UKSA: TRUTHS mission

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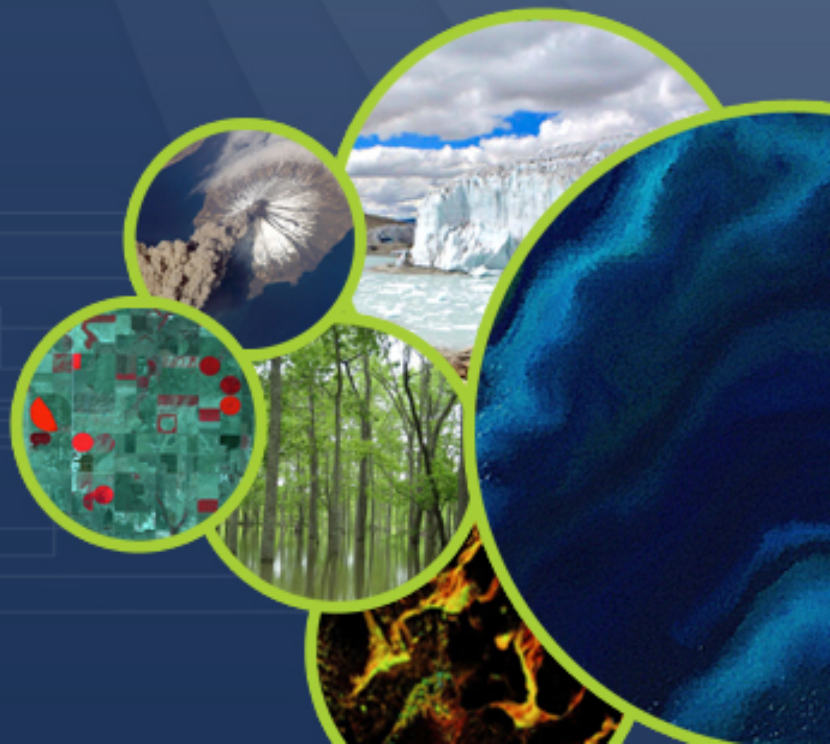
Professor Nigel Fox

WGCV 47



Working Group on Calibration and Validation

UK SPACE AGENCY

NPL National Physical Laboratory | pmod wrc

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Traceable Radiometry Underpinning Terrestrial- & Helio-Studies

Enabling a space-based Climate & calibration observatory

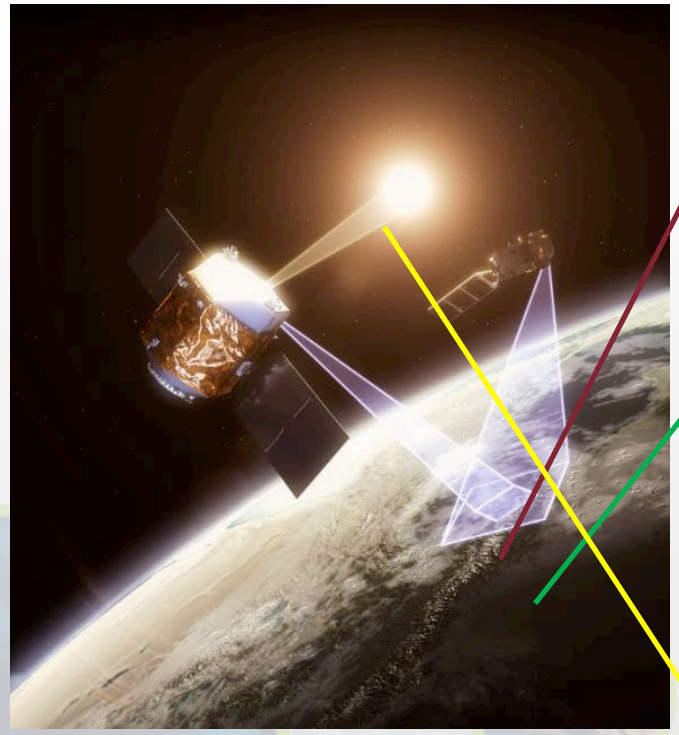
Approved as an ESA EarthWatch mission (Nov 19)

Phase A/B1 + EM prototyping industrial KO Sep20 following competitive ITT now closed

Open call for Mission Advisory Group imminent

esa

Mission objectives



TRUTHS is an **operational climate-focused mission**, aiming to:

1. **Climate benchmarking:** enhance by an order-of-magnitude our ability to estimate the Earth radiation budget (and attributions) through direct measurements of incoming & outgoing energy,
2. **Satellites cross-calibration:** establish a 'metrology laboratory in space' to create a fiducial reference data set to cross-calibrate other sensors and improve the quality of their data, robustly anchored to a primary SI reference in space.

and

3. provide SI-traceable measurements of the **solar spectrum** to address direct science questions and climate.

Mission Products

- L1: Earth-reflected Spectral Radiance (ToA), Solar Spectral Irradiance, Lunar Spectral Irradiance – all in the range 320nm to 2400nm;
- L1: Total Solar Irradiance integrated in the range 200nm to 30000nm;

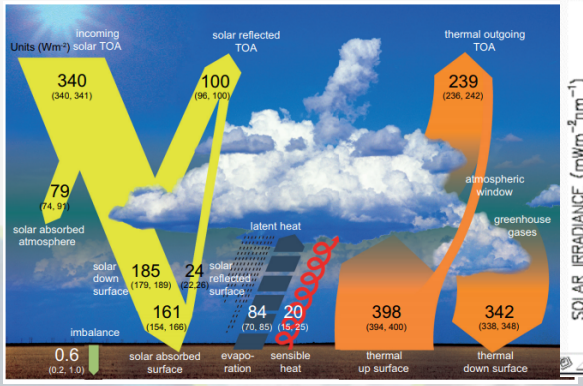
→ **Climate benchmark, solar measurement**

- L2: Spectral Surface Reflectance, at ground level (320nm to 2400nm);

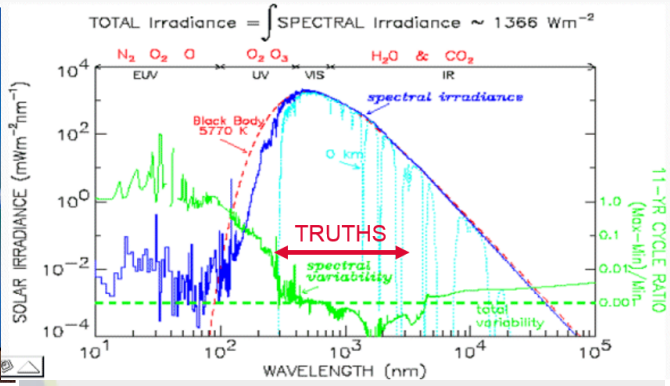
→ **Earth science**

- calibration coefficients & match-up products to determine biases for TBD other sensors over multi-scene types and view angles.

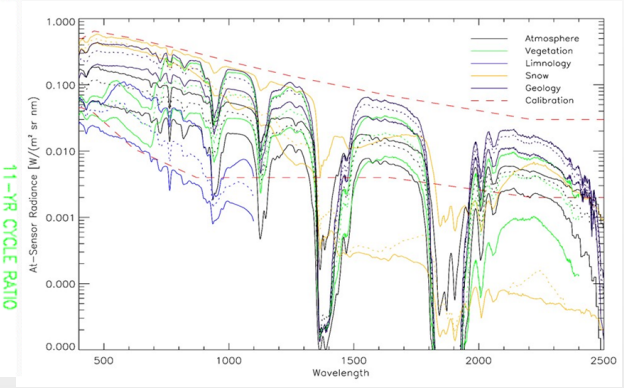
→ **Cross-calibration**



Radiation balance



Solar spectral irradiance



Surface reflectance

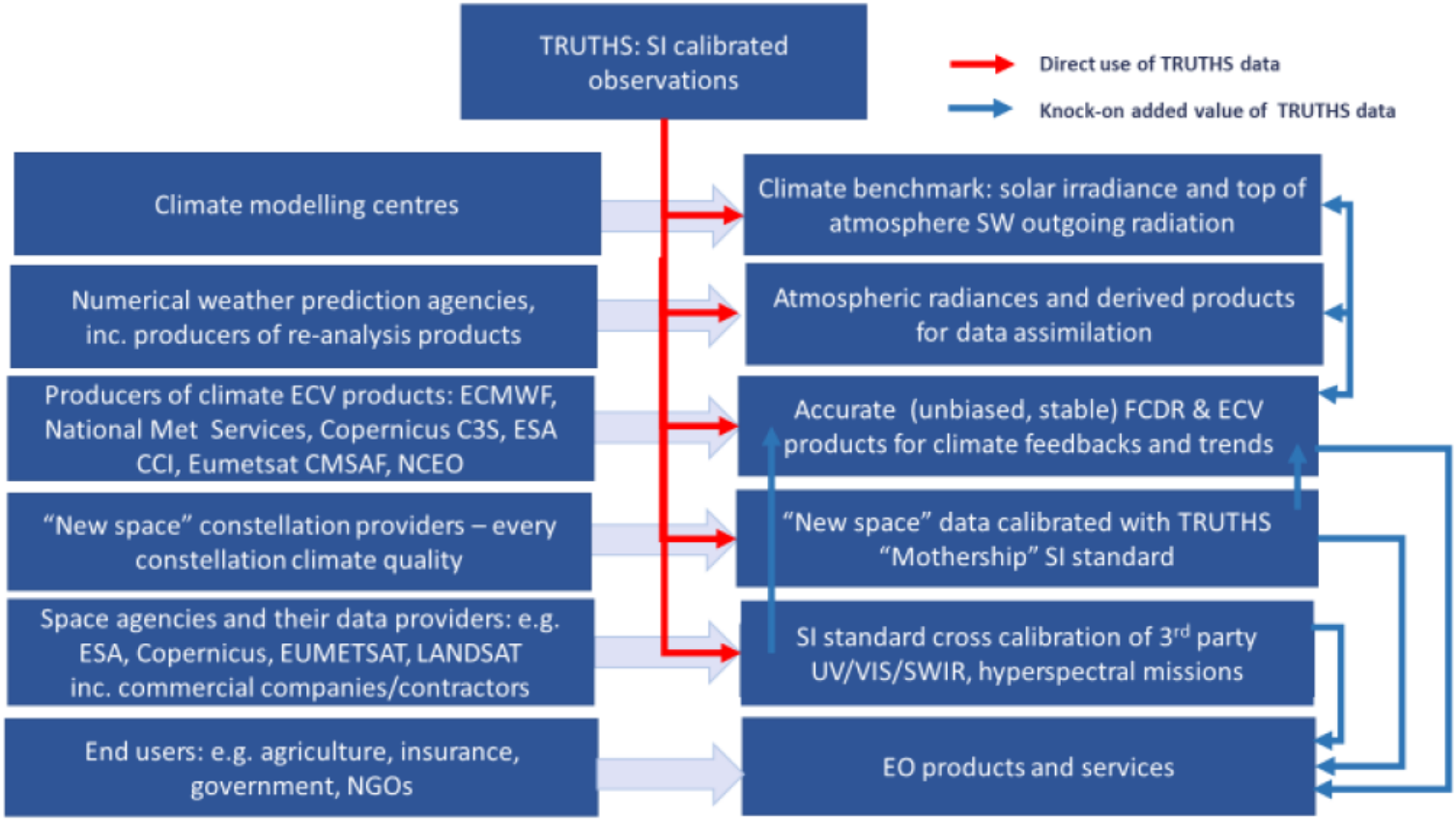
The TRUTHS design is driven by:

- **Radiometric demands** of the climate application ➔ *Payload and calibration*
- **Geometric** to optimally match other sensors (calibration) and secondary applications ➔ *FoV, Swath & SNR*
- **Orbit**: optimal sampling to quantify the climate and facilitate cross-calibration ➔ *Satellite and launch*

Key performance requirements

Level 1	Mission Requirement				
	Spectral range (nm)	Bandwidth (nm) Spec Samp Int ~0.5 FWHM	Uncertainty (%) (k=2)	SNR	GIFOV (m) @100 km Swath
Earth spectral radiance (Clim Benchmark)	320 - 2400	<8 for < 1000 <16 for >1000	0.3 (goal) <1.0 (Threshold)	>~50	250
Solar/lunar Spectral Irradiance	<320 – 2400	1 (<400), <5 (<1000), <10 (<2400)	0.3 (goal) <1.0 (Threshold)	300	NA
Total Solar Irradiance	Total	200-30000	<0.02 (goal) 0.05 (Threshold)	<500	NA
Earth radiance (Calibration / secondary applications)	<400 - 2400	<8 for < 1000 <16 for >1000	<1.0	To not limit uncertainty of application >~150 @ 50 m for 500-950nm	50 – 100 m Integrated up for GHG/Ocean Col/Climate Multi-angle sampling

Many & varied operational users



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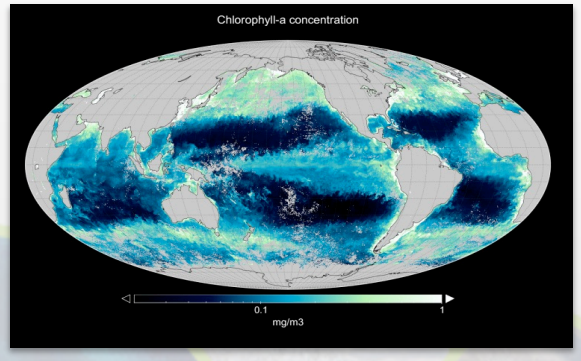
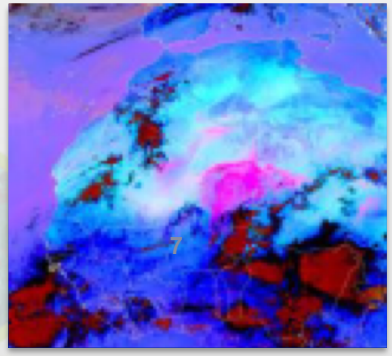
Underpinning operational ECV retrievals for cli monitoring and model improvement

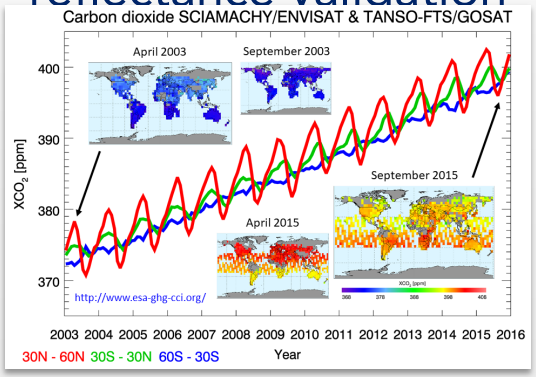
- **Carbon-sink- Ocean colour:** direct TOA cross-calibration of sensors to absolute radiometric accuracy of ~0.5%, meeting GCOS requirements



- **Aerosols:** "Climate closure points" unifying ground networks and multiple optical sensors through the TRUTHS FDR facilitating atmospheric correction code improvements.



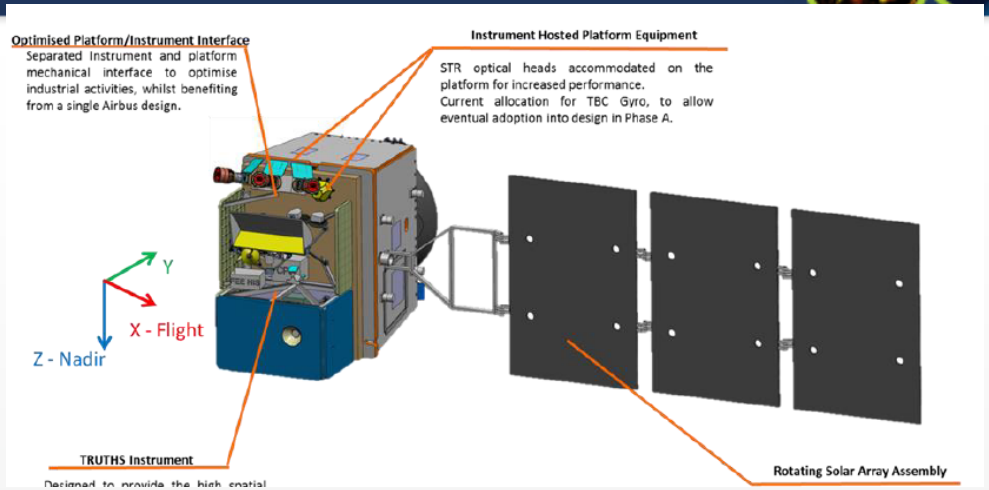
- **Emissions- CO_2:** Referencing Copernicus and multi-agency CO_2 constellations at 0.5-1.0% radiometry through cross-calibration.
- Land use change / BoA reflectance validation



TRUTHS Innovations

Mission design - Phase A/B1 Sep 20 to Spring/summer 22

- Breadboard Imager
- EM Cal system
- Combine above



Innovations:

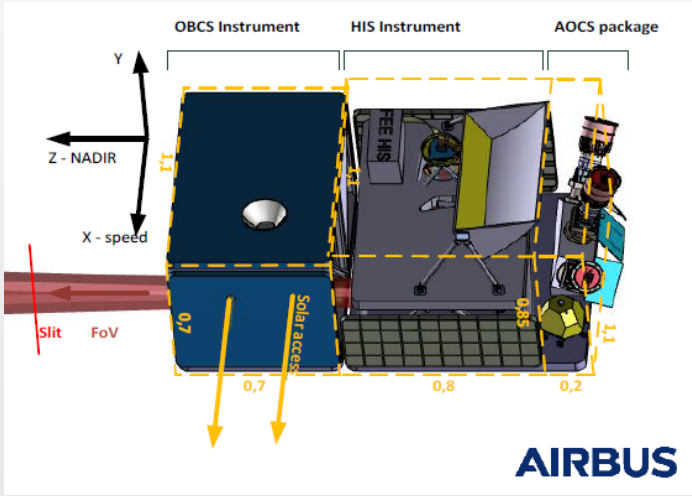
- **Polar orbit**

- **Hyper-spectral imager**

SI- Traceability on-board

- **Calibration system**
- **Primary standard**

- Establishing 'SI in space'

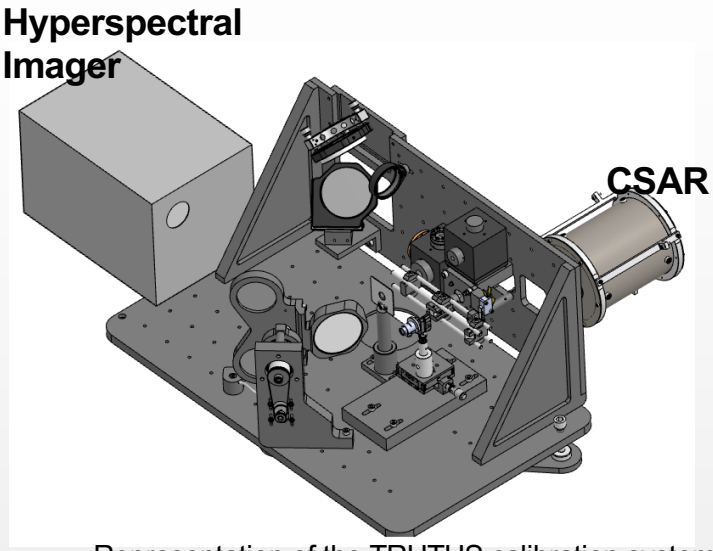


What makes TRUTHS different to other optical satellite missions?

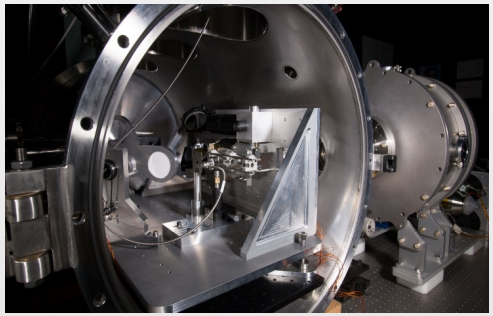
TRUTHS includes an on-board calibration system, that replicates the SI-traceable calibration chain employed in National Metrology Institutes (NMIs) globally, including flight of a primary standard - a Cryogenic Solar Absolute Radiometer (CSAR) (see calibration video).

The hyperspectral imager on-board TRUTHS is routinely re-calibrated, with SI-traceability.

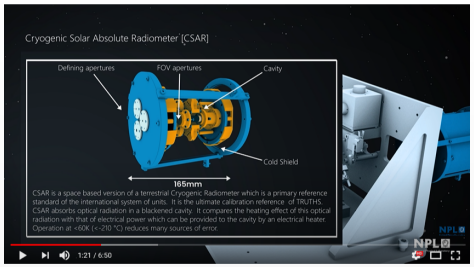
Maintaining it's SI-traceable high radiometric performance throughout the mission lifetime.



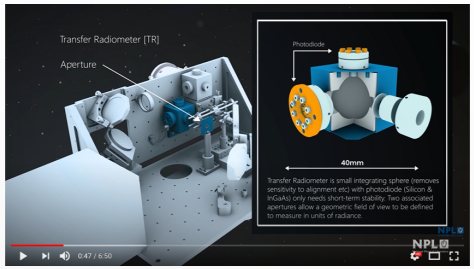
Representation of the TRUTHS calibration system



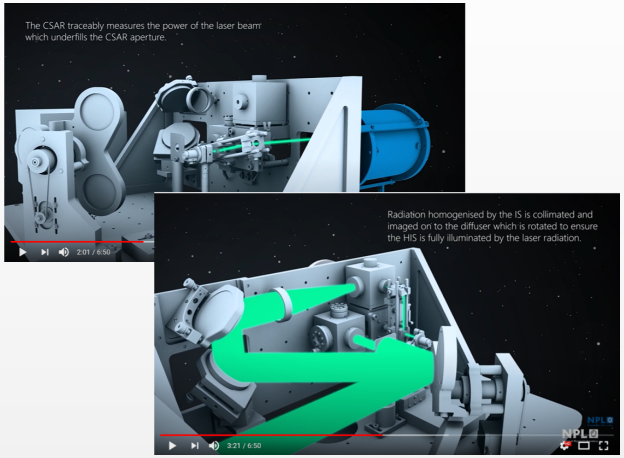
Describes the sub-systems



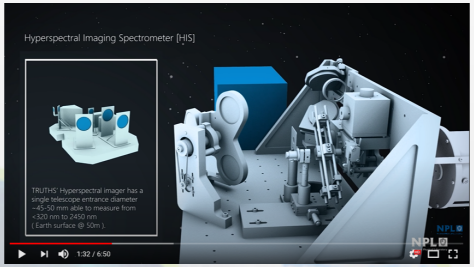
CSAR – Primary standard



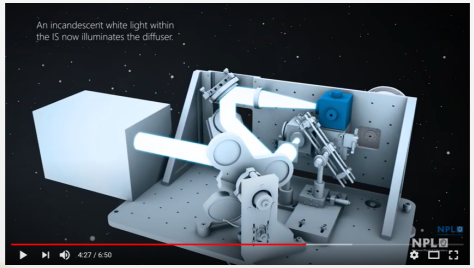
Transfer radiometer



Laser diode & delivery system



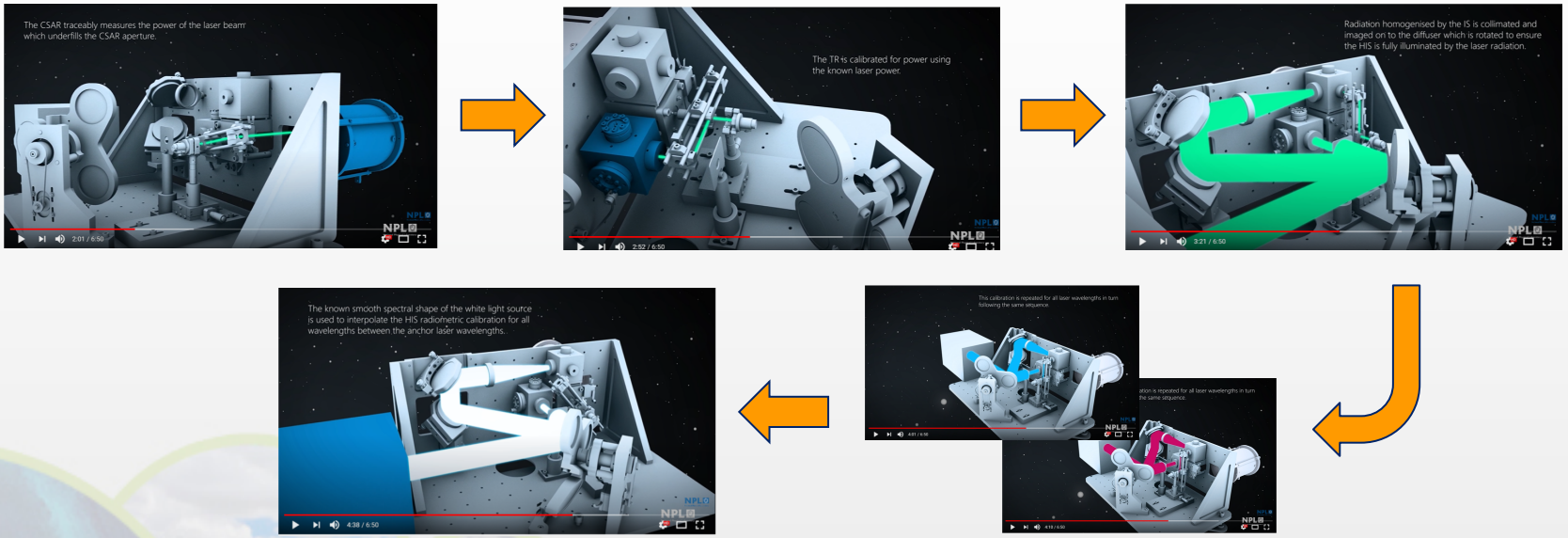
Hyperspectral Imager



Broadband interpolation

https://www.npl.co.uk/earth-observation/truths/satellite-calibration

Describes the linkages to SI using laser power to spectral radiance calibration



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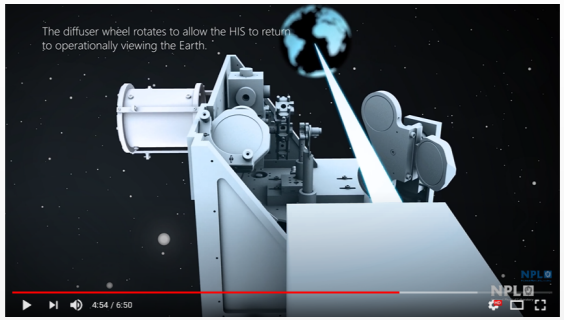
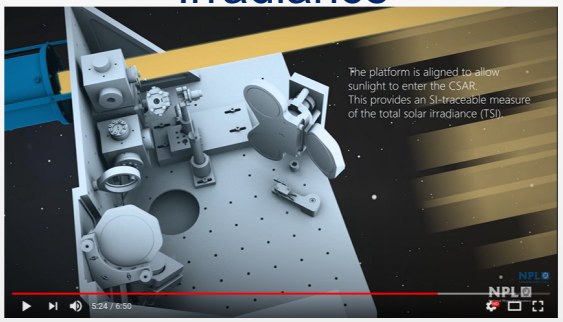
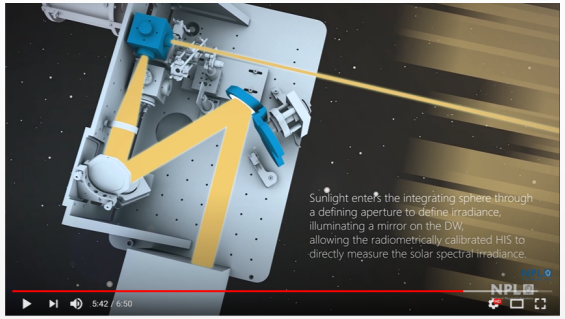
On-board calibration system (OBCS) enables the geophysical measurements



Earth-reflected Spectral Radiance

Total Solar Irradiance





Solar/Lunar spectral irradiance

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Traceability to CEOS & Cal/Val Infrastructure: enabling interoperability

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