UK SPACE AGENCY

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TRUTHS in the Earth Watch context – a proposal by UKSA

10th April 2019

What is the TRUTHS mission?

Traceable Radiometry Underpinning Terrestrial- & Helio- Studies

- TRUTHS is primarily a climate mission.
  - Measures the incoming & outgoing energy from the climate system.
  - Detects the spectral fingerprint for attribution of climate processes
  - Has the accuracy to detect climate trends in the shortest possible time.

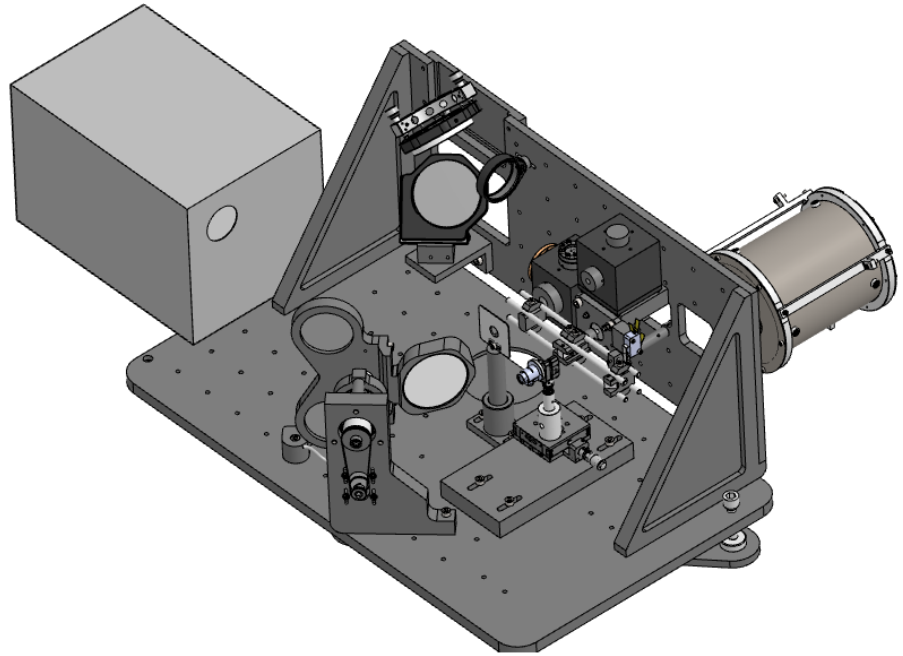
- The datasets needed to meet this objective have secondary applications.
  - Operational products for removing radiometric biases in other satellite instruments by cross-calibration with TRUTHS, improving accuracy & enabling inter-operability.
  - SI traceable measurements of the solar spectrum to address direct science questions.

TRUTHS Earth Watch proposal perimeter

- 5-7yr mission S/M platform [P/L Mass ~ 150 kg, Power ~ 280 W, Data ~ 4500 Gb per day]
- Hyperspectral imaging spectrometer payload, measuring the Earth, Moon & Sun.
- On-orbit SI-traceable calibration that provides 10x improved accuracy to current sensors.
- 90deg precessing 609km orbit to provide true diurnal cycle sampling & optimised cross-cal match-ups
- Data Products
  - L1 Earth-reflected spectral radiance (320nm to 2450nm)
  - Total Solar Irradiance (0.2um to 30um, integrated)
  - L1 Solar spectral irradiance (320nm to 2450nm)
  - L1 Lunar spectral irradiance (320nm to 2450nm)
  - Inter-calibration coefficients & match-up products.
  - L2 spectral surface reflectance (320nm to 2450nm)
- Sole-use Vega-C launch.
- Ground segment (FOS & PDGS) – download at Svalbard

What makes TRUTHS different to other hyperspectral missions?

- TRUTHS includes an on-board SI-traceable calibration system to 0.3% uncertainty (k=2), that replicates the calibration chain employed in NMIs globally.
  - No reliance on assuming maintenance of pre-flight performance, or modelled degradation.
  - No reliance on a contiguous overlapping mission series.
  - Not limited to Sun diffuser method accuracies (2-5%)
- The differentiator is the continuous (daily) re-calibration maintaining the TRUTHS HIS calibration to SI.
  - That mitigates internal components (diffuser, mirrors etc.) degradation – this is unavoidable.



Uncertainty budget propagation

CSAR (On-board SI Traceability primary standard) → HIS (On board calibration system) → SNO inter-calibration between 2 satellites → L2+ application product

Element	Uc (%)
Measurement of electrical power	0.010
Cavity absorptance	0.010
Scattered light	0.004
Random noise	0.06
TOTAL	**0.02-0.07**

Element	Uc (%)
CSAR	<0.06
Prism arm	< 0.01
Transfer radiometer	0.03
External aperture	0.02
Traceability	0.08
HIS thermal control (1K)	0.01-0.20
HIS SNR	0.03
TOTAL	**0.16-0.26**

Element	Uc (%)
TRUTHS HIS	0.16-0.26
Spectral mismatch	0.1-0.2
Spatial mismatch	0.1
View Angle	0.1-0.2
Atmos. corr.	0.1-0.3
BRDF	0.1
TOTAL	**0.4-0.7**

Element	Uc (%)
GHG retrievals	1% = 0.1ppm
Ocean Colour	0.5% = 5% WLR
Cloud Radiative Forcing	0.3%

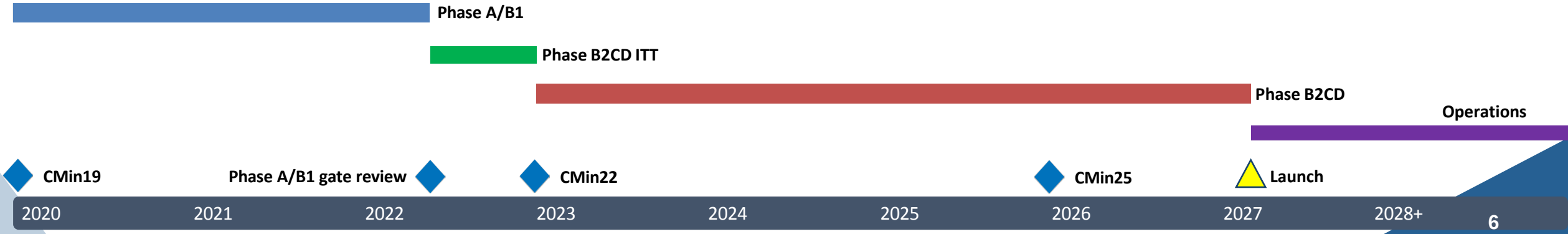
Mission programmatic

Overview

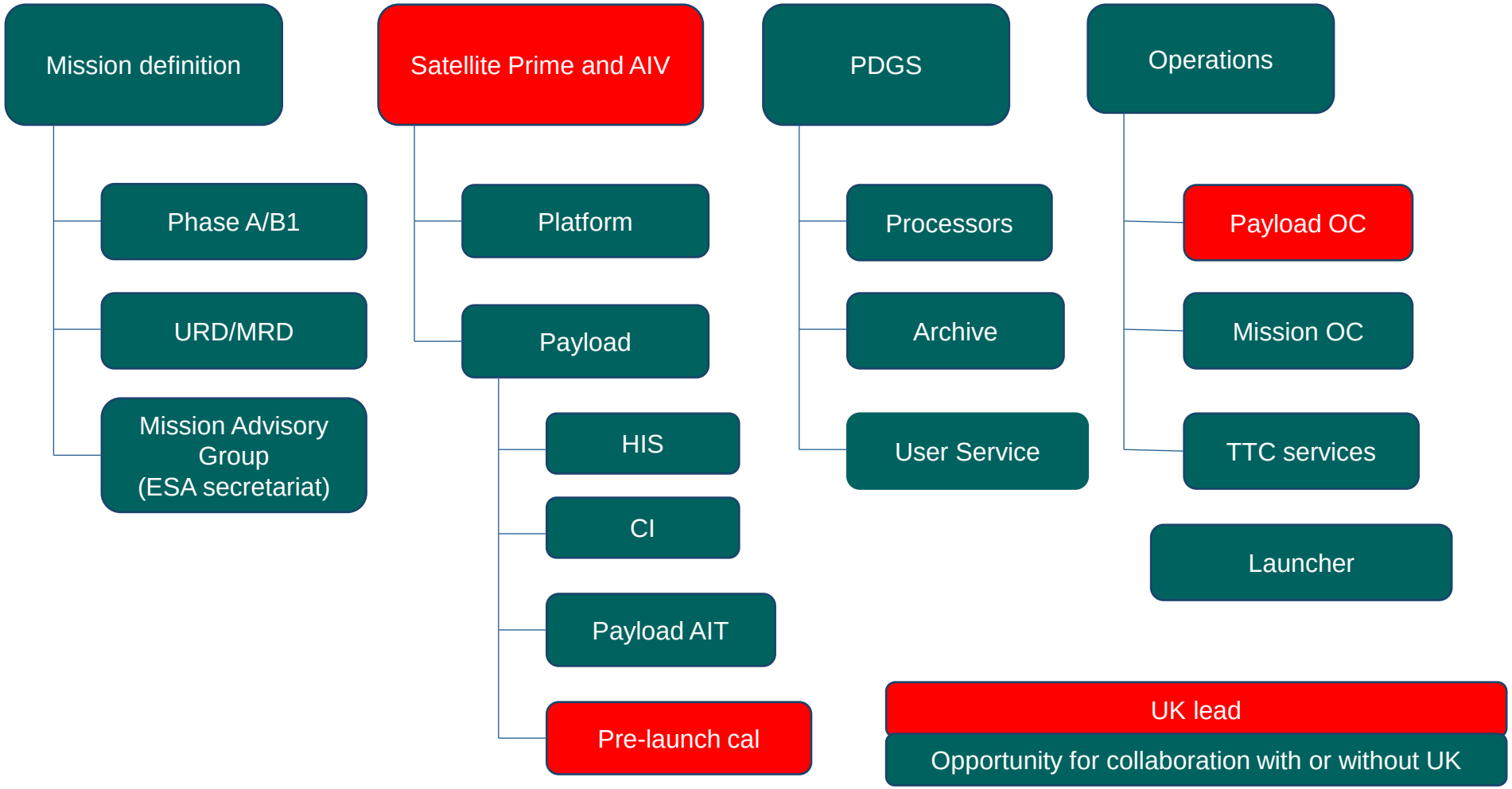
- **Total mission costs are estimated at between €230m and €360M**. This will include development, launch and operations.
- TRUTHS is expected to be flight ready between 2026 and 2028.

Phasing

- **CMin19 will seek a financial envelope of €42m to fund phase A/B1**, which will confirm the total mission costs.
- Phase A/B1 will take 21 months, and will be followed by a decision point in early 2022 on whether to proceed.
- Following a positive decision, further funds will then be sought at CMin22 to cover Phase B2CD, with Launch Services and Phase E1and E2 available for subscription at CM25.
- Following a positive decision, the tendering process for Phase B2/C/D will be started in early 2022, leading to the start of activities after CM22 once funding is secured.



TRUTHS Development (Phases B/C/D/E1)



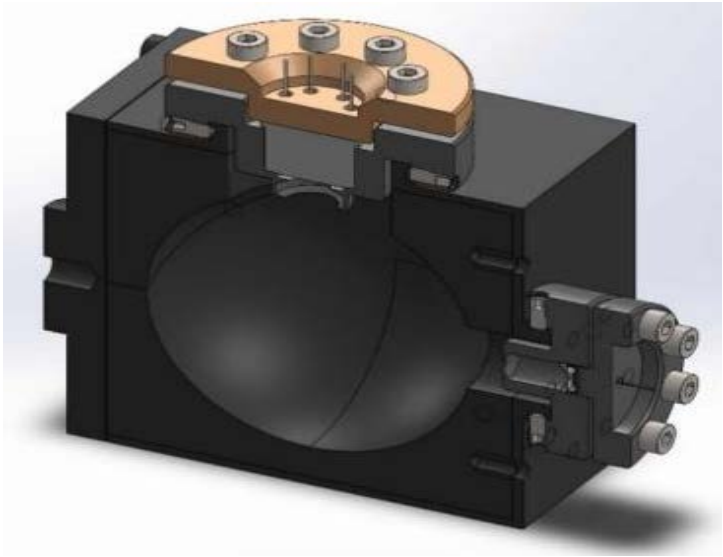
TRUTHS Calibration System

CEOI Flagship Project (2015-18)

The following slides are courtesy NPL

Overview of Calibration System

- Array of single-wavelength, power stabilized low power laser diodes
  → Range 350 nm to 2300 nm
- Beam delivery optics
  → Fibre combiner, collimator, rotating prism arm
- Transfer radiometer (calibrated with CSAR)
  → Integrating sphere with two detectors
  (Si and InGaAs)
  → External aperture to define radiance
- Spectralon diffuser plate and illumination optics
  - ➢ Illuminating sphere, collimating lens, steering mirrors
  - ➢ Viewable simultaneously by TR and EI



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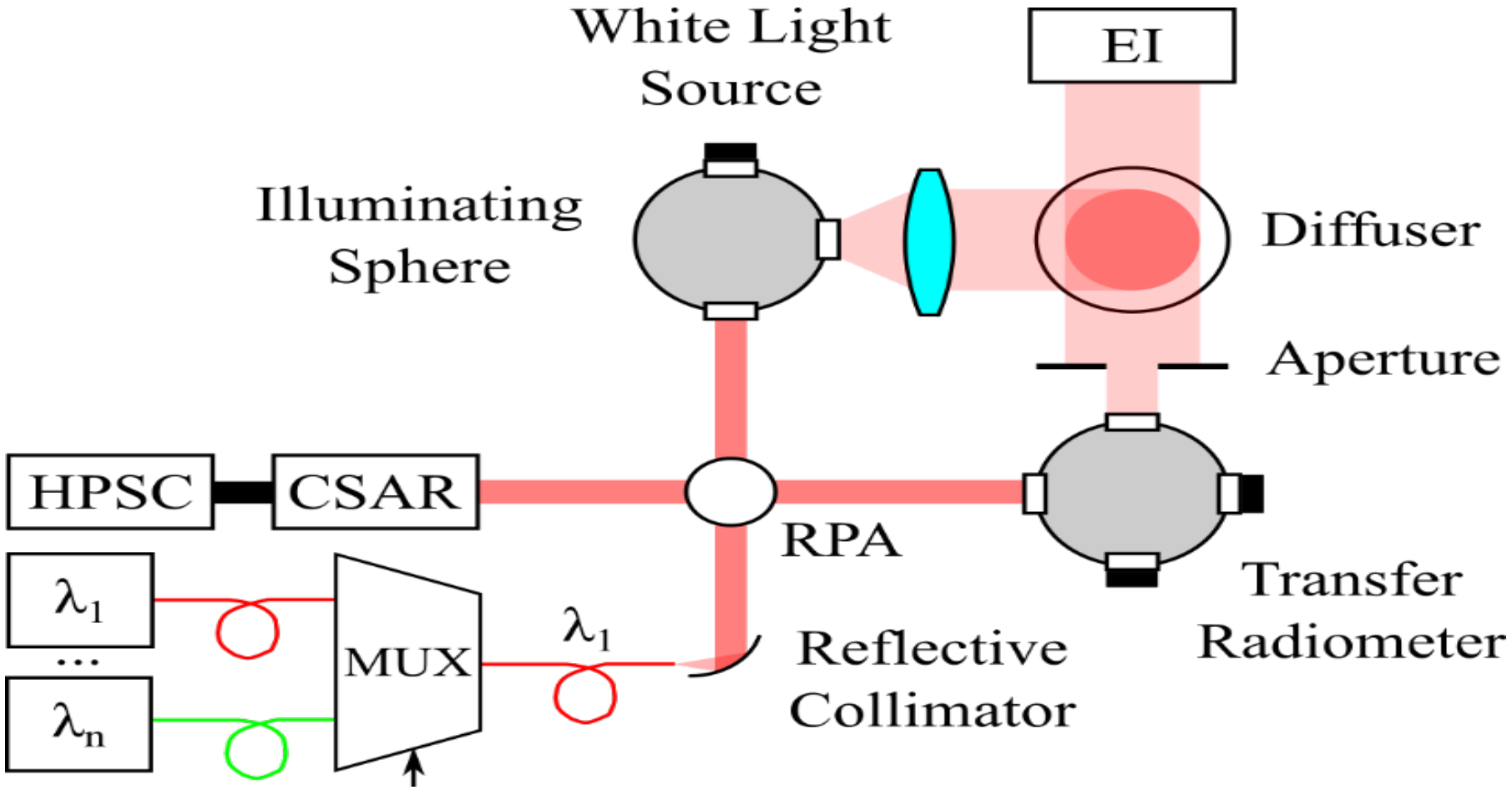
Cryogenic Solar Absolute Radiometer (CSAR)

- Provides SI traceability of Earth Imager (EI) calibration and TSI measurements as “primary standards lab in space”
- Ground-based CSAR V1 developed in Davos, Switzerland (future SI standard for solar irradiance)
- Recent work involved updating early prototype design to a more space ready design and ensuring compatibility with Airbus Defence and Space’s High Performance Stirling Cooler (HPSC)
- Challenge: limited cooling power means higher operating temperature

Calibration System Schematic



CEOI Flagship Project - Increasing TRL of TRUTHS Calibration system

- CSAR redesigned and integrated with upgraded space cooler
- Engineering model of calibration system tested in vacuum
  - Same scale and geometry as planned space instrument
- Transfer radiometer (TR) calibrated in situ via CSAR
- Instrument analogous to Earth imager calibrated in situ via TR
- Entire calibration carried out autonomously with simple control scheme
- Carry out reliability and feasibility assessment for 5 – 7 year mission

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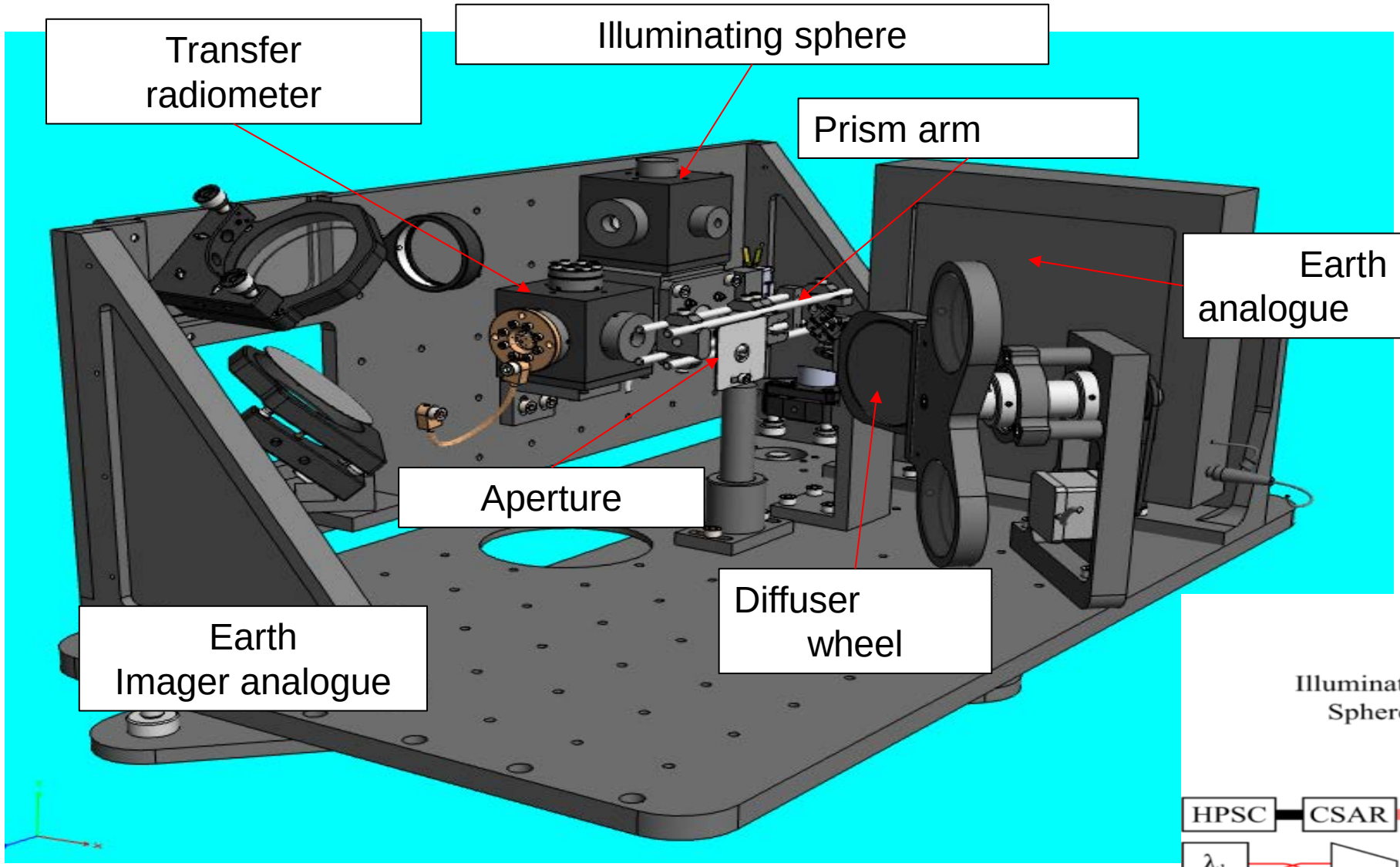
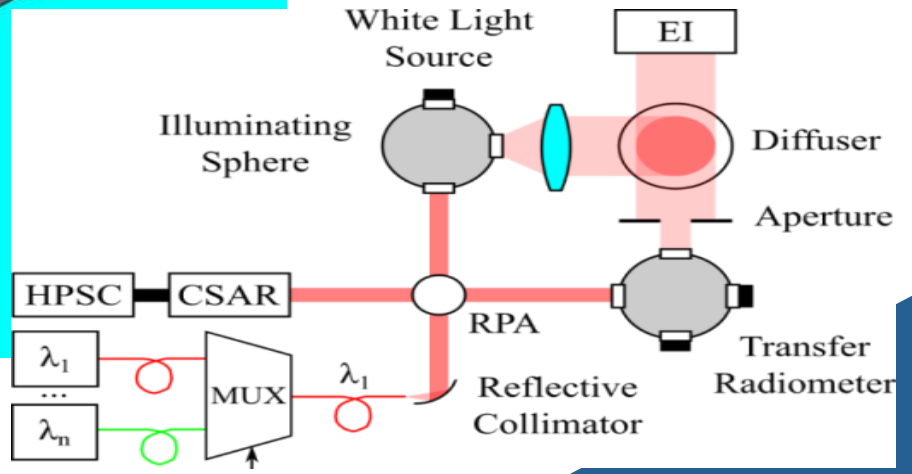
Calibration System Design





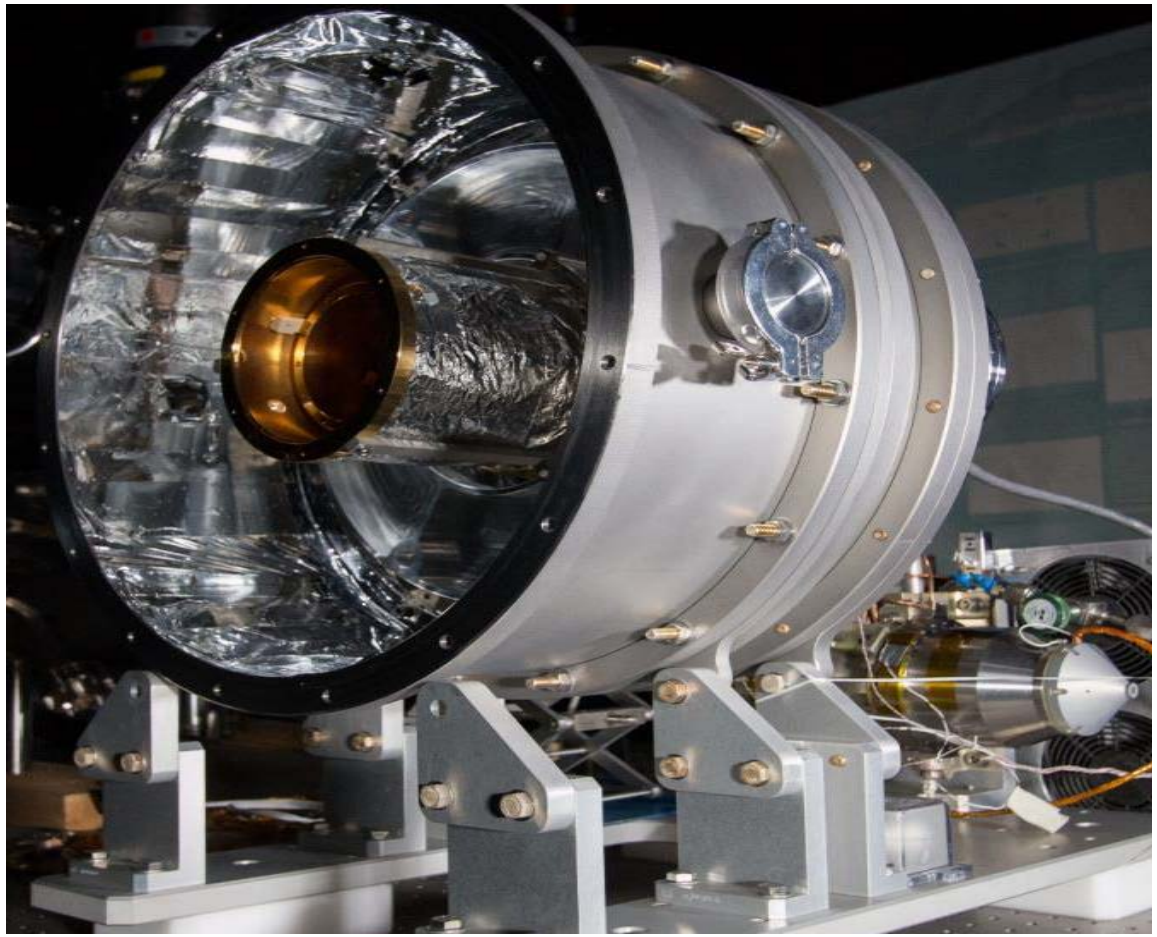
Design credit: Peter Lovelock – National Physical Laboratory

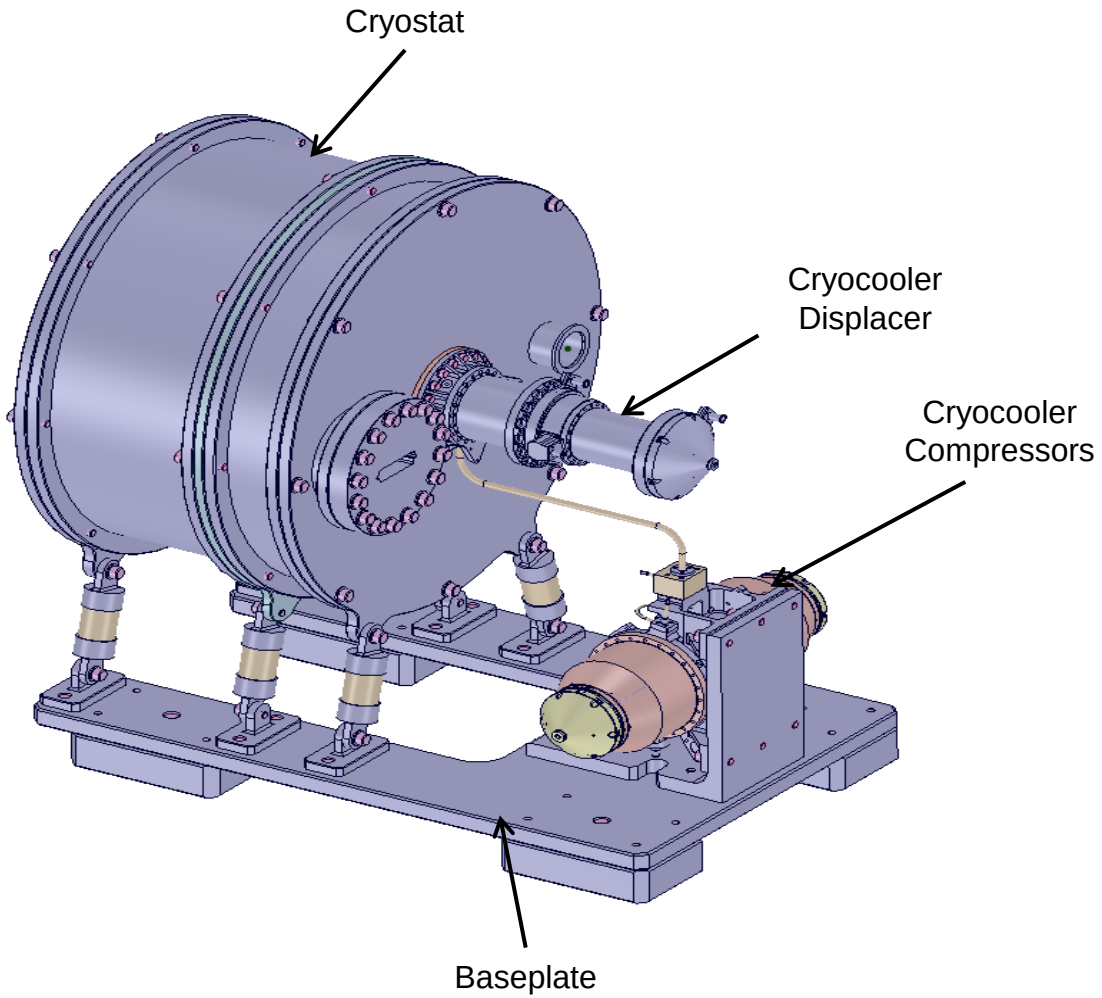
Uncertainty Budget of CSAR for TSI and calibration of TR

Source	TR Calibration (%)	Total Solar Irradiance (%)
Measurement of electrical power	0.010	0.010
Area of defining aperture	-	0.008
Cavity absorptance	0.010	0.004
Diffraction correction	-	0.020
Scattered light	0.004	0.004
Random noise	0.06	0.010
Total	**0.06**	**0.026**

Note: expanded uncertainties (*k* = 2)

CSAR Assembly and Testing





Calibration System Assembly