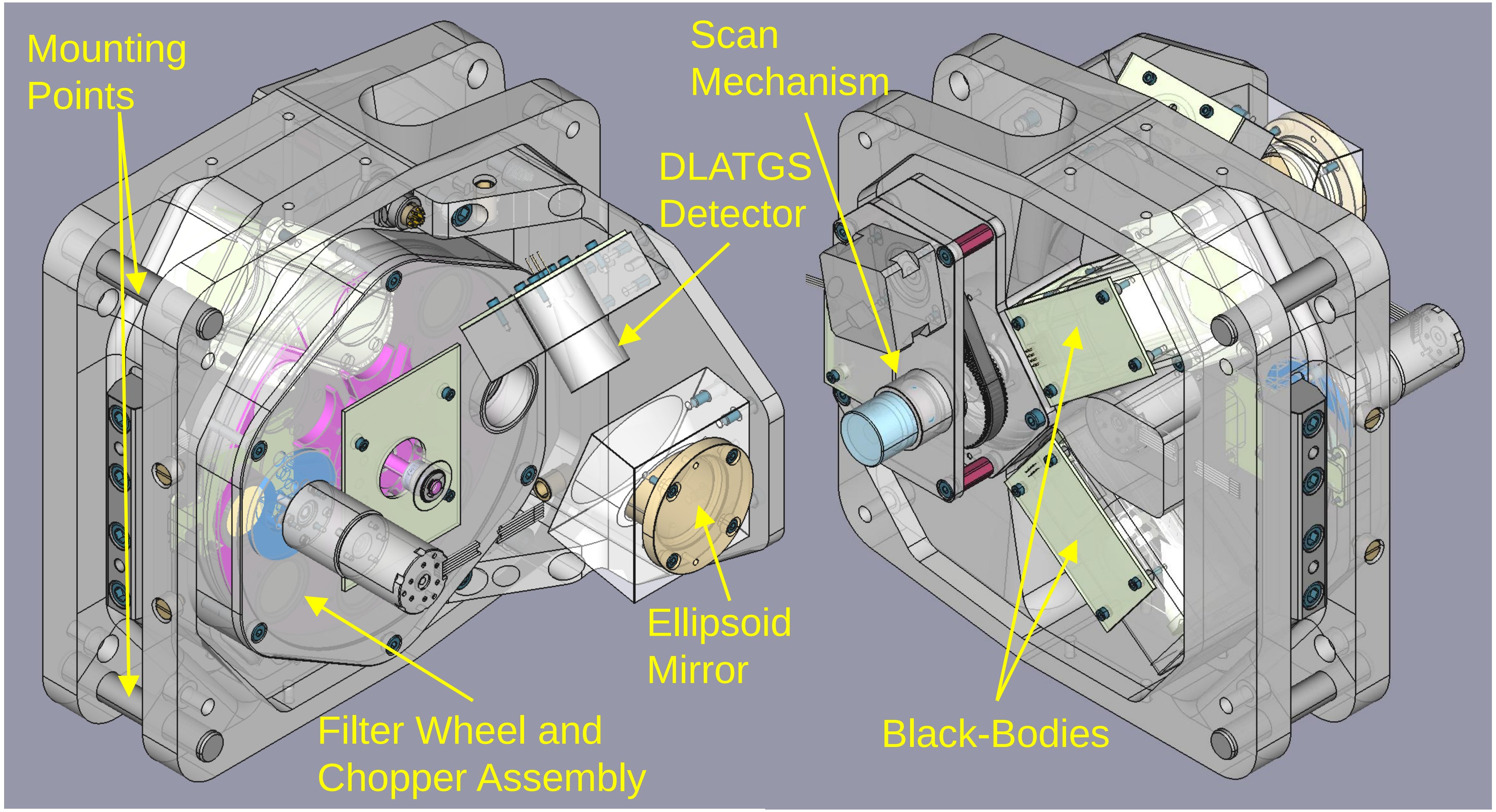
Spectral Characteristics

Band Centre	Band Width	Application	Source
8.6 µm	0.24 µm	LST, Emissivity	LSTM
8.9 µm	0.24 µm	LST, Emissivity	LSTM
9.2 µm	0.24 µm	LST, Emissivity	LSTM
10.8 µm	0.9 µm	SST, LST	SLSTR
12 µm	1.0 µm	SST, LST	SLSTR
14.6 µm	0.5 µm	Air Temperature	-

Instrument schematic



Instrument overview



IR Filters

Designed and built by the Infrared Multilayer Laboratory (IML) at Oxford University

Six bands in initial instrument design:

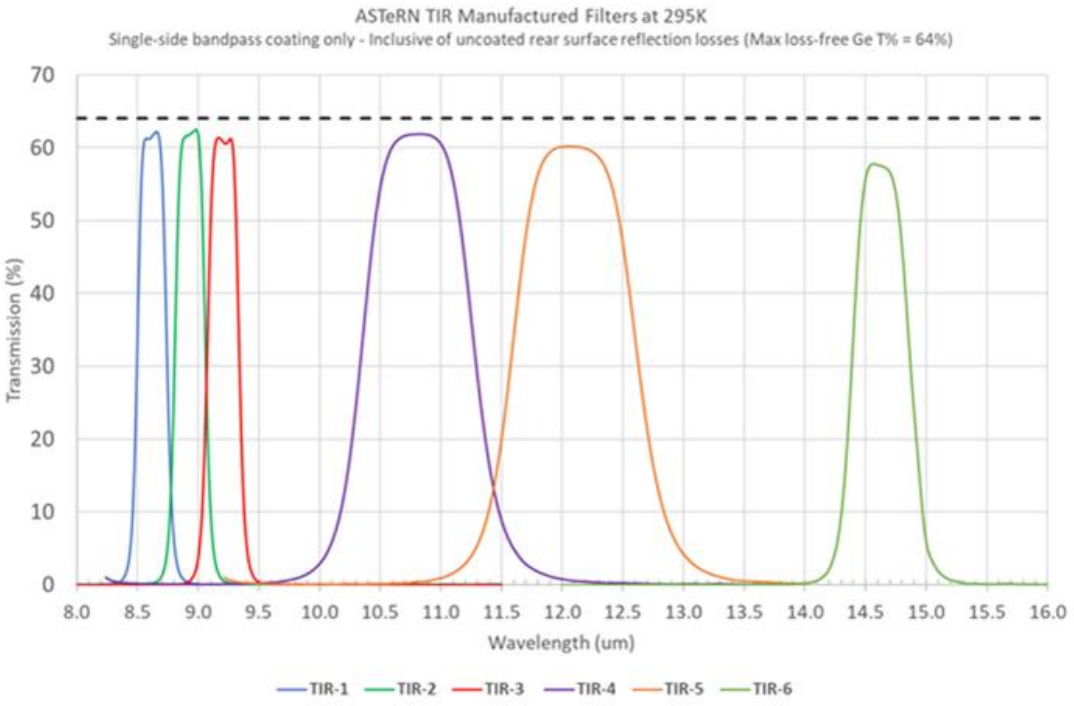
10.85 µm and 12 µm: split window (SST, LST, IST)

8.6 µm, 8.9 µm and 9.2 µm: surface characterisation (LST)

14.6 µm: CO_2 band (air temperature)

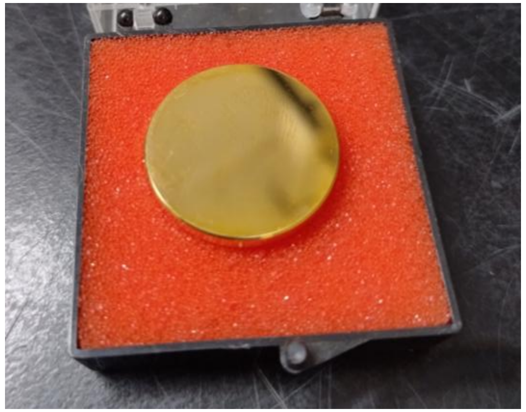
Low sensitivity to substrate temperature

All filters characterised at ambient temperature in representative (f/5) beam

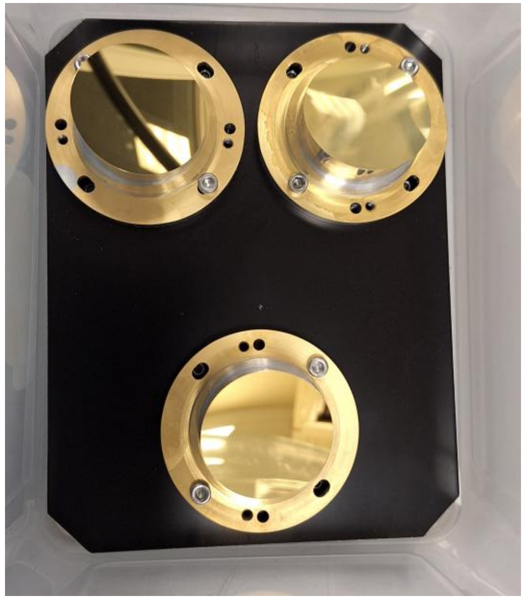


Optics

- **Scan Mirror**
  - Identical to ISAR scan mirror, hard gold on copper. Manufactured by ULO Optics



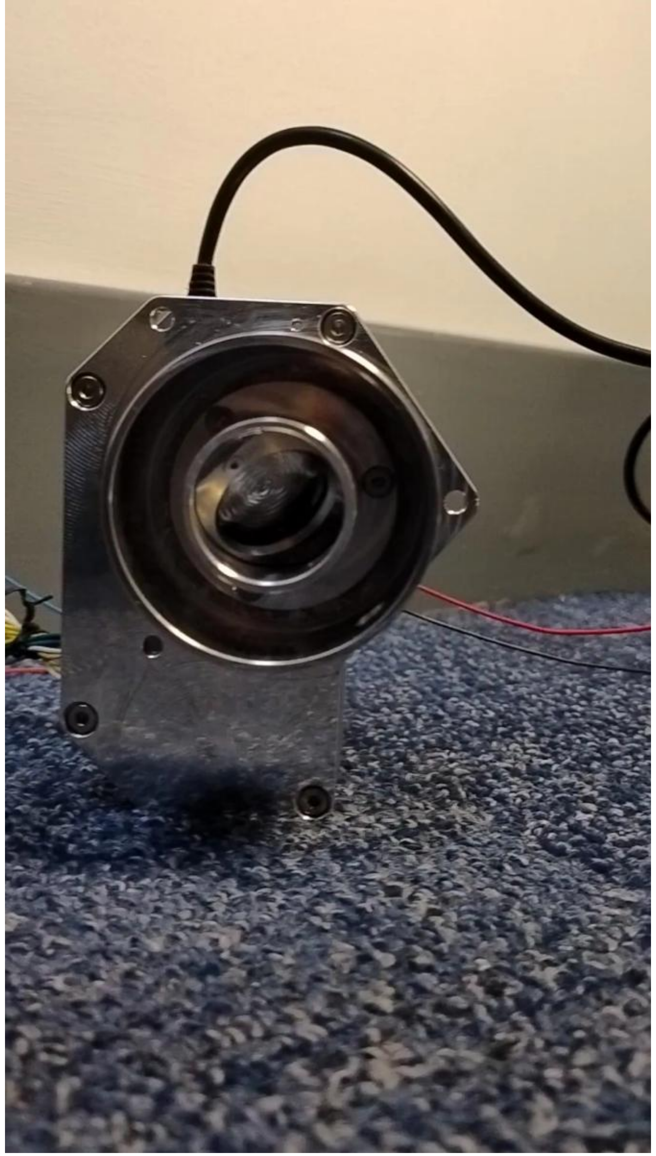
- **Ellipsoid Mirror**
  - Only powered optic in system
  - Diamond turned from aluminium
  - Gold sputtered coating with nickel adhesion layer



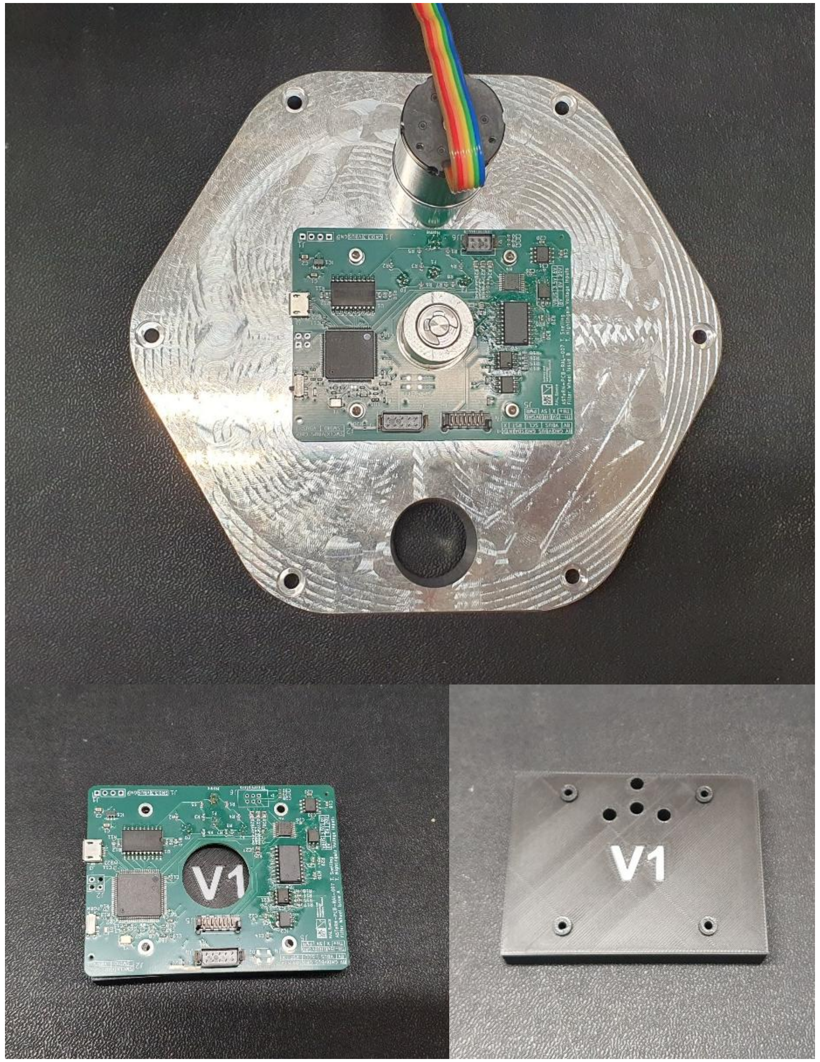
- **Window**
  - Protects internal optics from environment and damage

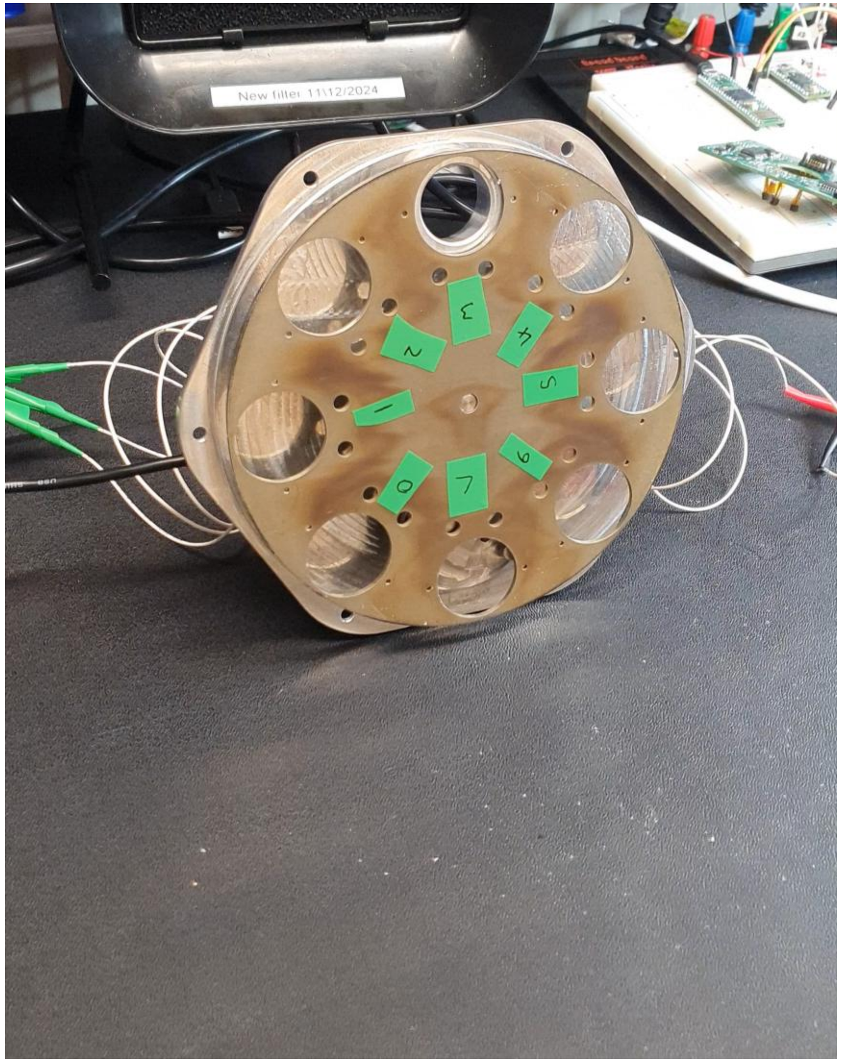
Scan mirror mechanism

- Easy access to the scan mirror for maintenance
- Belt driven 1:8 ratio from stepper motor
- 16-bit encoder for position feedback
- Dedicated motor drive electronics
- Scan mirror software
  - Receives command from scheduler
  - Reads position
  - Moves required steps
  - Checks position and fine adjusts if necessary
  - Reports new position back to scheduler

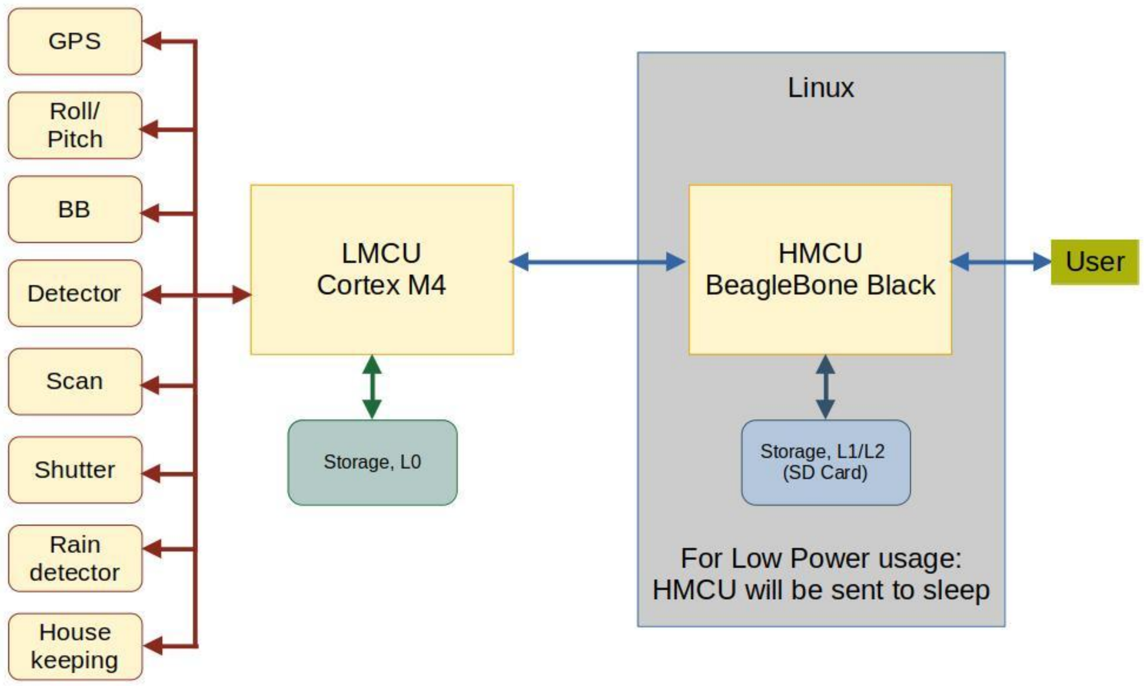


Filter wheel mechanism

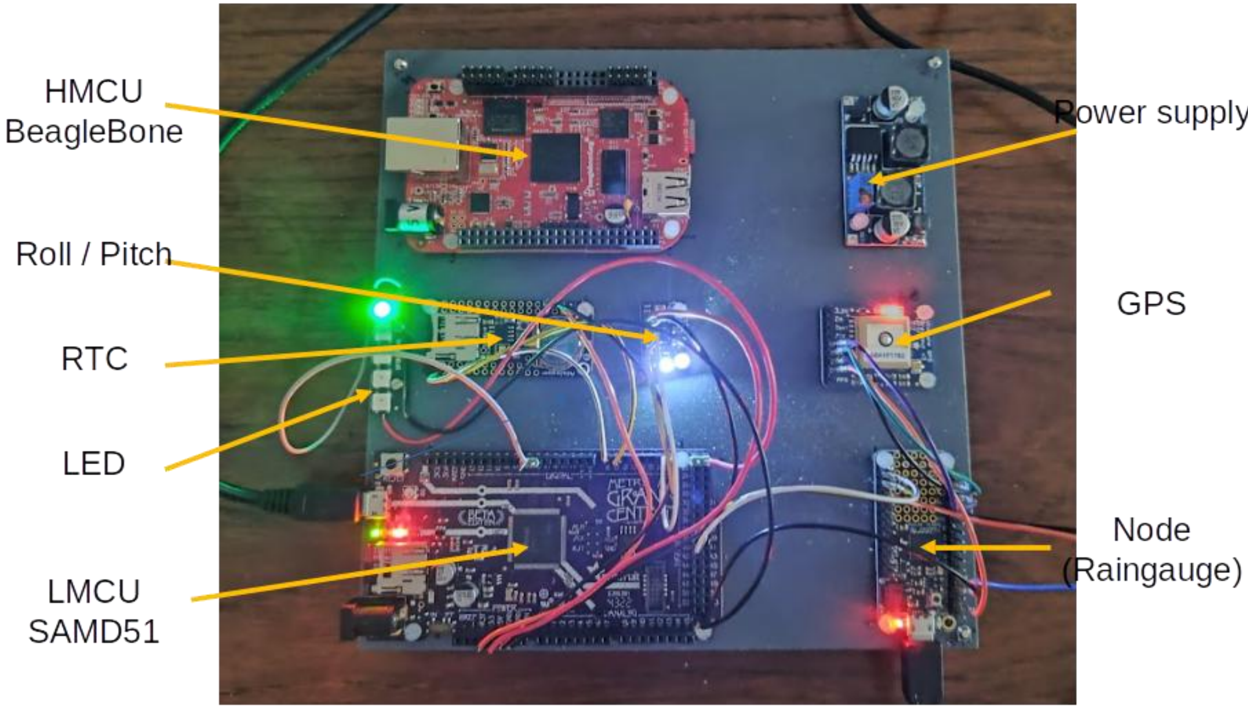




Electronics



Scheduler Breadboard



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Software

BeagleBone Black

Python for the processing and data storage (L1 and L2)

Python for user tools to interact with the instrument

Linux as OS

Can be set to sleep for low power consumption

Scheduler

Basic command parser for comms with BeagleBone

No OS, C code

1 s Timer for all tasks

Configuration file in JSON

L0 data storage

I2C interface with nodes

Nodes

I2C communication with scheduler

C code for programming

Progress summary – procurement

Complete

- All filters
- Scan mirrors
- "Off-the-shelf" hard carbon/AR coated ZnSe windows
- Extended AR coating for ZnSe windows

Awaiting delivery

- "Off-the-shelf" DLATGS detectors
- Extended bandpass DLATGS detectors

Remaining

- Anodising
- Painting (optical black)
- Painting (white epoxy on external surfaces)

Progress summary – Assembly and test

Complete

- Scan mirror mechanism assembly and functional test
- Filter wheel mechanism assembly and functional test
- Chopper mechanism assembly and functional test

Remaining

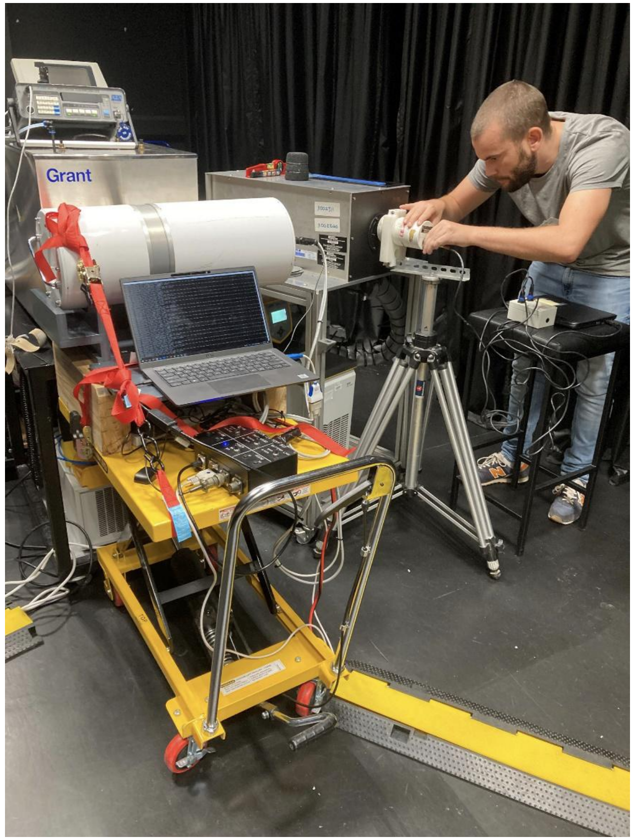
- Detector assembly and functional test
- Black body assembly and functional test
- Black body calibration
- Optical alignment
- Instrument assembly and functional test
- Instrument calibration verification

Calibration and Deployment

- Calibration of radiometers will be against reference blackbody source at per Ships4SST intercomparison protocols.

- Transport and install SST Radiometers on ships (e.g. QM2, Pride of Bilbao)
  - RAL + Southampton

- Transport and install LST Radiometer at land site
  - Performed by Leicester University
  - Comparisons with existing stock of LST radiometers
  - Complemented by Heitronics radiometers to increase the geographic coverage for LST validation



Radiometer Measurement against reference BB source at NPL during June- 2022 Radiometer Intercomparsons.
Ref: FRM4SST-CRICR-NPL-002_ISSUE-1