# ASTeRN

## Advanced Surface Temperature Radiometer Network

**A Next Generation In-Situ Radiometer**

ISFRN Workshop – Southampton 2024

Dave Smith - STFC RAL Space + ASTeRN consortium

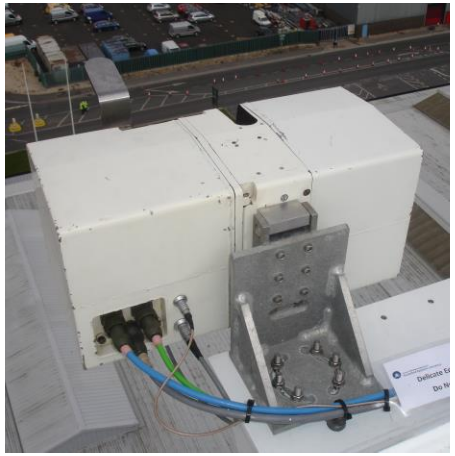
University of Southampton
UKRI Science and Technology Facilities Council RAL Space
NPL National Physical Laboratory
University of Leicester
Space ConneXions

# Background to Project

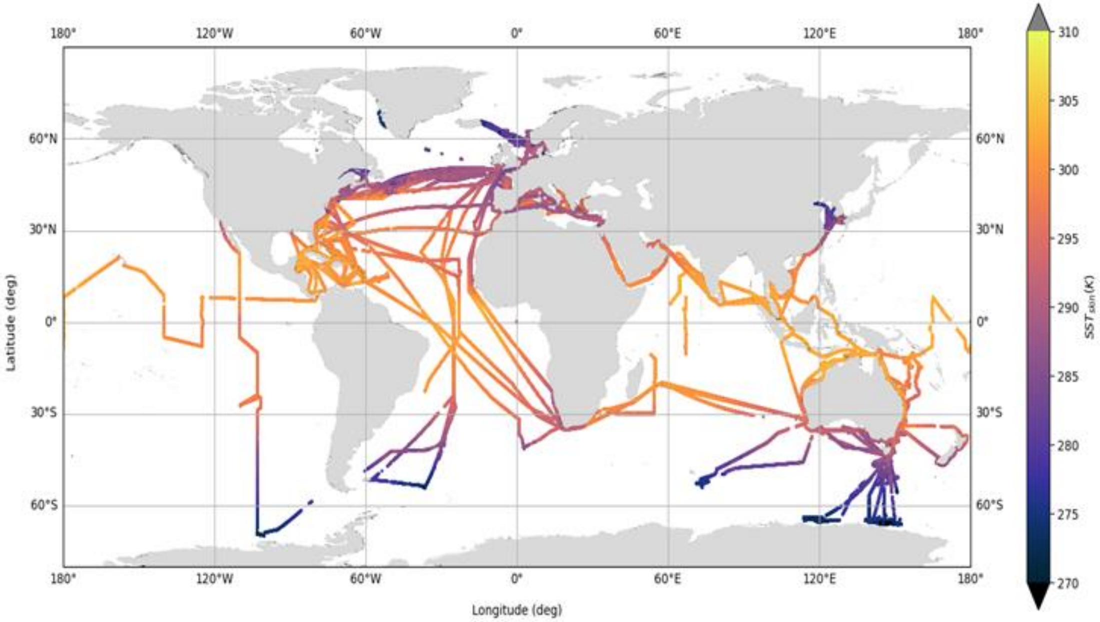
- Measurements of surface temperatures from satellite observations make an important contribution to long term climate data records
- To ensure the quality of these satellite data post-launch validation and in some cases recalibration against traceable 'truth' surface measurements is a fundamental element 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.

# 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

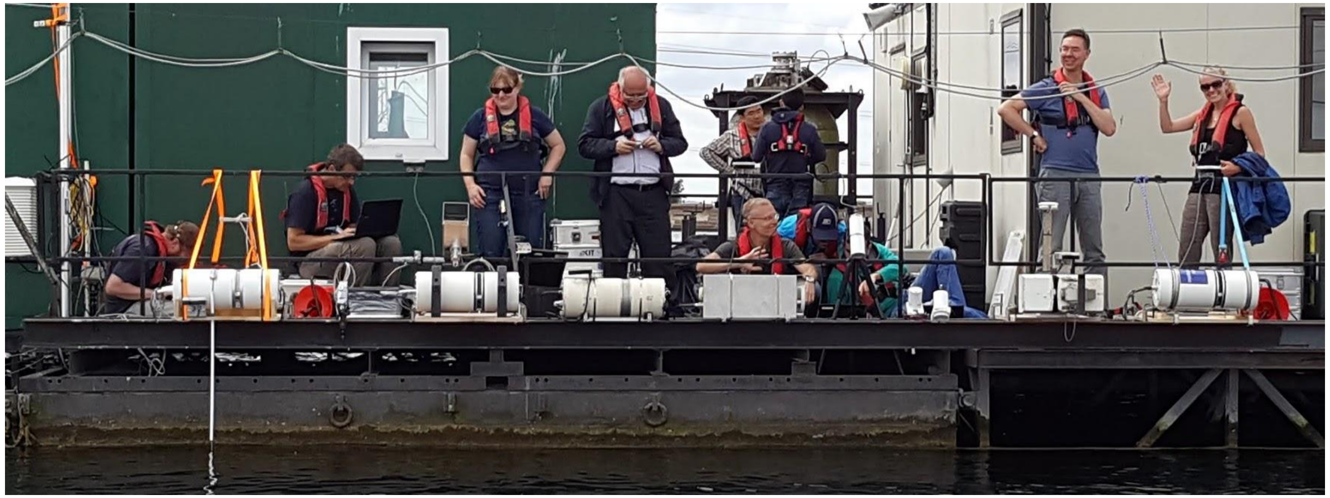
- The current UK in situ radiometer designs (ISAR, SISTeR) are now 25+ years old.
- A new generation of radiometers are required to enhance and maintain capability for next decade.
  - Additional spectral channels for atmospheric characterisation
  - Extend capability for measuring Land Surface Temperatures
  - 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

# 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
- ASTeRN is funded by UK Government EO Investment Plan

# 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

# 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 | - |

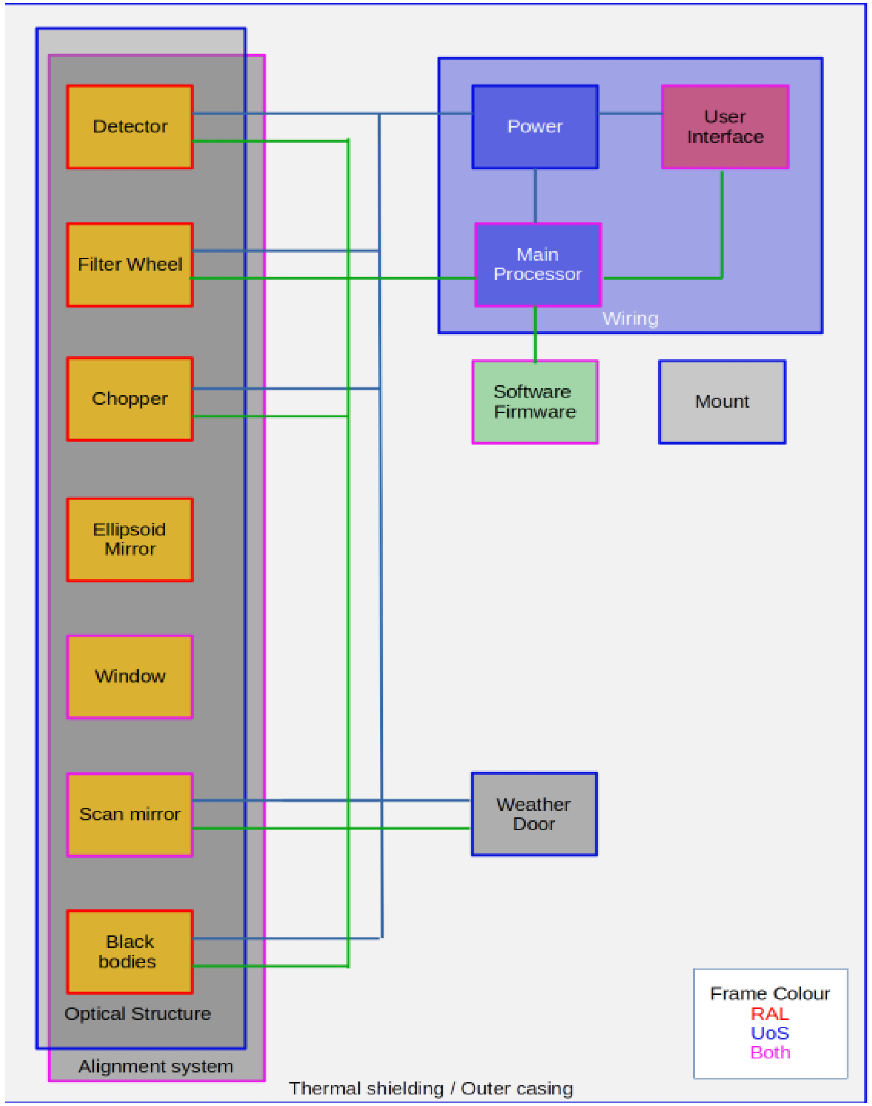
# System Architecture

## RAL Space

- Detection Chain
- Optical Bench Layout
- Blackbody Sources
- Electronics for opto-electronics

## Southampton University

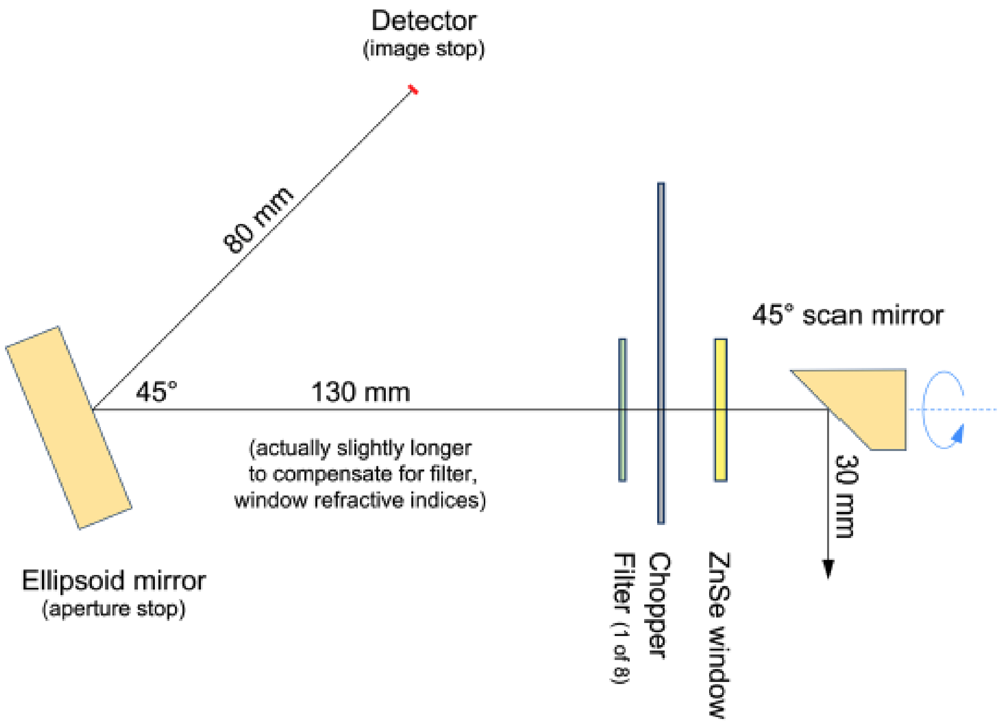
- Mechanical design and manufacture
- Main structure
- Rain gauge
- Door and shutter
- Main Electronics incl. processor and firmware.
- End-to-end checkout



# Optical Layout

- ASTeRN detection chain consists of:
  - DLATGS detector
  - Ellipsoid mirror
  - Filter wheel containing up to 8 filters
  - Rotating chopper.
  - Scan Mirror

| Band λ (μm) | *NEΔT* (mK) | | | |
|---|---|---|---|---|
| | −100 °C | 20 °C | 50 °C | 70 °C |
| 8.6 | 1145 | 62 | 44 | 37 |
| 8.9 | 1016 | 63 | 45 | 38 |
| 9.2 | 914 | 64 | 47 | 40 |
| 10.85 | 165 | 20 | 15 | 14 |
| 12 | 131 | 21 | 17 | 16 |
| 14.6 | 246 | 64 | 55 | 52 |



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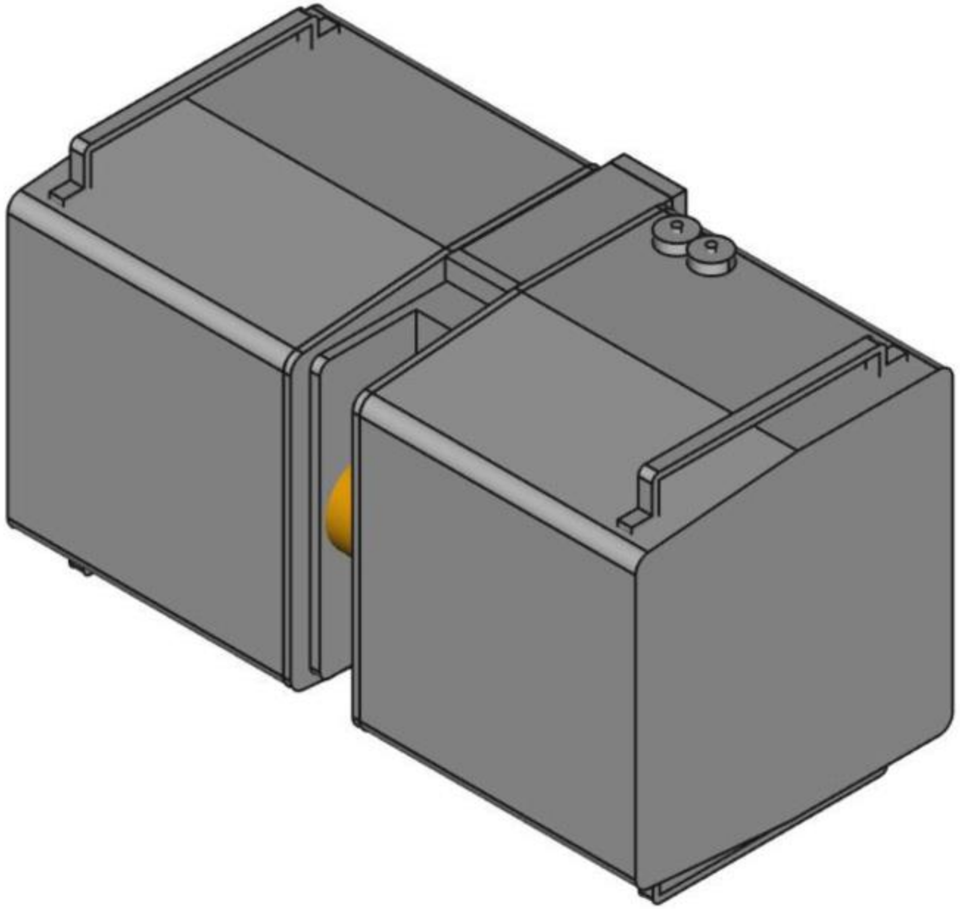
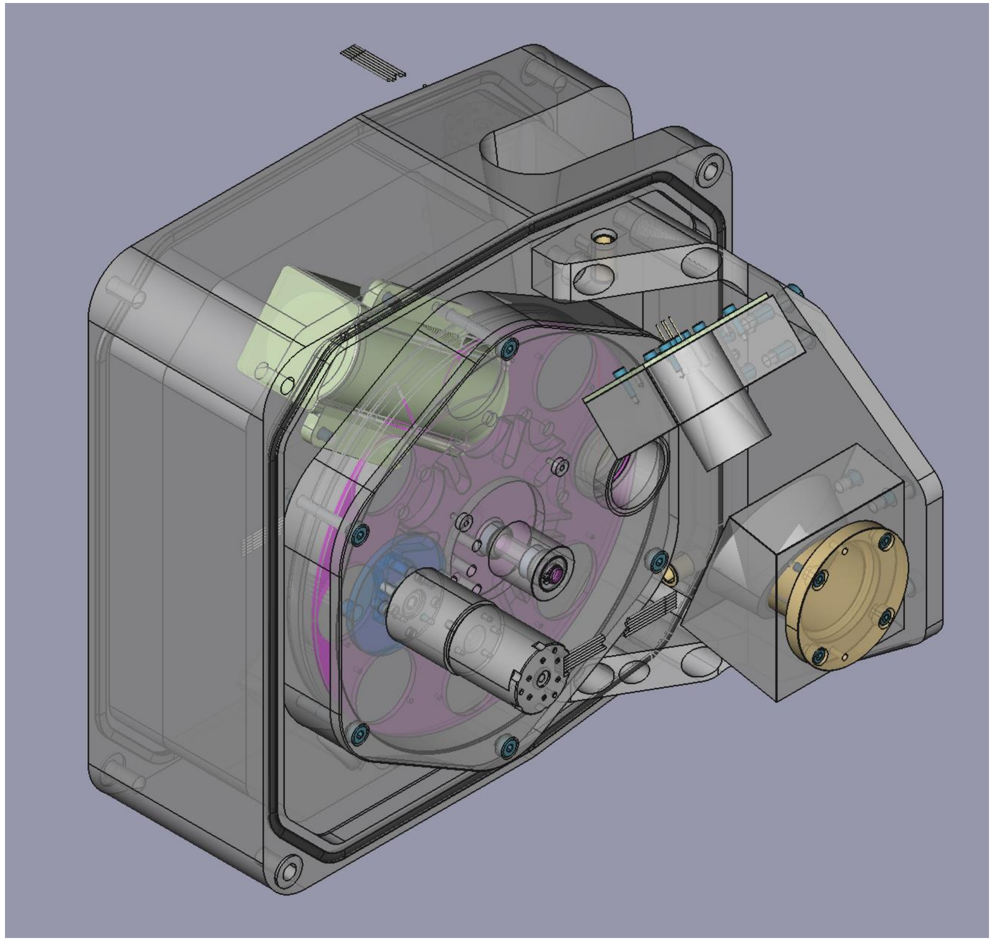
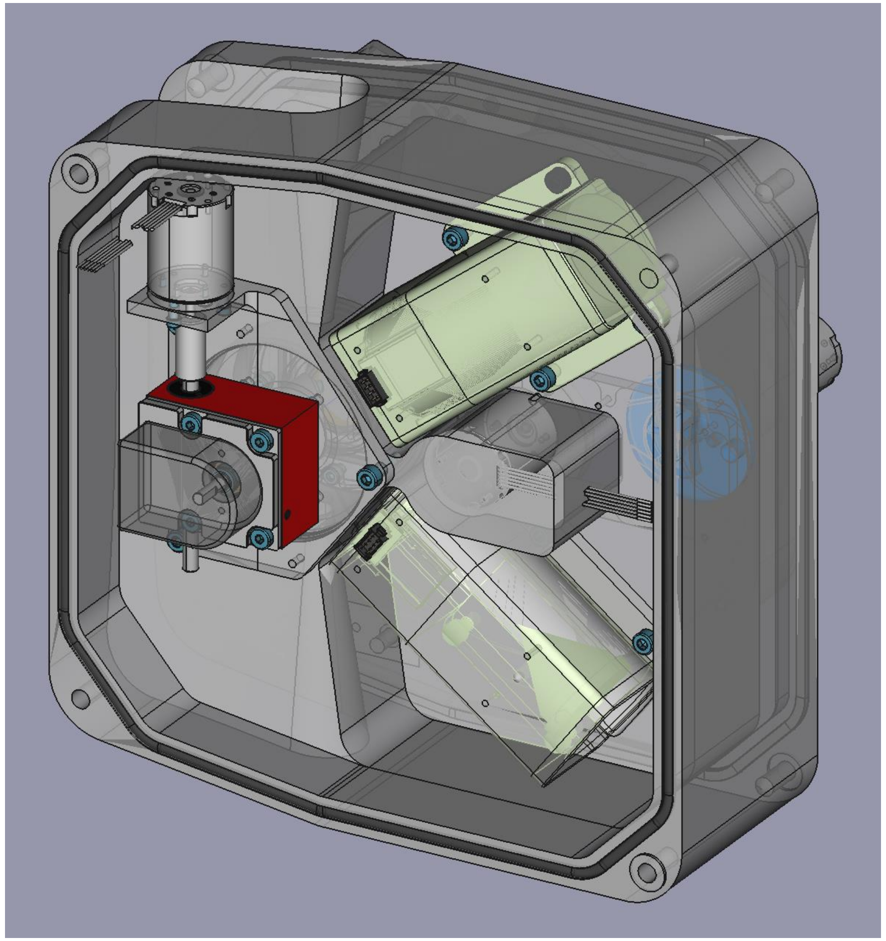
# Mechanical Design

- Optics + Mechanisms are mounted on a central bulkhead enclosed by 2 cases (as per ISAR + SISTeR)
- Cases have internal 15mm flanges with O-ring seals
- Further protection is provided by a weather protection door (not shown) activated by a rain gauge.



# Optical Design







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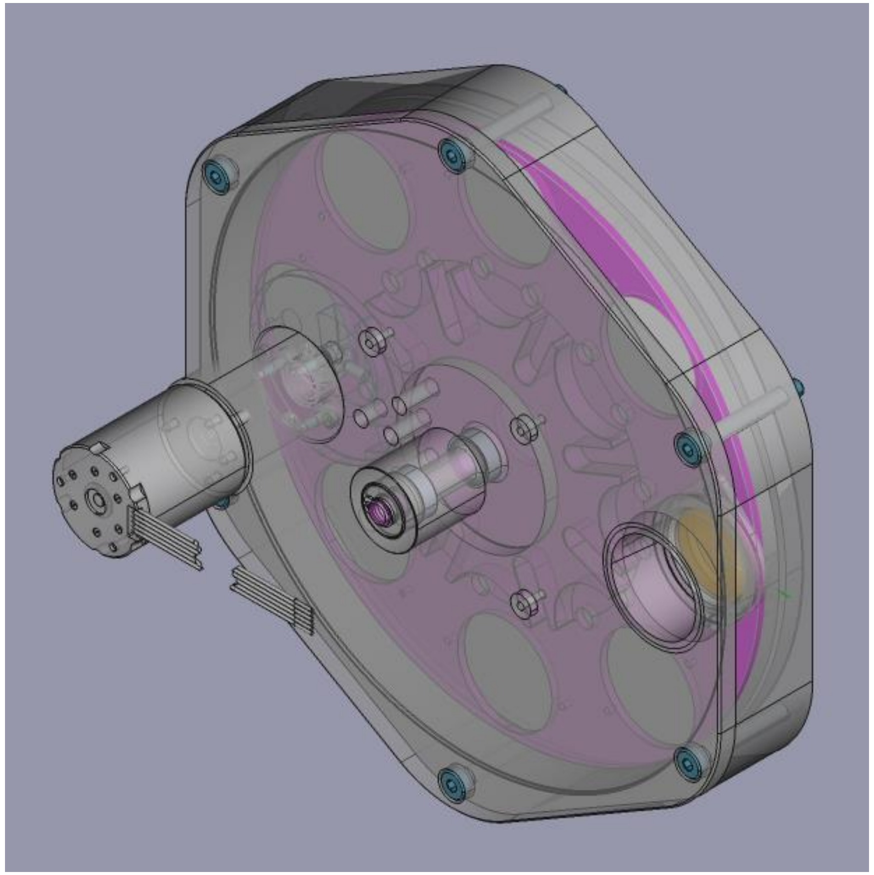
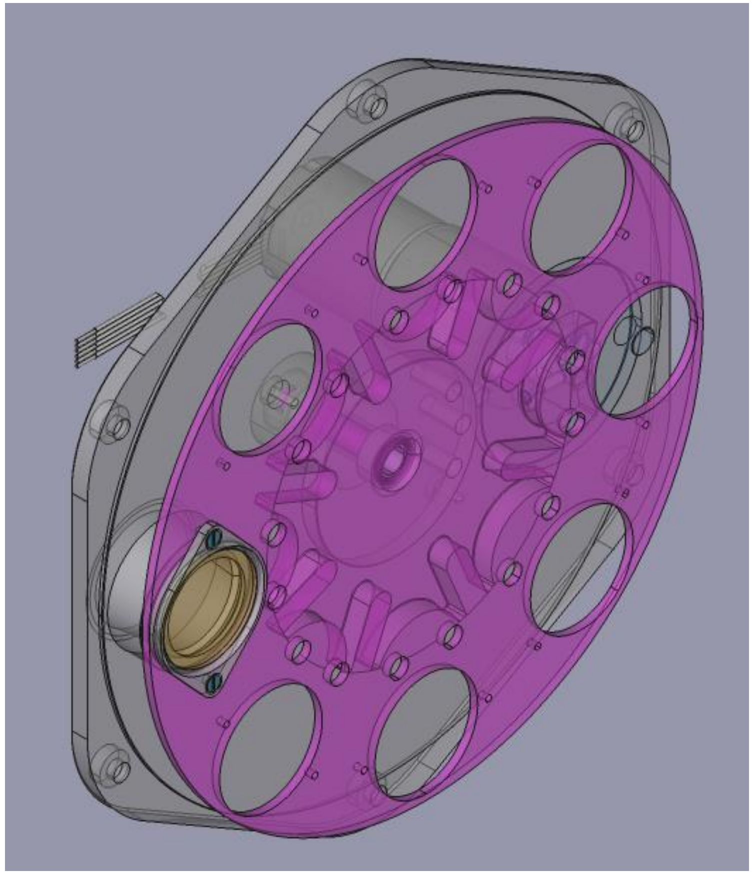
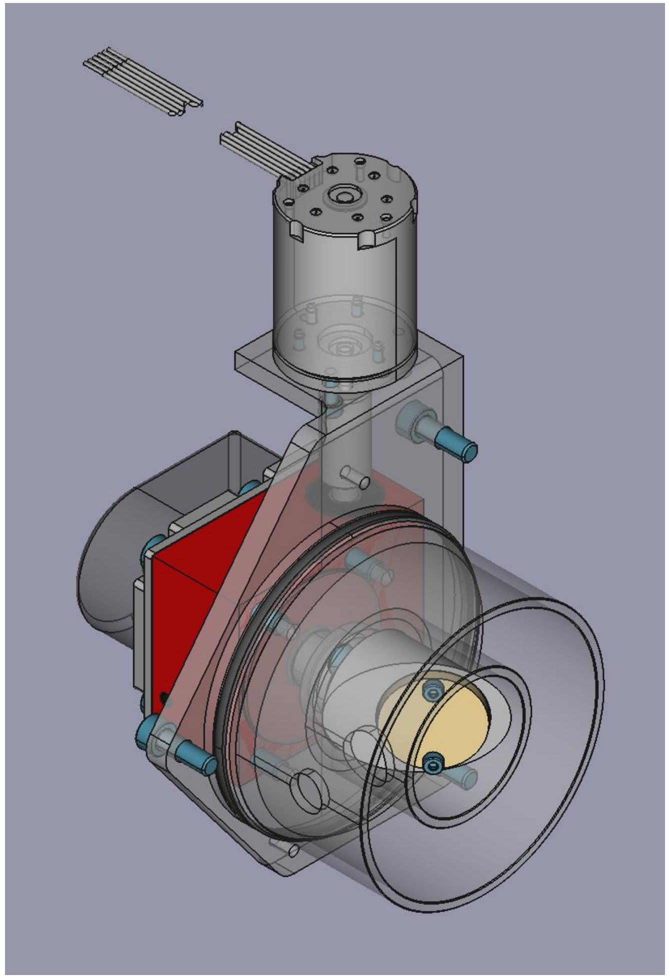
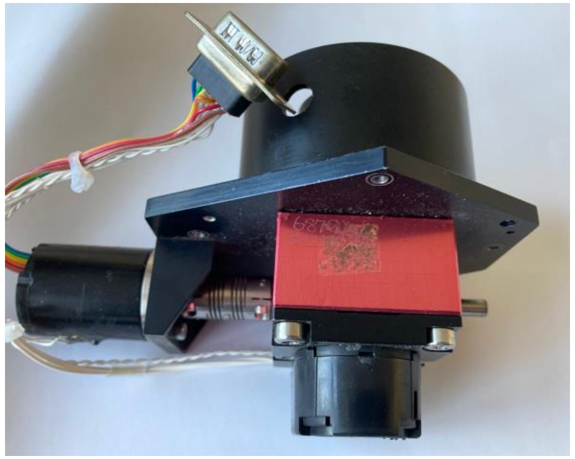
# Filter Wheel + Mechanism



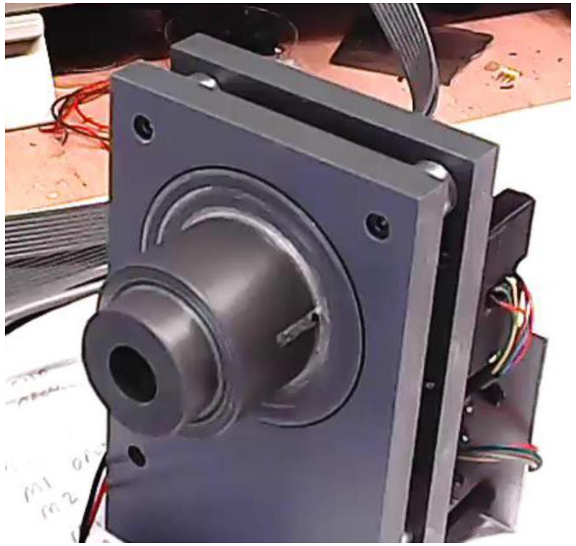


# Scan Mirror + Mechanism





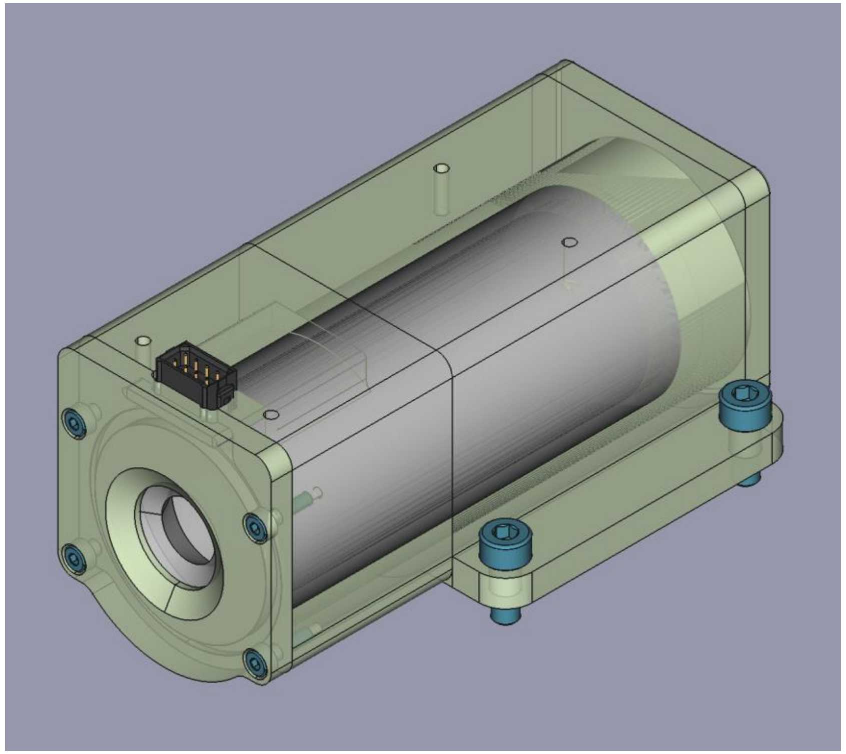
SISTeR Scan Drum



ASTeRN prototype Scan Drum

# Blackbodies

- Based on SISTeR and ISAR designs
- Outer insulating jacket with air gap
- Inner tubular body with aperture plate at top and re-entrant cone at base
- Thermometry
  - Baseline is two primary NTC thermistors embedded in base, two secondary thermistors bonded to body. From SiSTER and ISAR experience these have been shown to be sufficiently stable.
  - Readout circuit PCB bonded to base, Kapton flexible PCB thermal breaks (also heater element) bonded to body
  - To calibrate thermistors, entire BB inner will be calibrated in a thermal block immersed in a fluid bath
- Heater controller PCB attached to outside of jacket

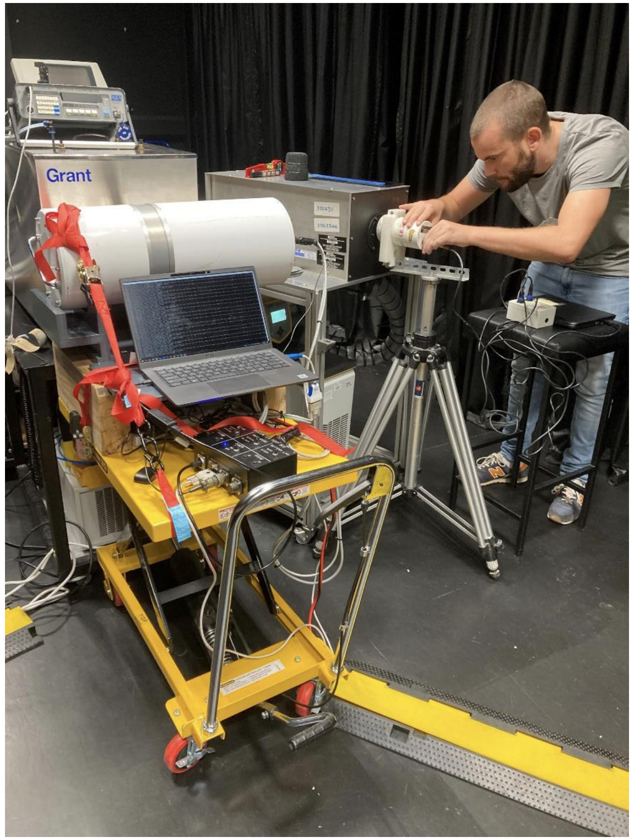


# Calibration and Deployment

- 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

# Project Status

- Opto-Mechanical design is well advanced

- Prototype manufacture of key elements is in progress
  - Scan mechanism, filter wheel, chopper, rain door

- Procurement of long-lead items is in progress
  - Filters produced by Oxford University filter group (originally Reading).

- First instrument built and demonstrated by Q1 2025.